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ADVANCES IN HORTICULTURAL CROPS

Joginder Singh
Rashmi Nigam
Wajid Hasan
Anant Kumar
Harpal Singh

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This book “Advances in Horticultural Crops” has been designed to provide an overall understanding of all aspects related to the study of horticultural crops. In this book, it is an up-to-date enlarged, comprehensive, and advanced book. It covers both the aspects of the subject such as brief and descriptive. This book provides an overview of the concise and clearly expressed principles and practices in horticulture crops. The aim has been to present a complete and modern view of the horticultural sciences.

Keeping the aforesaid points of view, I have made an attempt to compile the latest information on all facts and all the facets of horticulture based on my experience in this subject. The literature consulted to compile this book has been duly acknowledged to augment the wider acceptability and full utility of this book. Some chapters with modifications have been incorporated from literature surveys, and scientists and officials who helped me during this period. These might have been few errors in spite of best efforts made through carefully proofreading.

We are especially thankful to everyone who helped us for completing this book. We are thankful to our editors who have toiled along with me in editing the voluminous treaties. We hope that the book is useful and interesting to readers, teachers, and students, and would create in them the urge to know more about recent researchers going related to environment protection. We also thank international publisher Weser Books, Germany for taking keen interest to publish the book.

Dr. Joginder Singh
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PLASTICULTURE ROLE & APPLICATIONS IN NEXT GENERATION HORTICULTURE

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ABSTRACT

Plastic has become a popular material in our daily life due to its structural integrity, chemical property and versatile nature. Right usage of water is becoming increasingly important given the fact that India currently supports nearly 17.84% of the world population, with 2.4% land and 4% of water resources. At the same time, monsoons are also becoming erratic. Plasticulture (viz: the use of plastics in agriculture, horticulture, water-management, food grains storage and related areas) is a good answer to this challenge. It can play an important role in facilitating judicious usage of water. It is estimated that appropriate applications of micro-irrigation technologies can result in water saving up to 50-70%. Plastic has many valuable applications in high-tech horticulture includes drip irrigation, plastic mulches, packaging and storage for superior quality of produce and in post-harvest management. Plasticulture means the use of plastics in agriculture, horticulture, water-management, food grain storage and in related areas. Use of plastic in horticulture crop production has increased dramatically in the last ten years even though the number of agricultural plastic manufactures has been reduced by 40% over the same period. The use of plasticulture in the production of horticultural crops (vegetables, small fruits, flowers, plantation crops, and ornamentals) helps to mitigate the sometime extreme fluctuations in weather, especially temperature, rainfall and wind, which occurs in many part of the country. There is need to encourage the Plasticulture sector to enable it to realize its potential and contribute to the national economy. One of the major sectors of plasticulture application is in the area of water management. Application of micro irrigation can help in increasing productivity by 30 to 100 per cent with significant saving of water. Fertilizer use efficiency is also enhanced. In the present scenario of depleting water resources, coupled with increased need of food, plasticulture needs to be encouraged. Incidentally this also creates opportunities for the Indian plastic industry as same finds good applications in plasticulture.

Keywords: Plastic, plasticulture, horticulture
INTRODUCTION

Plasticulture includes all kinds of plant or soil coverings ranging from mulch films, row coverings, poly-tunnels to greenhouses. The benefits of Plasticulture are reduced water loss, UV stabilization to cool soil and prevent insects & prevention of weed growth. Polyethylene plastic film is used majorly for plasticulture, by growers, because of its flexibility, easy manufacturing and affordability. India's growing horticulture sector has currently been witnessing, on the one hand, small farmers taking bigger risks and experimenting with diverse cash crops, and on the other, entrepreneurs & corporate houses are taking to horticulture as a profitable business opportunity by bringing in investments and latest farming practices such as precision farming method, water efficient technologies & controlled environment for hi-tech horticulture with the help of various plasticulture applications under the govt. schemes & mission programmes. Plasticulture applications are one of the most useful indirect agricultural inputs which, hold the promise to transform Indian agriculture and bring in the "Second Green Revolution".

The word plastic is derived from the Greek words “PLASSIEN” and “PLASTIKOS” meaning to mould or shape a soft substance permanent or temporary. Plastic has become a popular material in our daily life due to its structural integrity, chemical property and versatile nature. LDPE (Low-density polyethylene) and LLDPE (Linear low-density polyethylene) plastic films are commonly used for mulching. LLDPE black colour mulch film is most popular, owing to the twin properties of down gauging and better puncture resistance. Plasticulture represents use of applications of plastics in Agriculture, Horticulture, Water management & related areas. Dr. Emery M. Emmert of the University of Kentucky was one of the first to recognize the benefits of using LDPE (Low-density polyethylene) and HDPE (High-density polyethylene) film as mulch in vegetable production. Plasticulture applications offer a multitude of benefits and are considered most important indirect agricultural inputs which results in moisture conservation, water saving, reduction in fertilizer consumption, helps in precise application of water & nutrients, controlled environment agriculture is economically viable, plant protection through the use of nets and use of innovative packaging solutions help in increasing shelf-life and during collection, storage & transportation of fruits and vegetables.

Plasticulture applications are considered the most important indirect agriculture input which results in moisture conservation, water saving, reduction in fertilizer consumption, helps in precise application is economically viable, plant protection through the use of nets and use of innovative packaging solutions help in increasing shelf-life and during collection, storage and transportation of fruits, flowers and vegetables.

Broad Classification of plasticulture applications are as follows.

Water management:
- Lining of canals, ponds & reservoirs with plastics film
Advances in Horticultural Crops

- Drip & Sprinkler Irrigation
- PVC & HDPE pipes used for water conveyance
- Sub-surface Drainage

**Nursery Management:**
- Nursery bags, Pro-trays, Plastic plugs, Coco-pits, Hanging baskets, Trays etc

**Surface cover cultivation:**
- Soil Solarisation
- Plastics Mulching

**Controlled environment agriculture:**
- Greenhouses
- Shade net houses
- Low tunnels
- Plant Protection nets

**Innovative Packaging:**
- Plastics crates, bins, boxes, leno bags, unit packaging products etc
- CAP Covers, Controlled Atmospheric Packaging (CAP) & Modified Atmospheric
- Packaging (MAP)

The unique advantages of plastic over conventional materials are:
- Higher strength/weight ratio
- Superior thermal insulation properties
- Excellent corrosion resistance
- Superior flexibility
- Resistance to most of the chemicals
- Excellent moisture barrier properties
- Favourable gas permeability.
- Smooth surface – resulting in reduction in friction losses
- Excellent light transmissibility
- Helps to enhance shelf-life of the produces
- Better visibility of the produce

**Table 2: Polymers used in Plasticulture applications** *Source: NCPAH*

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<th>S.no</th>
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<th>PVC</th>
<th>LDPE</th>
<th>LLDPE</th>
<th>HDPE</th>
<th>PP</th>
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<tr>
<td>1</td>
<td>1 Drip Irrigation</td>
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<td>--------</td>
<td>Lateral emitting pipes</td>
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<td>Control valves</td>
<td>Control valves</td>
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<td></td>
<td></td>
<td>valves</td>
<td>UV films</td>
<td>UV films</td>
<td>Main/sub main lines</td>
<td>Ropes</td>
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<td>Main/sub main lines</td>
<td>UV films</td>
<td>UV films</td>
<td>Main/sub main lines</td>
<td>Ropes</td>
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<td>UV films</td>
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<td>Tunnel</td>
<td>40-50</td>
<td>20-30</td>
<td>Under Trial</td>
</tr>
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Farm Pond Lined with plastic film | 100 | 40-60 | Under Trial

Source: NCPAH (PLASTICULTURE APPLICATIONS AND ITS SAVINGS)

Geo-membrane Farm pond

Canal Cover LDPE pond cover

Black mulching film Films

Transparent or Clear Plastic Mulching

LDPE Tarpaulins Sheets for Fish Farming

UV Stabilized Polythene Film
Future prospects –

More than 330 million people living in 254 of 678 districts in the country are under the spell of drought. The crisis seems to be unprecedented as ‘water trains’ ferry water to the parched lands in Maharashtra, women and children carry head loads of water from distant locations sometimes scavenging from deep holes and gorges, armed musclemen protect the water ponds in Bundelkhand region. Plastics such as PVC, LDPE, LLDPE, HDPE, PP, PTFEE etc find good applications in the sector. Ground water table has fallen more than 4 meters during last two decades and in some regions, of high agricultural productivity, it is falling at rate on one meter per annum. As per estimates by 2025 about a third of India would be under absolute water scarce condition. Water availability for irrigation is expected to come down from ~82% in 1997 to ~72% by 20251. Distribution of water remains a concern as three-fifth of the water is lost in conveyance and about half of the losses happen through seepage. These and other factors contribute to a wide gap in crop productivity in India which stands at ~40-60% of world's average while raising serious questions on sustainability of agriculture and eventually on food security. There is also heavy pre and postharvest losses which further contribute to low availability of food grains and fruits and vegetables. All these factors make use of plastics in agriculture an interesting proposition, as there are substantial benefits of employing the Plasticulture techniques to improve the productivity while saving the water consumption and minimizing the post-harvest wastages. As we are aware, there is a huge unrealised potential of further growth of plastic industry as indicated by the present very low per capita consumption level in the country Concluding, it can be stated that the plasticulture applications hold huge importance because of their relationship to water conservation and national food security. A very focused campaign to create awareness about its usage (thru demonstration centres) in which farmers are partners will be helpful. At the same time, there is need to ensure availability of quality products based on good standards by industry. There is also need for bringing out literature on the subject in regional languages, which may also include case studies. These steps will go a very long way in promoting the idea of plasticulture in India.
ROLE OF FARMING SYSTEM IN SUSTAINABLE HORTICULTURE

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Junagadh Agricultural University, Junagadh- 362001

INTRODUCTION

The concept of sustainable agriculture can be described as a "three-legged stool", with legs of economic viability, environmental soundness, and social acceptability. When one leg is weak, the farming system is likely to be unstable and not sustainable in the long run. Fruit production has addressed sustainability challenges in the past, including pesticide use, post-harvest quality, and changing consumer preferences.

Both integrated fruit production and organic production were developed with sustainability goals in mind. Studies of these systems do indicate improved sustainability relative to “conventional” systems in many cases. However, systems are not static.

Over the years, horticulture has emerged as one of the potential agricultural enterprise in accelerating the growth of economy. Its role in the country's nutritional security, poverty alleviation and employment generation programmes are becoming increasingly important. It offers not only a wide range of options to the farmers for crop diversification, but also provides ample scope for sustaining large number of Agro-industries which generate huge employment opportunities.

About 49 percent of the total area of the Gujarat state is under cultivation. The area under irrigation is about 33 percent of the net area sown, while rest of area is cultivated under rain fed conditions.

What is farming system?

Farming system is a complex inter-related matrix of soil, plants, animals implements, power, labour, capital and other inputs controlled in part by farm families and influenced by varying degrees of political, economical, institutional and social forces that operate at many levels.

Conceptually it refers to a set of elements or components that are interrelated which interact among themselves. At the centre of the interaction is the farmer exercising control and choice regarding the type and result of interaction.

What is sustainable horticulture?

A range of strategies for addressing many problems are affecting horticulture. Such problems include loss of soil productivity from excessive soil erosion and associated plant nutrient losses, surface and ground water pollution from pesticides, fertilizers and sediments, impending shortage of non-renewable resources and low farm income from depressed commodity prices and high production costs.
Furthermore, “sustainable” implies a time dimension and the capacity of a farming system to endure indefinitely.

**Fig. 1. Sustainable farming systems**

**Fig. 2. Share in production of horticultural crops in India (%)**
Objectives of farming system
- To increase productivity
- To increase profitability
- To increase potentiality
- Balanced food
- Environmental safety
- Income / cash flow round the year
- Saving energy
- Meeting fodder crises
- Solving timber and fuel crises
- Employment generation
- Scope for establishment of agro-industries
- Enhancement in input use efficiency
- Components of Farming system
- Farming system

Components of Farming system
A. Crop production
   Elements of crop production
   I Environment
      1. Climate
      2. Soil condition
      3. Social factors
   II. Cropping
      1. Principles
      2. Pattern
      3. Crop
      4. Economics
   III Farm resources
      1. Land
      2. Power
      3. capital
      4. National food need and productivity
   IV Technology
      1. Production
      2. Managerial
      3. Technology transfer

1. Principles of cropping system

   No widely accepted standards exist for sustainable agriculture, in contrast to organic or integrated fruit production. However, attempts have been made to articulate universal principles by which systems can be monitored and evaluated.

   “In a sustainable society, nature is not systematically subject to increasing:
1) Concentrations of substances extracted from the Earth’s crust,
2) Concentrations of substances produced by society,
3) Degradation by physical means; and in that society,
4) People are not subject to conditions that systematically undermine their capacity to meet their needs.”

2. Cropping patterns

The yearly sequence and spatial arrangement of crop fallow on a given area, region, province or country apportioning due consideration to natural features (soil and climate), crop efficiency and capability, socio-economic structure, technological and extension infra-structure and national agriculture policy.

**Zone wise existing cropping pattern in Gujarat**

<table>
<thead>
<tr>
<th>(1) South Gujarat heavy rainfall Zone- Hilly area</th>
<th>(2) South Gujarat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mango and Sapota Mono cropping</td>
<td>1. Mango and Sapota- Mono cropping</td>
</tr>
<tr>
<td>2. Mango - inter crop - Vegetable</td>
<td>2. Banana - Vegetable- Banana</td>
</tr>
<tr>
<td>3. Sapota - inter crop - Vegetable</td>
<td>3. Vegetable- Fallow- Vegetable</td>
</tr>
<tr>
<td>5. Vegetable - Fallow- Vegetable</td>
<td></td>
</tr>
<tr>
<td>6. Cereals - Vegetable –Fallow</td>
<td></td>
</tr>
<tr>
<td>(3) Middle Gujarat</td>
<td>(4) Bhal Tract</td>
</tr>
<tr>
<td>1. Vegetable - Fallow- Vegetable</td>
<td>1. Cereals-Vegetable-Fallow</td>
</tr>
<tr>
<td>2. Banana - Vegetable- Banana</td>
<td>2. Vegetable- Fallow- Vegetable</td>
</tr>
<tr>
<td>3. Cereals - Vegetable-Fallow</td>
<td>3. Cereals - Spices - Fallow</td>
</tr>
<tr>
<td>4. Spices - Fallow -Vegetable</td>
<td>4. Fruit crops-Inter crop- Vegetable</td>
</tr>
<tr>
<td>5. Fruit crops -Inter crop – Vegetable</td>
<td></td>
</tr>
<tr>
<td>(5) North Gujarat</td>
<td>(6) North Saurashtra</td>
</tr>
<tr>
<td>1. Vegetable- Fallow- Vegetables</td>
<td>1. Cereals-Vegetable-Fallow</td>
</tr>
<tr>
<td>2. Cereals-Vegetable-Fallow</td>
<td>2. Cereals - Spices - Fallow</td>
</tr>
<tr>
<td>3. Cereals - Spices – Fallow</td>
<td>3. Fallow - Spices - Fallow</td>
</tr>
<tr>
<td>4. Spices crops - Vegetable- Fallow</td>
<td>4. Vegetable - Fallow - Vegetable</td>
</tr>
<tr>
<td>5. Fruit crops - Inter crop - Vegetable</td>
<td>5. Fruit crops-Inter crop – Vegetable</td>
</tr>
<tr>
<td>(7) South Saurashtra</td>
<td>(8) Kutch Tract</td>
</tr>
<tr>
<td>1. Cereals-Vegetable-Fallow</td>
<td>1. Cereals-Vegetable-Fallow</td>
</tr>
<tr>
<td>2. Vegetable - Fallow – Vegetable</td>
<td>2. Cereals - Spices - Fallow</td>
</tr>
<tr>
<td>3. Fruit crops - Inter crop - Vegetable</td>
<td>3. Vegetable - Fallow - Vegetable</td>
</tr>
<tr>
<td></td>
<td>4. Fruit crops - Inter crop – Vegetable</td>
</tr>
</tbody>
</table>
3. Multiple cropping

Multi-cropping is the simultaneous cultivation of two or more crops. In Indian agriculture tradition, farmers have been known to sow as many as 15 types of crops at one time.

An example of multi-cropping is Tomatoes + onions + marigold (where the marigolds repels some of tomato’s pests).

It includes….

a) Sequential cropping
b) Inter-cropping
c) Mixed cropping.

(a) Sequential cropping

Growing two or more crops in a sequence on the same field in the farming year (twelve month) for irrigated land and is limited to the period of adequate soil moisture availability for crop growth in semi arid & arid areas. There is no inter-crop competition. Farmers manage only one crop at a time in the same field.

(b) Inter-cropping

Inter-cropping is the cultivation of another crop in the spaces available between the main crops. A good example is the multi-tier system of coconut + banana + pineapple/ ginger/ leguminous fodder/ medicinal or aromatic plants.

Types of inter-cropping

1. Mixed inter-cropping: Growing two or more crops together in no distinct row management.
2. Row inter-cropping: Growing two or more crops in well defined rows.
3. Strip inter-cropping: Growing two or more crops in strips, wide enough to permit independent cultivation, but narrow enough for the crops to interact.
4. Relay inter-cropping: Planting a second crop into a standing crop at a time when the standing crop is at its reproductive stage but before harvesting.

c) Mixed cropping

Mixed cropping is growing of two or more crops simultaneously on the same piece of land seeded either after the seed of the crops intended to be grown mixed or sowing alternate rows in various replacement ratios. The basic objective in mixed cropping is minimization of risk and insurance against crop failure due to aberrant weather conditions.

B. Agroforestry

- Agroforestry systems make maximum use of the land. Every part of the land is considered suitable for useful plants.
- Emphasis is placed on perennial, multiple purpose crops that are planted once and yield benefits over a long period of time.
Trees in agroforestry systems also have important uses such as holding the soil against erosion and improving soil fertility.

**Benefits of Agroforestry**

- Improved year-round production of food and of useful and saleable products.
- Improved year-round use of labour and resources.
- Protection and improvement of soil and water sources.
- Increased efficiency in use of land.
- Medium and long-term production of fruits.
- Long-term production of fuel and timber.
- Increase of total production to eat or to sell.

**Components of agroforestry**

- **Agri-horticulture** (Fruit trees + Crops)
- **Agri-silvi-horticulture** (Trees + Fruit trees + Crops)
- **Agri-silvi-pasture** (Trees + Crops + Pasture)
- **Silvi-olericulture** (Tree + Vegetables)
- **Horti-pasture** (Fruit trees + Pasture)
- **Horti-olericulture** (Fruit tree + Vegetables)
- **Silvi-horti-sericulture** (Fruit trees + Sericulture)
- **Horti-apidiculture** (Fruit trees + Honeybee)

**C. Dairy farming**

Dairy farming is one of the economically viable enterprises that could provide constant income throughout the year to farmers when combine with cropping. The success of dairying depends solely on the availability of inputs like feed and fodder and better marketing facilities to milk. To maximize benefits from dairying selection of proper breed to suit the local condition is very essential.

**D. Poultry farming**

Poultry farming is emerging as important livestock activity in farming system for enhancing economic stability, nutrition and providing regular employment and cash flow.

**E. Fisheries**

Ponds serve various useful purpose, viz., domestic requirement of water, supplementary irrigation source to cropping and fisheries.

- With the traditional management, farmers obtained hardly more production of wild and culture fish per hectar annually.
F. Apiculture

Apiculture is the keeping of honey bee colonies on a large scale for the purpose of honey production and other products such as pollen, wax and royal jelly. The honey bees can also be kept for the sole purpose of selling them to other farmers. Apiculture refers to the honeybee, the vital role all bees play in the pollination of crops and flowering.

G. Ornithology

Birds constitute an important component of agro-ecosystems. The dual role of birds in agriculture is very well known. Agriculture provides a concentrated and highly predictable source of food to birds.

This food in general is of three kinds:

- Grain, Seeds and Fruits,
- Green vegetation of the crop plants and grasses, and
- Insects, other arthropods, rodents, etc., found in the soil, crops and other plants.

Types of Farming system

A. Organic farming

Organic farming is a method of farming system, which primarily aims at cultivating the land and raising crops in such a way, so as to keep the soil alive and in good health. It is the use of organic wastes (crop, animal and farm wastes, aquatic wastes) and other biological materials, mostly produced in situ, along with beneficial microbes (bio-fertilizer), to release nutrients to crops, which connotes the ‘organic’ nature of organic farming. It is also termed as organic agriculture. In the Indian context it is also termed as ‘Javik Krishi’.

<table>
<thead>
<tr>
<th></th>
<th>Total organic area</th>
<th>&gt; 1,08,650 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Total projects</td>
<td>2099</td>
</tr>
<tr>
<td>3</td>
<td>No of Grower groups</td>
<td>919</td>
</tr>
<tr>
<td>4</td>
<td>Total organic farmers</td>
<td>548,045</td>
</tr>
<tr>
<td>5</td>
<td>Total certified production</td>
<td>17.11 lakh t</td>
</tr>
<tr>
<td>6</td>
<td>Number of processors</td>
<td>427</td>
</tr>
<tr>
<td>7</td>
<td>Total export</td>
<td>58,408 t</td>
</tr>
<tr>
<td>8</td>
<td>Value of export in Rs.</td>
<td>5254.9 million INR</td>
</tr>
<tr>
<td>9</td>
<td>Number of exporters</td>
<td>299</td>
</tr>
</tbody>
</table>

Table 1. Organic statistics in India
Concept of organic farming is based on following principles:

- Nature is the best role model for farming, since it does not use any inputs nor demand unreasonable quantities of water.
- The entire system is based on intimate understanding of nature's ways of replacement. The system does not believe in mining of the soil of its nutrients and do not degrade it in any way.
- The soil in this system is considered as a living entity
- The soil's living population of microbes and other organisms are significant contributors to its fertility on a sustained basis and must be protected and nurtured at all cost.
- The total environment of the soil, from soil structure to soil cover is more important and must be preserved.

**IMPORTANT STEPS IN ORGANIC FARMING**

- **Enrichment of soil** – Use crop residue as mulch, use organic and biological fertilizers, adopt crop rotation and multiple cropping, avoid excessive tilling and keep soil covered with green cover or biological mulch. Do not use any chemicals.
- **Management of temperature** - Keep soil covered, Plant trees and bushes on bunds.
- **Conservation of soil and rain water** – Dig percolation tanks, maintain contour bunds, farm ponds in sloppy lands and adopt contour row cultivation, maintain low height plantation on bunds.
- **Harvesting of sun energy** – Maintain green stand throughout the year through combination of different crops and plantation schedules.
- **Self reliance in inputs** – develop your own seed, on-farm production of compost, vermicompost, vermiwash, liquid manures and botanical extracts.
- **Maintenance of life forms** – Develop habitat for sustenance of life forms, never use pesticides, create enough diversity.
- **Integration of animals** – Animals are important components of organic management and not only provide animal products but also provide enough dung and urine for use in soil.
- **Use of renewable energy** – Use solar energy, bio-gas and bullock driven pumps, generator and other machine.

**B. Integrated farming system**

- Integrated farming (or integrated agriculture) is a commonly and broadly used word to explain a more integrated approach to farming as compared to existing monoculture approaches.
- It refers to agricultural systems that integrate livestock and crop production. Integrated farming system has revolutionized conventional farming of horticulture, livestock, aquaculture, agro-industry and allied activities.
It could be crop-fish integration, livestock-fish integration, crop-fish-livestock integration or combinations of crop, livestock, fish and other enterprises.

Advantages of integrated farming system

- The waste products of one component serve as a resource for the other.
- The result of this cyclical combination is the mixed farming system, which exists in many forms and represents the largest category of livestock systems in the world in terms of animal numbers, productivity and the number of people it serves.
- Integration of allied activities will result in the availability of nutritious food enriched with protein, carbohydrate, fat, minerals and vitamins.
- Integrated farming will help in environmental protection.
- Animals play key and multiple roles in the functioning of the farm, and not only because they provide livestock products (meat, milk, eggs, wool, and hides) or can be converted into prompt cash in times of need.

C. Rainfed farming system

- Integrated and holistic development of rainfed areas including hill, dry lands and coastal areas need to be promoted by resource conservation techniques on watershed basis for improving productivity profitability and thereby removing hunger and poverty.
- Rainfed Agriculture has a crucial role to play in the economy and food security of India.
- However, climate change, aberrant behaviour of monsoon rainfall, land /soil degradation with multiple nutrient and water deficiencies, declining the ground water table and poor resource base of the farmers are principle constraints for low and unstable yields in rainfed areas
- Horticulture crops (fruit and vegetable trees) to maintain nutritional security of the farm family besides earning some income to meet felt needs of the farm family.
- Arable crops (cereals, oilseeds, pulses) to meet the food requirement of the family.
- Fodder crops on degraded lands and field boundaries to meet feed needs of the cattle. Economic bushes for higher income in marginal lands.
- A well-developed farmstead area covering small and large ruminants (diary, sheep/goat, poultry, piggery, apiry) to provide year round flow of small income and for higher employment opportunities.

• ALTERNATE LAND USE IN RAINFED FARMING

To cope up increasing population of both human and livestock and rising demand for food, fodder and fibre, more and more marginal, sub marginal lands are
brought under cultivation. These lands are unable to sustain productivity, cultivating such lands leads to imbalances in the ecosystem.

**D. Indigenous farming system**

1. **Shifting cultivation**

   This type of farming system is found in north eastern areas. Traditionally, the fallow period is 10-20 years but in recent times, it is reduced to 2-5 years in many areas due to increasing population pressure. The fallow period is drastically reduced and the system has degraded causing serious soil erosion depleting soil fertility resulting in low productivity.

2. **Taungya cultivation**: Tauang = hill, ya = cultivation, i.e., hill cultivation.

   The taungya system is like an organized, scientifically managed shifting cultivation. The word is reported to have originated in Myanmar. It involves cultivation of crops in forests or forest trees in crop field and was introduced to Chittagong and Bengal areas in colonial India in 1890.

**E. Precision farming**

Precision Farming is defined as Information Technology Based, Relatively Better Management System that Identifies, Procures, Analyzes & Manages, Natural Variability Amongst the Fields & Optimizes Productivity, Profitability, Sustainability, Which Protects the Land Resources.

Objectives of precision farming system

- Promotion of market-led horticulture.
- Empowerment of farmers and farmers forum.
- Training the farmers in the latest state of art cultivation of technologies.
- Promoting hi-tech horticulture in built with precision elements.
- Exploitation of genetic potential 100 per cent.

What is precision horticulture?

- High-horticulture has been defined as “technology which is capital intensive, less environment dependent having capacity to improve productivity and quality of produce.”

- At present, emphasis is being given for precision farming which pertains with efficient management of resources through location specific high-tech interventions.

**Use of remote control**

- Remote Sensing
- Geographic Information System (GIS)
- Differential Global Positioning System (DGPS)
- Variable Rate Applicator
- Yield monitoring
Remote Sensing

Remote sensing is a tool for collection, processing and analysis of data to extract information from earth surface without coming in to physical contact with it.

Geographic Information System (GIS)

The Geographic Information System (GIS) contributes significantly to precision farming by allowing presentation of spatial data in the form of a map. In addition, GIS forms an ideal platform for the storage and management of model input data and the presentation of model results, which the process model provides.

Differential Global Positioning System (DGPS)

GPS makes use of a series of military satellites that identify the location of farm equipment within a meter of an actual site in the field.

Variable Rate Applicator

The variable rate applicator has three components:

- Control computer
- Locator and
- Actuator

Yield monitoring

Sensors mounted on the combine measuring yield as the crop is harvested. It is coupled with a GPS logging location and data can be mapped.

F. Balance farming

- A farm is a carefully balanced system. A system that encompasses the elements of animal, feed, water, the animal environment and the farmer.
- Regardless of the production system, all these elements need to be in balance if a farm is to maximise output and profit.

To make a profit out of farming is harder to do now than for some time, and the prospects are not too bright for next year.

Those farmers who do the best job of farm management are the ones that are most likely to make a profit.

Why is it important?

- Farmers and their advisers can struggle to get an overview of the farm system. It is not always the farmer’s struggle – it can be hard to really see what the problem is when you are so close to the everyday work.

- The cow herself is a carefully balanced biological system. The cow needs the ‘six freedoms’ to function and perform. Cow health will underpin production. Cow nutrition will drive health and create efficiency. One sick cow takes as much work as 40 healthy cows.
• Animals are always susceptible to disease; by maintaining the correct balance for the production system used on the farm, there is less risk of disease.

• Animals will not realise their genetic potential if placed in a system that is out of balance. The animals must be fit for purpose and the farm system must be fit for the cow.

CONCLUSION

For going discussion, use of organic manure, balanced chemical fertilizers, adopting integrated and precision farming system with balanced biological system, plays an important role of sustainable horticulture. It also improves the standard of living through maximizing the total net return and providing more employment, recycling of crop residues, optimizing resource use, minimizing risks and keeping harmony with the environment by comprising a combination of carefully selected components/enterprises under a given set of agro-climatic condition. Thus, integrated horticulture production and organic production are developing sustainable horticulture.

Future thrust

➢ Effectiveness of farming system in different agro-climatic regions need to be determined.

➢ Greater awareness about the additional benefits of farming system need to be created amongst farmers.
POST-HARVEST MANAGEMENT OF CUT FLOWERS

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3 Associate Professor, Department of Floriculture and Landscape Architecture, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India.

Floriculture is gaining importance throughout the world and is now considered as one of the country’s sunrise industry both of cut flowers as well as loose flowers. Floriculture is emerged as a viable diversification option in the agri-business. It is a rapidly expanding industry recording a growth rate of more than 15 per cent annum in the last two decades. Rapid urbanization, increased income levels and changes in social values resulted in increase of domestic market both for cut flowers as well as loose flowers significantly. Improvement in the general level of well being in the country and increase affluence particularly among the middle class is also another reason for increase in the volume of local flower market. The quantum of Indian floricultural exports, although, increased manifold since early nineties, still there is huge scope to become a key player in the world flower trade. The floriculture industry in India is characterized by growing loose flowers and cut flowers under open field conditions and protected environment conditions respectively. India also has a strong dry flower industry, which contributes a major share to the overall trade. Other segments like fillers, potted plants, seeds and planting material, turf grass industry and value added products also contribute a share in the overall growth of the floriculture sector. At present, the area under flower crops in India is 3.6 lakh ha with a production of 16.99 lakh MT of loose flowers and 5,93,000 million numbers of cut flowers (Anon., 2016 - 17).

❖ Importance of post harvest handling of flowers:

Post harvest care is one of the most important factors influencing the quality of flower, a highly perishable commodity. It rather decides the face value of flower at national and international market. The quality of flowers, which reaches the final consumer, depends on the pre-harvest and post-harvest handling. Quality is the pillar for creating value and customer satisfaction. The flowers are highly perishable need utmost care. When flowers are detached from the plant, they deprived of food, water, minerals and hormones. It is estimated that about 50% of flowers perish during the entire market chain in view of lack of improper post harvest care. It is the post harvest technology that has the potential to rescue the post harvest losses and further to maintain improved cut flower quality and vase life. Optimum post harvest handling of cut flowers not only maintains improved flower quality and vase life of cut flowers but also provides an alternative of storage during periods of market glut and further upsurge new avenues for development of market strategy. The post harvest handling techniques for short duration like pulsing and for long duration like preservative solution using sucrose, different chemical, anti-microbial agents, anti-ethylene agents, acidifiers and plant growth regulators have suggested by the scientists for different cut flowers. The
evaluation of proper technology of packaging and storage of flowers is also important for the development of market strategy and its accessibility at international level for enhancing export potentiality. The study and understanding of the post harvest physiology and biochemistry of cut flowers is further important to work out the influence of these post harvest handling techniques on the quality and vase life of cut flowers. It is the post harvest management of cut flowers which drastically influences the floral market, directly or indirectly. This new model of value addition in cut flowers has high export potential and can play a significant role in generation of new flower market strategy. Therefore it is important to study post-harvest handling of flowers to keep flowers in good quality.

❖ Post harvest losses in flowers
- About 20 percent losses due to improper handling.
- About 10 percent flowers are unmarketable and are not harvested.
- Shrinkage losses during marketing.
- Over all about 50 percent losses occur.

❖ Post harvest Operation:

![Post-harvest Operations Diagram](image)

❖ Harvesting of cut flowers:

Harvesting of cut flowers should be done in proper way, considering the following points:

- **Stage of Harvest:**

  Harvesting stage is dependent upon market distance. Flowers may be selected at some advanced stage for local market while for distant markets especially for export; flowers at early stage should be selected.
- **Time of harvest:**
  Early morning or evening time should be preferred for harvesting of cut flowers.

- **Mode of harvest:**
  Flowers should be harvested using sharp tools to obtain sharp and slant cut.

  ❖ **Why immediately after harvest flower stalk ends should be kept in water?**
    - Cut stem is a living entity, deprived of natural source of water further.
    - The flowering buds require water for opening.
    - The turgidity of the floral parts and cut stem depends on water absorption by the stem, to meet water loss through transpiration.
    - To avoid plugging of xylem vessels caused due to micro organisms and
    - To avoid air bubbles block in the xylem vessels.
    - The physical blockage of xylem vessels leads to decrease in water uptake by the stem tending towards senescence.

  ❖ **Factors influencing longevity of cut flowers**
    - Genetic or inherent factors (crop species and cultivar)
    - Environmental factors (light – quality, intensity and photoperiod, temperature – aerial and growing medium, relative humidity, air composition, pressure, growing season)
    - Management factors (growing media, nutrition, irrigation – amount and frequency, fertilizers, insecticide – pesticides, insect – pests and diseases, growth regulators)
    - Harvesting factors (stage of harvest, method of harvest, time of harvesting, mode of harvesting, distance of market, consumer preference)
    - Ethylene
    - Post – harvest factors (handling, pre cooling, storage environment – light, temperature, relative humidity, air circulation, CO₂ and O₂, water quality & pH, nutrition, preservative solution, control of diseases, packing, transportation, ventilation and spacing).

  ❖ **Harvesting factors**

- **Stage of harvest**
  Flowers remain in turgid condition for a long time if harvested at the proper stage of development. Cut flowers are generally harvested at early stage (matured stage) for long distance transport & at advanced stage for the local market. In some cases, the longer stem length is higher post harvest life & quality of flowers.
- **Harvesting stages of different cut flowers**

<table>
<thead>
<tr>
<th>Flower</th>
<th>Harvest stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roses</td>
<td>Tight bud but developed stage</td>
</tr>
<tr>
<td>Gladiolus</td>
<td>Basal two buds show the colour</td>
</tr>
<tr>
<td>Carnation</td>
<td>Fully developed bud at paint brush stage</td>
</tr>
<tr>
<td>Gerbera</td>
<td>Ray florets are fully expanded, two whorls of disc floret become mature</td>
</tr>
<tr>
<td>Chrysanthemum</td>
<td>Standard: Fully open before the central disc is fully mature</td>
</tr>
<tr>
<td></td>
<td>Spray: When four flowers are fully open before the pollens are shedded</td>
</tr>
<tr>
<td></td>
<td>Decorative: Central of the oldest flower fully open</td>
</tr>
<tr>
<td>Gypsophilla</td>
<td>25-30% flowers are fully open in the inflorescence</td>
</tr>
<tr>
<td>Tuberose</td>
<td>Single: Buds are fully developed but yet not open</td>
</tr>
<tr>
<td></td>
<td>Double: Baal 3-4 buds start to open</td>
</tr>
<tr>
<td>Orchids</td>
<td>Most species: Fully open flowers.</td>
</tr>
<tr>
<td></td>
<td>Dendrobium: 75% inflorescence is open</td>
</tr>
<tr>
<td>Anthurium</td>
<td>When one third to one half of spadix show change in colour.(mature )</td>
</tr>
<tr>
<td>Bird of paradise</td>
<td>When first florets is fully open</td>
</tr>
<tr>
<td>Lilium</td>
<td>When all buds are mature and show colour</td>
</tr>
</tbody>
</table>

- **Post harvest factors affecting the longevity of cut flowers**

- **Temperature**
  
  High temperature accelerate floral development, senescence and respiration rate. Low temperature slower down the respiration rate and the less utilization of carbohydrates and other storage material in plant tissues. In lower temperature flower produce less ethylene and also retard water losses and development of micro organisms. So, the after harvest flowers put in low temperature between 0-15°C.

- **Water quality**
  
  Hard water containing calcium and magnesium is harmful. Sodium and fluoride ions are also harmful. So, it is better to use distilled water for cut flower. pH of water should be 3.0 to 5.0.

- **Quality control and grading**

  (A) **Quality control**
  
  Cut flower must be correct shape, not too tight or open and flowers should not be affected by mechanical injury and insect or disease. All flowers must be clean, uniform size, proper foliage color, no chlorosis and necrosis symptoms.
(B) Grading

Uniform size, color, proper stem length and diameter must be sort out in different bunches.

- Ventilation, spacing and packaging:

  Provisions for air circulation, commodity spacing and adequate packaging are essential. There should be high rate of air movement to remove large amounts of respiration heat.

- Preservatives:

  Commercial preservatives are prepared containing a mixture of chemicals such as sugars, salts, growth regulators. Among sugars – sucrose (30%), ethylene inhibitors – STS, hydrated compounds – Tween – 20 beneficial for keeping freshness of flowers. Among growth regulators_ BA, IAA, NAA, 2,4,5-T, GA, BA, CCC, Nutrient solutions of N, P, K & organic acids – citric acid, tartaric acid & benzoic acid used to reduce microbial growth.

- Diseases & pests:

  Among bacteria – pseudomonas, Enterobacter, Erwinia, Bacillus, Acetinobacter & Flavobacterium commonly found. Fungal species- Botrytis, fusarium, Mucor, Penicillium, Rhizopus, Aspergillus are responsible for early senescence & wilting of flowers. Respiration & ethylene evolution is generally higher in injured plants, further reducing storage & vase life.

- Post harvest technology in cut flowers

  It is important to know the factors, which influence the postharvest quality of cut flowers in order to develop post harvest handling strategy. Various factors, which should be considered for post harvest handling technology in cut flowers.

1. Flower sensitivity to ethylene:

  Ethylene is an important factor influencing postharvest quality and life of flowers. There is production of ethylene in cut flowers and peak in ethylene is observed just before flower senescence. Flowers show variation in their behaviour towards sensitivity to ethylene. i.e. few flowers are highly sensitive while some are less sensitive to ethylene. Flowers like rose, carnation, chrysanthemum etc are highly ethylene sensitive while flowers like gladiolus, tuberose etc are low to insensitive to ethylene. There is need to treat ethylene sensitive flowers with anti-ethylene compounds to improve their vase life and quality.

2. Consumer preference:

  Consumer preference is generally observed in stalk length, bud size and at the stage of bud opening.

3. Distance to the market:

  The stage of harvest is dependent upon distance to the market. For long distance, firstly, the flower should be harvested at early bud stage and secondly, proper
packing is must to ensure quality at the distal end. Further, pulsing treatment should also be employed. However, for short distance markets i.e for direct sale, one can go for some advance stage of harvest.

4. Market - status/position:

Generation of market information and accordingly formulation of market strategy is necessary. Here, post harvest technology plays a vital role. It is very important to know the prevailing market status for the particular flower. The factors influencing status flower market like festival time and should well be identified.

❖ Postharvest techniques:

• Conditioning:

  Condition the flowers to rehydrate and to overcome slight wilting. Flowers are treated with demineralised water supplemented with germicides and acidified. The purpose is to load the flower with water to ensure maximum turgidity at the time of sale and utilization. Follow these steps for proper conditioning: Remove about 5-8 cm or 2-3 inches or more of the stem ends if the stems have been out of water for a long time. Soak the cut stem ends in warm water (40-43°C, pH 3.5), preferably in a cool room, until flowers are fully rehydrated. Sugar should be added to the water of flowers at the bud stage, or if flowers are to be shipped to distant markets or stored for an extended period. The stalks should be put in a 10-20% sugar concentration for between 12 and 24 hours. Too much sugar may result in leaf yellowing, although there may be no noticeable injury to the flowers. To acidify the solution, it is suggested that you add a small amount of citric acid as follows:

  For soft water, use 0.1 g/L
  For medium hard water, use 0.3 g/L
  For hard water, use 0.45 g/L.

  Some chemicals like STS, 8-HQC, 8-HQS, sucrose etc can also be used for conditioning. Wetting agent like Tween-20 @ 0.01-0.1 per cent can also be added. More wilted flowers can be immersed in water for an hour and then transferred to plastic container with the stem in warm water and placed in cold room.

• Pre–cooling:

  Flowers harvested should be immediately placed in distilled water after rehydration and then should be move to cold storage without packaging for pre – cooling till a desired temperature is reached. Pre – cooling is fast removal of field heat and it is important to slow down the metabolic activities of cut flowers. Pre- cooling temperature reduces respiration rate and decreases breakdown of nutritional and other stored material in the stems, leaves and petals, delays bud opening and flower senescence. It is decreases flower sensitivity to ethylene. Pre-cooling of flowers to optimal storage temperature, also prevents moisture from condensing on flowers, reduces the risks of botrytis infection. Several pre- cooling techniques such as room cooling, forced air cooling, hydro cooling, vacuum cooling and ice bar cooling are available. The pre-cooling temperature varies with the species and cultivars of flower.
**Pre-cooling temperature suitable for cut flowers**

<table>
<thead>
<tr>
<th>Flowers</th>
<th>Pre-cooling temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthurium</td>
<td>13 °C</td>
</tr>
<tr>
<td>Chrysanthemum</td>
<td>0.5-4.0°C</td>
</tr>
<tr>
<td>Orchids</td>
<td>0.5-4.0°C</td>
</tr>
<tr>
<td>a. Cymbidium</td>
<td>7-10 °C</td>
</tr>
<tr>
<td>b. Dendrobium</td>
<td>5-7°C</td>
</tr>
<tr>
<td>Carnation</td>
<td>1 °C</td>
</tr>
<tr>
<td>Gerbera</td>
<td>5-7 °C</td>
</tr>
<tr>
<td>Gladiolus</td>
<td>4-5°C</td>
</tr>
<tr>
<td>Rose</td>
<td>1-3°C</td>
</tr>
<tr>
<td>Alstoemeria</td>
<td>4°C</td>
</tr>
</tbody>
</table>

- **Impregnation:**
  It refers to permeation or infusing of the stem ends for a short time with chemicals. It protects the blockage of the water vessel in stem by microbial growth and decay. Chemicals like CoCl$_2$ or NiCl$_2$ are used at high concentration for a period of 10-15 minutes. Flowers like aster, gerbera, carnation, chrysanthemum and phalanopsis respond to it very well.

- **Pulsing**
  It consists of placing the lower portion of cut flower stems in solution containing high percentage of sugar and germicide for a period of few hours to two days. Specific formulations developed very with the flower species as sucrose 2-20% for 12-48 hours at 20 – 27 °C and relative humidity 80 -100 % under 2000 – 2500 lux cool light. It is a principle, in which plant tissues are filled with carbohydrates to ensure sufficient substrate for the flowers to mature and possess longevity. Fresh cut flowers are pulsed by placing lower portion of flower stems in solutions containing sugar and germicides for a period ranging from few hours to 2days, depending upon the flower species. The addition of sucrose in the vase water alone may encourage increased growth of micro-organisms in the vase medium. Hence, the antimicrobial agents viz. 8-HQ, 8-HQC, 8-HQS, silver salts, citric acid etc should also be incorporated to enhance better solution uptake that would suffice maximum effects of the supplied sugar. The concentration of pulse solution varies in different flowers. Generally for rose and carnation,5-8% sucrose solution sufficient while for multi-floret spikes like gladiolus and tuberose, high concentration of 0-20% is needed (Singh et al, 2008). Pulsing is a very effective treatment for the farmers, as his treatment can be given just after harvest, at the site of production itself. The treatment can be given in the evening and in morning, the flowers can be sending to the market.
Preservative-Solution:

Preservative or vase solution refers to a solution consisting of sucrose, anti-microbial agent and or growth regulator in which cut flowers can be continuously placed. Basically, the concentration is much lower than pulse solution. The anti-microbial agents like 8-HQC, 8-HQS, aluminium sulphate, anti-ethylene agents like STS, AgNO₃ and acidifying agents like citric acid are widely used as vase solution. Even plant growth regulators like Gibberellic acid, Benzyl adenine are also reported to improve vase life and quality of gladiolus and chrysanthemum. Growth retardants like CCC, SADH and MH have also been reported to improve vas life of some cut flowers. Ethylene inhibitors like Amino Ethoxy Vinyl Glycine (AVG), Methoxy Vinyl Glycine (MVG) and Amino Oxyacetic Acid (AOA) are beneficial in ethylene sensitive flowers. Besides, chemicals (anti-oxidants and minerals salts) like lipoic acid, Sodium Benzoate, Calcium Nitrate, Ammonium Sulphate, Zinc Sulphate are also used for prolonging life and quality. Recently, chemicals like 1-MCP and 1-OCP have been found to be highly effective especially for ethylene insensitive flowers.

Minerals solutes used in prolonging flower longevity

- Sucrose : 5 to 10 %
- Sugar: 2 to 20 %
- 8 – HQC: 250 mg/lit
- 8 – HQS: 250 mg/lit
- Citric acid : 1 to 5 %
- Aluminium nitrate: 100 mg/lit
- Aluminium sulphate: 100 mg/lit
- Borax
- Calcium nitrate: 250 mg/lit
- Silver nitrate : 100 mg/lit
- Silver thiosulphate : 100 to 150 mg/lit

Storage:

Storage of flowers at optimum stage and quality is important for high market value. Flowers can be stored generally in two ways, dry storage and wet storage. For long term storage dry storage is beneficial as it restores the flowers stage while for short term storage wet storage can be employed. Dry storage consists of packaging and cold storage of flowers while wet storage employs placement of flower stems in preservative solution for required duration in cold storage.

Methods of storage of cut flowers:

There are 3-4 general methods of storage of flowers.

1. Refrigerated storage: Most widely used method of storage of cut flowers.

   There are two types (a) Wet storage and (b) dry storage.

   (a) Wet storage:

   Flowers stored with their bases dipped in water or preservative solution, Good for short duration, day to day handling. Stored at a temperature at 2-4°C.
(b) **Dry storage:**

Flowers sealed in plastic bags are stored to prevent loss of moisture. More laborious but hold the flowers for longer duration. Pre-cooling and pulsing before dry storage is important. Stored at 0.5 to 1.0 °C is ideal for most flowers, for tropical flowers like anthurium, cattleya and poinsettia is 10-15° C and for sub-tropical flowers like gladiolus, strelitzia and anemone is 2-8° C.

2. **Controlled Atmospheric storage (CA):**

Low temperature storage in gas tight chambers under decreased levels of oxygen (O₂) and increased levels of carbon dioxide (CO₂). CO₂ levels higher than 4% and O₂ level lower than 0.4 per cent causes injury and anaerobic conditions respectively. Different types of flowers cannot be stored in the same room at the same time since the O₂ and CO₂ required for storage vary for different flowers and it is one major limitation in CA storage.

3. **Modified Atmosphere storage (MA):**

Less precise form of CA storage, the dry storage of flowers in sealed bags leads to reduction in O₂ and increase in CO₂ levels due to respiration of the tissue. Build up of very high level of CO₂ may cause damage to flowers. Flowers stored in partially permeable materials are beneficial.

4. **Hypobaric or Low pressure storage (LPS):**

Storage at low atmosphere pressure under refrigerated conditions, continuous ventilation and high relative humidity. Rapid loss of water from tissues is major disadvantage and cost of installation is also high.

* The optimum storage temperature and duration of storage varies with flower type. The recommended commercial storage conditions for important flowers at 90-95% RH is as follows.

<table>
<thead>
<tr>
<th>Storage</th>
<th>Crop</th>
<th>Storage temperature (° C)</th>
<th>Maximum storage period (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>Carnation</td>
<td>0-1</td>
<td>16-24</td>
</tr>
<tr>
<td></td>
<td>Chrysanthemum</td>
<td>0.5-1</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Gerbera</td>
<td>2.00</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Gladiolus</td>
<td>4-5</td>
<td>5-7</td>
</tr>
<tr>
<td></td>
<td>Rose</td>
<td>0.5-2</td>
<td>7</td>
</tr>
<tr>
<td>Wet</td>
<td>Anthurium</td>
<td>13</td>
<td>14-28</td>
</tr>
<tr>
<td></td>
<td>Carnation</td>
<td>0.5-1</td>
<td>21-28</td>
</tr>
<tr>
<td></td>
<td>Dendrobium</td>
<td>5-7</td>
<td>10-14</td>
</tr>
<tr>
<td></td>
<td>Gerbera</td>
<td>4</td>
<td>4-7</td>
</tr>
<tr>
<td></td>
<td>Gladiolus</td>
<td>4-5</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Tuberosa</td>
<td>7-10</td>
<td>3-5</td>
</tr>
<tr>
<td></td>
<td>Rose</td>
<td>2-3</td>
<td>5-7</td>
</tr>
</tbody>
</table>
Grading

Grading means grouping of flowers based on quality prior to marketing. Grading is done on the basis of

A. Sort the flowers according to the following: cultivar, stage of maturity, extent of damage due to pests and diseases, malformed floral parts and color defects.

B. Grade according to stem length or size.

C. Bunch flowers according to number, cost, susceptibility to injury, and display quality of individual flower heads.

D. Tie bunches below the flower head, and about two inches from the cut stem ends. Tying should not be too loose or too tight. Rubber bands are best, because they can hold the bunches securely. They are easier to use and cheaper than tape or wire.

All the requirements for quality should be fulfilled in a particular grade for export. Flowers should look fresh, turgid and spotless along with proper bud size and stalk length as per the requirement. In US, the society of American florists has recommended four types of grading of cut flowers such as blue, red, green and yellow. Grading is done manually scale fixed on stand on a platform. Recently, new techniques like machine vision system, image processing techniques, neutral network analysis, Buyers decision theory etc are being developed for flower grading.

Packing

Packaging plays a major role in flower quality, appearance and opening ability. Poor packaging practices lead to deterioration of the quality and poor market value. The cell turgor controls the structure of plant organ, while the loss of water due to improper packaging induces a stress, which in turn hastens the senescence and reduces the vase life. Proper packaging of the cut flowers is must for ensuring good quality at the retailer or customer end even after long transportation or storage duration.

Merit of packaging

- It protects flowers from bruising and physical injury during transportation.
- It brings down rate of metabolism.
- Maintains turgidity in cut flowers and avoids dehydration effect of cold storage.
- Minimizes low temp. Chilling injury during cold storage.
- Improves opening ability in cut flowers.
- Retains petal pigment.
- Maintains overall freshness and quality.

Types of packaging

- The packaging of the cut flower is basically of two types:
  1) Internal packaging

The internal packaging consists of direct packaging of the cut flowers with a single or double layer film. The different types of packaging films have different air permeability rates. Hence, depending upon the requirement, the flower type, temperature and duration, the packaging film should be selected. Ex.: cellophane,
polypropylene, low density polyethylene, high density polyethylene, paper: butter paper, parchment paper and news paper, corrugated paper.

2) **External packaging**

External packaging is done for protecting the cut flower from physical injuries or bruises during the transport system. The CFB boxes of different sizes with or without vents are found to be highly beneficial for the external packaging of the cut flowers. The CFB boxes posses good physical strength depending upon the number of layers used in CFB sheet. The box should be strong enough to support the weight of at least 8 full boxes placed on the top under high humidity.

- **Box sizes, which are commonly used for packing flowers are:**

<table>
<thead>
<tr>
<th>Flower</th>
<th>Length (cm)</th>
<th>Width (cm)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carnation</td>
<td>100</td>
<td>40</td>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td>Chrysanthemum</td>
<td>80</td>
<td>50</td>
<td>23</td>
<td>15</td>
</tr>
<tr>
<td>Gladiolus</td>
<td>120</td>
<td>50</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Rose</td>
<td>100</td>
<td>40</td>
<td>30</td>
<td>17</td>
</tr>
</tbody>
</table>

- **Do’s and Don’ts for improving vase life of cut flowers**
  - Harvest flowers at right stage
  - Remove 1/3 rd leaves and all the leaves below water
  - Don’t dip more than 3 -10 cm stem in vase solution
  - Add 1 -2 teaspoons of sugar in vase water or use recommended preservatives
  - Keep flower vases in red or blue light about 2000 lux or more
  - Higher humidity in room is good
  - Change vase water every 2 -3 days
  - Cut the lower stem end by 1 -2 cm alternate day

- **Do’s and don’ts for improving longevity of cut flowers**
  - Don’t keep flower vases under/near direct sunlight or electric appliances like fans, heaters, blowers, etc.
  - Avoid smoking or combustion of gases in room
  - Allow clean and fresh air to pass through the room
  - Spray water with barber sprayer at least twice a day
  - Keep on removing dried or faded flowers/florets
  - Keep stems (2-3 cm) in boiling water for about 60 seconds particularly when stems having milky fluid exuding like poinsettia.

- **Reference:**


PLANT GROWTH REGULATORS (PGR) IN NURSERY

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Plant growth regulators are the chemical compounds other than nutrients which are required in small or minute quantities to regulate, modify or inhibit the plant physiological processes.

Plant Hormones

Plant growth hormones are the chemical compounds synthesized by the plant inside its body and transported from site of production to site of action to regulate, modify or inhibit the plant physiological processes.

Types/Groups/Classes of Plant Growth Regulators (PGR)

1. **Gibberellins**: Play important role in cell elongation in plant cells e.g., Gibberellic Acid GA1, GA3, GA7

2. **Auxines**: Play important role in cell division and cell multiplication. These substances are used mainly for the root initiation, e.g., Indol Acetic Acid (IAA), Indol Butaric Acid (IBA) and Naphathalic Acetic Acid (NAA).

3. **Cytokinins**: Play important role in cell elongation, e.g., Kinetin, Zeatin

4. **Abscisic Acid**: Growth retarding substance and plays an important role in fruit drop and thinning, e.g., ABA

5. **Ethylene**: Mainly called as ripening hormone which hastens ripening in fruit crops. Ethrel also useful for sex expression in cucurbitaceous vegetable crops. Eg. Ethephon, Ethrel.

Role of Plant Growth Regulators on Fruit Production

1. **Propagation**

Large number of plants are propagated by stem cutting, leaf cutting and layering. For promoting rooting, the commonly used hormone is IBA followed by NAA. IBA enhances root formation on cuttings. Cytokinins also help in quick and profuse root formation on cutting and layers. By use of IBA, profuse root formation is observed in cutting at fig, pomegranate, croton, rose rootstock, hibiscus, grape etc.
(A) Seed Germination

Plant growth regulators are used to promote early seed germination and improve the germination percentage. Many seeds have natural dormancy which can be overcome by dipping the seeds in auxins.

- GA₃ @ 500 ppm solution enhances seed germination in aonla
- Guava seed- 1% KNO₃
- Papaya seed- 20 ppm Sodium thiosulphate 24 hour soaking
- Papaya seed- 20 ppm Thiourea 24 hour soaking
- Ber- 500 ppm GA
- 200 ppm GA + 5% Sucrose.
- Aonla seed, rayan seed- 500 ppm GA3 8 hrs soaking.

(B) Vegetative Propagation

a. Cutting: Auxins play an important role in the initiation of roots in cuttings.

- A concentration of 500-1000 ppm auxins are used by quick-dip method of treating cuttings for species which are difficult to root.
- A concentration of 20-40 ppm auxins are used to the species which can be rooted easily.

- Guava cuttings: 5000 ppm IBA by quick dip method
- Grape cuttings: 4000 ppm IBA by quick dip method
- Pomegranates: 2000 ppm IBA by quick dip method
- Litchi cuttings: 3000 ppm IBA by quick dip method
- Jamun cuttings: 5000 ppm IBA by quick dip method
- Fig cuttings: 1000 ppm IBA by quick dip method
- Air layering-guava: 3000 ppm IBA by pasting lanoline paste
- Air layering-pomegranate: 3000 ppm IBA by pasting lanoline paste
- Air layering-litchi: 5000 ppm IBA by pasting lanoline paste
- Air layering-jamun: 10000 ppm IBA by pasting lanoline paste
- Air layering-tamarind: 4000 ppm IBA by pasting lanoline paste
- Air layering-cashew: 500 ppm IBA by pasting lanoline paste

b. Layering: Paste of auxin pasted on the operated portion of the plant part helps in initiation of roots in grafting and layering eg Air layering in Guava.

Air Layering in Guava
c. **Grafting:** IBA+6BA (500:500 ppm) in Bee wax paste is useful in joining the scion on stock in many fruit crops. Grapes, Mangoes, Sapota.

d. **Budding:** The treatment of IBA+6BA (500:500 ppm) in Bee wax paste is useful in bud joints in Citrus, Roses, Ber, Jamun, etc.

e. **Breaking Dormancy:** Gibberellins play an important role in breaking the dormancy of seeds of fruit crops by loosening the seed coat to permit water inside the embryo for germination, e.g., 500-700 ppm of GA3 in Ber.

f. **Hastening Rootstock Growth**

- Rangpur lime seedlings: 200 ppm of GA3 at one month interval.
- Jamberi rootstock seedlings: 200 ppm of GA3 at one month interval.
- Aonla seedlings: 20 ppm 6-BA at one month interval.
- Khirni and Custard apple seeds: 1000 ppm GA3, 20-24 hours seed soaking.

**Methods of Application**

The effectiveness of plant growth regulator is not only dependant on the concentration of substance, type of the plant species but also on the method of application. Different methods are used for the treatment of cuttings and layers with plant growth regulators.

1. **Prolonged Soaking Method**

   In this method the basal end of cutting are dipped in the dilute solution (20 to 200ppm) of the hormone for 24 hour in a cool dry place. After the treatment, the cuttings are planted in the nursery or in other suitable growing medium. The concentration of the hormone or growth regulator usually varies from 20 ppm to 200ppm, depending on the plant species and type of the cuttings. The concentration is usually low for easy rooting species and higher for difficult to root species. The nurserymen rarely use this method. However, it is very useful for difficult to root species, where some materials like vitamins, sugars and nitrogenous compounds are also used along with the growth regulators for facilitating rooting in such species.

2. **Quick Dip Method**

   The method is an improved version of the previous methods. It is very effective method of treating cuttings with growth regulating chemicals. It is followed by most of the plant propagators for raising plants through cuttings. In this method, the basal ends of cutting are dipped in the concentrated solutions of a hormone for a short time, usually for 5 seconds to 2 minutes. The treated cuttings are then planted in the nursery or field for rooting. The concentration of hormone for quick dip method ranges between 500 ppm and 10,000 ppm, depending on the species and type of the cuttings. Usually a concentration of 4,000 to 5,000 ppm is used for the purpose. Higher concentrations may cause injury to the cuttings and thus should be avoided.
Dipping of Cuttings in IBA Solution

3. Powder Dip Method

In this method, the basal ends of freshly prepared cuttings are dipped in the carrierbased hormonal powder for some time. After treating the cuttings, extra powder adhering to the cuttings should be removed by shaking. Cuttings are immediately inserted in the rooting medium. Seradix, a popular formulation is used by thenurserymen in this method. For effective rooting, the cut ends of the cuttings should be moistened before the treatment. At the same time, the excess of powder should be removed to avoid adverse effects on the rooting process.

4. Spray Method

Spraying of growth regulators is sometimes done to the mother plants before taking cuttings from them. Spraying of stock plants with CCC/Ethepon in concentration ranging from 500 ppm to 1000 ppm is sprayed 30 to 40 days before taking cuttings from the trees. Cuttings taken from such plants, root better as compared to untreated plants.

5. Lanoline Paste Method

As described earlier, IBA is applied to the girdled portion of a layer or stool it is applied in lanoline paste for inducing rooting in plants. Honeybee wax may also be used in place of Lanoline.

Preparation of PGR Solution

1. Plant Growth Regulator Powder

For preparing hormonal powders, the required quantities of the hormone are weighed precisely on electronic balance and dissolved at the rate of 1 gm in 100 ml of acetone in a beaker. This material is poured into one kilogram of talc powder taken in mortar and mixed thoroughly with a glass rod. After mixing, the mixture is kept open in air for few hours. The alcohol evaporates. The dried talc is then ground to fine powder. This fine powder should be kept in airtight container and can be used for treating cuttings as and when required.

2. PGR Solution

For the preparation of hormonal solution, the required quantity of the hormone is measured and weighed accurately on electronic balance. It is then dissolved in a small quantity of acetone or alcohol. When the contents are fully dissolved, the final volume is made with distilled water. The pH of the solution should be nearly neutral. If the pH of the solution is higher or lower, it may not induce rooting; rather it would affect the rooting process adversely. The pH of the solution can be adjusted with the help of 0.1 N HCL or 0.1 N KOH. Citric acid, humic acid may also be used for lowering the pH of an alkaline solution. Hormonal solution should preferably be prepared fresh to avoid the solution becoming inactive. The cans of solution, however, can be stored in a cool, dry and dark place.
3. PGR Pastes

For preparing hormonal pastes, the required quantities of hormone are measured and weighed accurately and dissolved completely in small quantity of alcohol. The required quantity of the lanolin (greenish-yellow colored grease like substance) is also weighed and heated slightly in a beaker under gentle flame. When, the lanolin slightly liquefies, the dissolved hormone is poured in it. The contents are mixed thoroughly with constant stirring with a glass rod. The contents are then allowed to cool down. The paste is thus ready for use. Until use, the paste may be kept in a cool, dry and dry place.

Precautions

The use of root promoting hormone for the induction of rooting in the cuttings and layers has now become the backbone of the nurserymen. These are readily available in the market in various forms but it is always better to prepare them at nursery site itself. The hormones not only induce rooting but also help in growth and development of the roots. Indole butyric acid (IBA) and Naphthalene acetic acid (NAA) are most effective in cuttings and layers and these are used in tissue culture media also. To have better and desired result from growth regulators, the following precautions should be taken for their preparation and further use;

☐ Check for expiry date of the hormonal powder.
☐ Hormones/growth regulators should be weighed and measured precisely and accurately, preferably with electronic balance, measuring jars and cylinders.
☐ As most of them don’t dissolve in water, a proper solvent like acetone or alcohol etc. should be used.
☐ Purchase of required amounts PGRs as they are costly and difficult to store.
☐ Hormones are known to deteriorate faster in warmer temperatures. Therefore, they must be stored in cool and dry places preferably in a refrigerator.
☐ Solutions should always be made fresh. If required to store for some time, use of refrigerator is desirable.
☐ Use hormonal solution for treatment of cuttings and lanolin paste for layers.

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PLANT PROPAGATION STRUCTURES

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Learning objective

☐ Utility of plant propagation structures
☐ Different types of Plant propagation structures

INTRODUCTION

The structures which facilitate propagation of plants are called propagation structures. Propagation structures are required for propagating plants by seed, cuttings and grafting. Propagation structures are of two types; i) The first type a structure with temperature control and ample light, such as a green house, modified quonset house, or hotbed-where seeds can be germinated or cuttings are rooted or tissues culture micro-plants are rooted and acclimatized and the ii) The unit is structure into which the younger, tenderplants can be moved for hardening, preparatory to transplanting out-of-doors. Cold frames,low polyethylene tunnels or sun tunnels covered by saran cloth and lath-houses are usefulfor this purpose.

Greenhouses

Greenhouse has been used long back by horticulturists as a mean of forcing rapidgrowth of plants and extending the growing season particularly in colder areas. These are being used for whole sale production and propagation of floricultural plants, nursery stock of fruit crops and vegetable crops.

A greenhouse greatly extends the variety and scope of propagation. Many kinds of green houses are used for propagation but the most suitable type is the one that admits the maximum amount of light. This is important, particularly where most of the propagation is done in late winter and early spring. Good light conditions are essential for the study growth of the seedlings. Experiments have shown that a greenhouse that runs from east-to-west is best for better light penetration in winter and early spring, and consequently preferable for raising seedlings at this time of the year. Moreover, it is important that the green houses should be well away from any kind of shade such as a tree of building, including other greenhouses. Some shelter, however, from north to northeast winds is desirable. These glasshouses may be plastic polyethylene covered or made form fiberglass. Modern greenhouses are well equipped with elaborate structures and have precise control on temperature, light intensity and humidity.

The size and type of greenhouses, primarily depends upon the need of the plant propagator. Glass covered greenhouses are expensive but they have long life. However, for shorter benefits, plastic covered green houses can also be made. Two types of plastics are available for the construction, polyethylene and fiberglass. Both are
lightweight and inexpensive as compared to glass. Plastic covered greenhouses are lighter than glass covered ones but there is very high increase in humidity is such houses, especially in winters, which results undesirable water drops on the plants. It can however be overcome by making adequate ventilation. Polyvinyl chloride (PVC) has also been used in construction of greenhouses but it tends to darken pre-maturely in sunlight. In India, construction of temporarily low-cost poly-houses is in fashion for raising nursery of fruit plants in off season. Such low cost greenhouses are constructed either on wood or metal framework and are covered with polyethylene sheet of 0.10 to 0.15mm thickness, which is resistant to ultra-violet rays. These houses are equipped with thermostat, cooler or air conditioner or humidifier etc for rigid control on temperature and humidity. Greenhouses made from fibreless sheet are more durable than the polythene houses, but are quite expensive. In greenhouses, two types of beds are used for raising goring seedlings. In greenhouses, the beds may either be prepared on ground itself or raised beds or bench type beds are used.

Greenhouse structures vary from elementary home constructed to elaborate commercial installations. Commercial greenhouses are usually independent structures of even span, gable-roof construction, well proportioned so that the space is well utilized for convenient walk ways and propagating benches. On commercial scale several greenhouses units are often attached side-by-side for eliminating the cost of conversing the adjoining walls with glass or polyethylene. The heating and cooling equipment is more economical to install and operate, as large area can be shared by the same equipment. Greenhouse construction begins with a metal framework, to which metal rash bars are fastened to support panels of glass or some type of plastic materials. Now a day’s metal prefabricated green house with pre-bolted trusses are available from several manufacturers. The two most common structural materials for green houses are steel and aluminum. Most greenhouses are made from galvanized steel, which is cheaper, stronger and lighter.

**Heating and cooling system in greenhouses:** Ventilation, to provide air movement and air exchange with the outside, is necessary in all green houses to aid in controlling temperature and humidity. The attempt of sloppy green houses near the mud houses in Ladak is an attempt in these directions. The heat can be conserved by proving sealed polyethylene sheeting outside green houses, glass or fibre glasses.

**Environmental control:** Greenhouses can be cooled mechanically in the summer by use of large evaporative cooling units. The “pad and fan” system is installed at one side of a greenhouse with large exhaust fans at the other end. Fog or sprinklers can be used to cool greenhouses and maintain humidity but it is costlier than pad fan cooling. A maximum night temperature of 13 to 15.50 C and a day temperature of 240 C are generally set to start the heaters and fans, respectively. Spraying of greenhouse with whitewash in summer and opening and cooling side and ridge vents with a crank to control temperature and by turning on steam valves at night, whereas humidity is increased by spraying the walls and benches by hand at least once a day.
i) Analog control: In this system proportioning thermostats or electric sensors are used to gather temperature information. Analog controls are costlier than thermostats, but offer better performance.

ii) Computerized environment control: The amplifiers and logic circuit analogs have now been replaced by computerized environmental system, which involves microprocessor, which gathers information on a variety of sensors like temperature, humidity, light intensity, wind directions etc. to provide more precision. Although more costly than thermostats or analogs but computer controls offer significant energy and labour saving and increases production efficiency in propagation. The deviations from the present levels of temperature and humidity can trigger alarms by the computer.

Green house covering materials: The covering materials used for construction of green houses include glass, polyethylene, UV-stabilized polythene, acrylic, polycarbonate and fibreglass. The glass covered greenhouses are expensive but for a permanent long term installation under low light winter conditions because glass has superior light transmitting properties and less expensive relative humidity problems. Polyethylene materials are light weight and relatively less expensive compared to glass. Being light in weight, permits a less expensive supportive frame than is required for glass. Polyethylene has relatively short life than glass. The UV-stabilized sheets can last for 3-4 years. Polyethylene having a thickness of 100-200 micron is generally used. The acrylic is highly weather resistant and does not yellow with age, has excellent light transmission properties and retains twice the heat of glass, but it is more costly and brittle.

Polycarbonate: It is probably, the most widely used structures sheet material today. This material is similar to acrylic in heat retention properties, with 90% light transmission of glass. It is light in weight 1/6th of glass and easy to install. It is resistant to impact. Polycarbonate textured surface diffuses light and reduces condensation drip. For providing rigid panels fibreglass is used widely for construction of greenhouse. It transmits 80-90% of light. New materials are continuously coming onto the market, for constructing better glass houses.

Hot frames (Hot beds)

A hotbed is a bed of soil enclosed in a glass or plastic frame. A hotbed is a bed of soil enclosed in a glass or plastic frame. It is heated by manure, electricity, steam, or hotwater pipes. Hotbeds are used for forcing plants or for raising early seedlings. Instead of relying on outside sources of supply for seedlings, you can grow vegetables and flowers best suited to your own garden. Seeds may be started in a heated bed weeks or months before they can be sown out of doors. At the proper time the hotbeds can be converted into a cold frame for hardening. Hot beds are small low structures, used for propagation of nursery plants under controlled conditions. Hot beds can be used throughout the years, except in areas with severe winters, where their use can be restricted to spring, summer and fall. Another form of a hotbed is a heated, low
polythene tunnels or sun tunnels that is made from hooped metal tubing or bent PVC pipe, which is covered with polyethylene. The standard size of hot frame is 0.9 by 1.8 m. If polyethylene is used as the covering, any convenient dimensions can be used. Plastic and PVC tubing with recirculation of hot water are quite satisfactory for providing bottom heat in hot beds. Seedlings can be started and leafy cutting rooted in hotbeds early in the season. For small propagation operations, hot beds structures are suitable for producing many thousands of nursery plants, without the higher construction expenditure for larger, propagation houses.

**Cold frames**

A cold frame is a bottomless box with a removable top. It is used to protect small plants from wind and low temperatures. No artificial heat or manure is used inside a true cold frame but many gardeners experiment with a variety of soil conditions. They utilize the sun's heat. The soil inside the box is heated during the day and gives off its heat at night to keep the plants warm. The frame may be banked with straw or strawy manure to insulate it from the outside air and to retain heat. Cold frames include not only low polyethylene-covered wood frames or unheated sun tunnels that people cannot walk within, but also low-cost, poly-covered hoop houses. The covered frames should fit tightly in order to retain heat and obtain high humidity.

Cold frames should be placed in locations protected from wind. The primary use of cold frames is in conditioning or hardening of rooted cuttings or young seedlings prior to field, nursery row or container planting. Cold frames can be used for starting new plants in late spring. Low-cost cold frame construction is the same as for hot beds, except that no provision is made for supplying bottom heat. In these structures, only the heat of the sun is retained by the transparent or opaque, white polyethylene covering. When young, tender plants are first placed in a cold frame, the coverings are generally kept tightly closed to maintain a high humidity but as the plants become adjusted, the sash frames are gradually raised or ends of the hoop house to permit more ventilation and drier conditions. The installation of mist line or irrigation provision in cold frame is essential to maintain humid conditions. During sunny days, high temperature conditions can be controlled by providing ventilation and shading.

**Lath houses**

Lath (lath - thin strip of wood) or shade houses provide outdoor shade and protect container-grown plants from high summer temperature and high light irradiance. They reduce moisture stress and reduce the moisture requirement of plants. Lath houses have many uses in propagation, particularly in conjunction with the hardening off and acclimatization of liner plants prior to transplanting and for maintenance of shade requiring plants. In mild climates, they are used for propagation, along with a mist facility and can be used as overwintering structures for liner plants. However, snow load can cause problems in higher latitude regions.
Lath house may be constructed with many kind of materials, although aluminium prefabricated lath house are available, but may be more costly than wooden structure. Mostlath houses are covered with high density, woven plastic material such as saran, polypropylene fabric and UV-treated polyethylene shade cloth, which come in varying shade percentage and colors. These materials are available in different densities, thus allowinglower irradiance of light, such as 50 percent sunlight, to the plants. They are light weight and can be fastened to supporting posts.

**Propagation frames**

Sometimes in a greenhouse, the humidity is not enough to allow satisfactory rooting in the leaf cuttings. In such cases, enclosed frames covered with glass or plastic material maybe used for rooting of cutting. These frames are useful only on grafted plants as these retain high humidity during the process of healing. Large inverted glass can also be kept over a container having cuttings. Though, high humidity is required is such frames but ventilation and shading is necessary after the rooting process has started in the cutting. Warm and humid conditions inside these structures provide excellent environment for growth of pathogenic organisms, which may infect the propagation material. It is therefore, necessary to maintain cleanliness and proper sanitation in such structures.

**Net house**

Net houses are widely used as propagation structures in tropical areas, where artificial heating is not required and artificial cooling is expensive. In these areas, net houses may be constructed with roofs covered with glass or plastic film and its sides are covered with wirenet. It provides necessary ventilation and maintains an ideal temperature for germination of seeds and subsequent growth of the seedlings. The roof of net house may be covered with gunny cloth or even with live plant creeper to cut off the solar radiant energy and to keep the house cool. Net house can be constructed as per the need of the propagator and therefore its size varies with the requirements of the nurserymen.

**Bottom heat box**

It is a simple box for promoting rooting of cutting in difficult-to-root fruit plants like mango and guava. It consists of two chambers made from galvanized iron sheets. The outer chamber has a height of 70cm with 46 cm width and the inner chamber has a height of 68cm and width of 44cm. The space between the two chambers is filled with glass wool for heat insulation.

Another chamber is fitted inside the inner chamber with the height of 35cm fitted with two electric bulbs at the bottom for providing heat to the cutting. The innermost chamber is filled with soil mixture or any other propagation medium and the
cuttings are inserted in it. Two electric bulbs of 100 watt capacity are fitted at the bottom of the chamber to provide heat and light to the cuttings. Similarly, the temperature in the box is maintained and controlled automatically by a thermostat fitted at the bottom of the chamber. The most ideal temperature to be maintained in the box is 30± 20°C because at this temperature, cuttings of mango, walnut, olive and guava root easily and profusely. The initiation of rooting in cutting varies from species-to-species but in general, it takes 1-2 months for proper development of the roots.

**Mist propagation unit**

The rooting of softwood leafy cutting under spray or mist is a technique now widely used by nurserymen and other plant propagators throughout the world. The aim of misting is to maintain humidity by a continuous film of water on the leaves, thus reducing transpiration and keeping the cutting turgid until rooting take place. In this way, leafy cuttings can be fully exposed to light and air because humidity remains high and prevents damage even from bright sunshine. Mist also prevents disease infection in the cuttings by way of washing off fungus spores before they attack the tissues. While the leaves in this process must be kept continuously moist, it is important that only minimum water should be used. This is because excessive water leaches out nutrients from the compost, which may cause starvation. Moreover, a directly injurious effect on the cutting may occur from over watering. Hence, it is necessary to utilize nozzles capable of producing a very fine mist.

A small mist propagating units are mostly used by small farmers, whereas, highly advanced impermanent units are used by the commercial nurserymen in advanced countries. Mist propagation units are used for propagation of “difficult to root, cutting in most advanced countries. Mist beds are constructed within a greenhouse. A fine mist is sprayed intermittently over the cutting at regular intervals during day and night. The mist unit is controlled by a time clock, operating a magnetic solenoid valve and is set in a way to turn on the mist for 3-5 seconds to wet the leaves and turn off for some time and when the leaves are dry. The mist is again turned on.

In general, the mist has 5 control mechanisms. Timer, electronic leaf, thermostat and timer, screen balance and photoelectric cell. The two types of timers are used in a mist unit, one turn on in the morning and off at night and the second operate during day hours to produce an intermittent mist, usually 6 seconds “on” and 90 seconds “off”. In electronic leaf, a plastic with two terminals is placed under the mist along with cuttings, the alternate drying and wetting of the terminal breaks of the current, which in turn control the solenoid valve. A thermostat controls the temperature of the mist. In screen balance control mechanisms, stainless steel screen in attached to a lever with mercury switch. When mist is on, water is collected on the screen and when weight of water is more, it trips the mercury switch. The photoelectric controls are based on the relationship between light intensity and transpiration rate.

The mist unit can be set up in a glasshouse or in a polyethylene tunnel. Usually, it is set up on the propagation beds with 1.2 m width. The layout of the jets is very
important. While installing mist propagation until, all the jets should be at equal height. For proper functioning of mist, there must be proper supply of water. The water should have good pressure and it must be free from salts. The optimum pH of water to be used in mist unit is 5.5 to 6.5. Hard water or alkaline water may be avoided as it may block the nozzles of the mist chamber and it may accumulate on the young leaves of the cutting and thus inhibit the growth and development of roots. Further, it is essential that a well-drained rooting media should be is used and there should be provision for removal of excess water. Similarly, development of blue and green algal growth is very common in mist propagation structure which is considered very harmful to the propagating material and thus every care should be taken to keep mist propagating unit free from any type of algae. After rooting in the mist, hardening of the rooted cutting is important for better success in the field. When cuttings are rooted, misting should not cease abruptly as this may help in drying out of the young plants followed by scorching, instead, a weaving off process should be adopted in which misting is continued but the number of sprays/days gradually reduce. The way is to shift the rooted cutting to a greenhouse, fog chamber, and frames, maintained at higher temperature and low relative humidity. After phase-wise hardening only, the rooted cuttings are planted at permanent location or in the nursery.

**Growing rooms**

A growing room is an insulated building from which natural light is usually excluded. In it, illumination is provided by artificial means. Growing rooms are now widely used commercially for the production of seedlings of bedding plants, tomatoes and cucumbers in most advanced countries. The seedlings are usually grown in trays or pots kept on benches. To save space, the benches are usually installed in tiers being vertically about 2 feet long and 6 inches wide. Each bench is illuminated with 8 feet long 125-watt fluorescent tubes mounted 1 foot 6 inches above the bench. Seven tubes over each bench provide a light intensity of 500 lumens per square feet, which is adequate for bedding plants. However, if plants grown in such houses have higher requirements for light, more fluorescent tubes can be installed over the benches containing the plants. The heat of the tubes usually maintains a temperature of at least 70°F and excessive temperatures are prevented by use of fans installed in building.

**The automatic greenhouse**

Today, the modern greenhouses can be almost completely automated thus assisting propagation. For instance, by the use of thermostats, air and bed temperature can be maintained as per the requirement. Similarly, automatic ventilation allows the ventilators to open and close in relation to temperature. Even, automatic systems of irrigation are installed in the modern greenhouses and water is supplied to the plants through drip or trickle system to each pot or plant by individual nozzle of time switch. Most advancement in raising of plants under highly controlled environmental conditions has been the use of phytotron facility. National Phytotron Facility is available at IARI, New Delhi.
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POSTHARVEST HANDLING OF MANGO

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POST-HARVEST MANAGEMENT:

Post-harvest management means the handling of an agricultural product after harvest to prolong storage life, freshness and an attractive appearance. In order to deliver a quality product to the market and ultimately to the consumer to command buyer attention and gives the grower a competitive edge, proper post-harvest management is the need of the hour.

Nearly, 20-25 per cent of fruits are wasted due to faulty Post-harvest practices during harvesting, packaging, storage, grading etc. This wastage can be reduced to some extent through proper and scientific methods.

Post-harvest management can be considered as second production operation to add values to the products and the basic means for effective marketing. Post-harvest management operations are quite diversified, consisting of collection, curing, pre-treatment, grading, packaging, pre-cooling, low temperature storage, pallet loading, transporting, and depending upon various crops.

Like post-harvest management, the pre-harvest and subsequent harvesting of the fruits also plays an important role in enhancing the shelf life and quality of the fruits.

Pre-harvest factors influencing the post-harvest management:

The pre-harvest cultural practices like use of fertilizers, pest control, growth regulators, climatic conditions like wet and windy weather and tree conditions influence the fruit potentiality for storage by modifying physiology, chemical composition and morphology of fruits.

The spray of calcium is found useful in delay in ripening of Mangoes improves the storage life and increased the marketability. Similarly, pre-harvest spray of fungicide like Dithane M-45 (0.2%), Bavistin 0.1%, Topsin-M (0.1%) and Captan (0.2%) is effective in controlling storage disease due to anthracnose and stem end rot in Mango varieties.

1. Maturity:

External colour, appearance, pulp colour and soluble solids content are the reliable indicators for judging the fruit maturity. At the time of maturity, stone becomes hard and pulp colour changes from white to cream. In few varieties, at maturity stage, fruits sink in water (Langra, Chousa).

2. External Colour:

As the Mangoes mature, the skin colour changes from green to yellow. Normal size fruit that have started to turn yellow are ripe and ready for immediate harvest.
2.1 Fruit Appearance:
The shoulder area swells and rises above the stem end. This is accompanied by the stem end sinking and forming a small pit around the stem.

2.2 Internal Pulp Colour:
The pulp colour of Mango fruit at maturity changes from light yellow to deep yellow.

2.3 Soluble Solids Content:
Mangoes are ready for harvest when the soluble solids content (sugars) of mature fruit is at least 10%.

2.4 Maturity Indices:
The maturity indices are as under

- Color change from green to yellow.
- Development of "shoulders" on the stem end of the fruit.
- Fruit flesh turns from white to yellow starting at the endocarp and progressing outward to the skin during maturation.
- Stone becomes hard and pulp colour changes from white to cream.
- In few varieties fruits sink in water (Langra, Chousa)
- In case of Alphonso Mangoes, the fruit is considered mature when the shoulder outgrows the stem and the external colour becomes light green with a yellowish red blush.
- The harvest maturity in Dashehari and Langra cultivars reaches 12 weeks after fruit set. In Chausa and Mallika it takes about 15 weeks.

The best way to observe maturity in mango is the colour of the pulp, which turns cream to light yellow on maturity and hardening of stone.

3. Few facts about the maturity of Mango:

- Mango fruits need 120 to 140 days after fruit set to mature
- When a few semi-ripe fruits fall from tree – traditionally it is considered as maturity stage
- Picking fruits when their specific gravity is 1.01-1.02 gives good quality fruits
- Sinking of fruits in water indicates full maturity
- Fruits dipping in water have Sp Gr. >1.02
- Fruits dipping in 2.5% salt solution but floating in 5% salt solution: Sp Gr 1.02-1.04
- Fruits dipping in 5% salt solution have Sp Gr >1.04 and are over matured

Four Maturity stages:

- Fruit shoulders are in line with stem end and the colour is olive green
- Shoulders outgrow the stem-end and colour is olive green
- Shoulder outgrow-stem end and colour becomes light
- Flesh becomes soft and blush develops
- Fruits harvested at any of the above stages ripen well but those harvested at second and third stage give best taste and flavour.
- When a few semi-ripe fruits fall from the tree, it is traditionally considered that the fruits are mature for harvest.
If immature Mangoes are picked, fruits develop white patches or air pockets and this effects taste and flavour, whereas over-mature fruits lose their storage life. Such fruits present numerous problems during handling.

It is desirable to pick the fruits at the correct stage of maturity to facilitate ripening, distant transportation and maximum storage life, and thus to increase their quality and market value.

**Harvesting**

Harvesting is the most important factor, governing the post-harvest management. The harvesting of the fruit is done, either by hand picking, or plucking with a harvester at green mature stage. When the Mangoes are fully-grown and ready for picking, the stem will snap easily with a slight pull. If a strong pull is to be applied, then fruit is still somewhat immature and should not be harvested. A long-poled picking bag, which can hold nearly four fruits, is also used for plucking of the fruits. During harvesting precaution should be taken so that the fruit is held in the pouch and between the divider and knife and as the device is pulled, otherwise the blade may cut the stalk. This process avoids the falling of the fruits. Low fruits are generally harvested with the help of clippers. At the time of harvesting, precaution is to be taken to leave a four-inch stem to avoid the spurt of milky/resinous sap that exudes if the stem is cut close. Such fruits are less prone to stem-end rot and other storage diseases. Therefore, proper care should be taken to harvest the fruit cleanly and be kept as clean as possible.

It is a common practice to harvest fruits early in the season (premature stage) to capture early market. But, fruits should be harvested, when there is some yellow colour on the tree on the fruits. If immature fruits are harvested then white patches or air pockets are developed and effects the taste and flavour, whereas over-mature fruits lose their storage life. Such fruits present numerous problems during handling.

For export market, fruit should be harvested, when firm and at the mature-green colour stage. Fruits harvested at the mature green stage ripe quite rapidly after harvest and begin to turn yellow within 3 to 5 days at ambient temperature, while fruits harvested immature green will not ripen properly, having poor taste and shrivel soon.

Fruits should also not be harvested by stick, which may cause injury / bruises due to impact, resulting in decay, poor quality and attract low price. For efficient harvesting of Mangoes a simple, low cost and portable Mango harvesting device has been designed and developed at the **Central Institute for Subtropical Horticulture, Lucknow**. Mango fruits are taken into the pouch and held between the divider and knife and as the device is pulled the blade cuts the pedicel. Then the fruits are conveyed through a nylon chute to collecting boxes without bringing down the device every time. This saves time and protects fruits from mechanical damage due to impact. It also protects operator's hand from the sap, which oozes out from the point of detachment. On an average, a man can harvest about 800 to 1000 fruits per hour with the help of this device, depending on the skill of the worker, fruiting and height of the tree. It consumes 50 per cent less energy as compared to local methods. Harvested Mangoes should be placed in field containers of not more than 25 kg capacity for movement to the packing
shed. The harvested fruits should be kept in the shade and handled carefully at all times.

The harvesting of Mangoes is best done in the late morning, because in the early morning, the oil glands of the fruit are full, causing immediate discolouration of the peel, if they are accidentally pressed or bumped. A torn skin will expose the fruit to microorganism attack and result in rapid decay. Harvesting, under wet conditions should also be avoided, since wet fruits are more susceptible to microbial growth and soil particles may cling to wet crops, exposing them to soil-borne rot organisms.

The harvesting time of Mangoes varies with the distance to the market and local consumption. Nevertheless, the factors such as market price, market glut, etc., should also be considered while harvesting the Mango fruits.

After harvesting, fruits are generally heaped under the tree on the ground. Bruised and injured fruits should be removed from the heap, as they might cause damage to adjacent fruits. Post harvest losses in Mangoes have been estimated in the range of 25-40% from harvesting to consumption stage.

**Precautions during harvesting:**

The following precautions should be taken during harvesting.

i) Harvesting should be done by using appropriate instruments like clippers or by carefully twisting and pulling the fruit from the tree.

ii) The harvesting under wet conditions should be avoided, since wet fruits are more susceptible to microbial growth and soil particles may cling to wet crops, exposing them to soil-borne rot organisms.

iii) Harvesting of fruits is best in the late morning, because the oil glands of these fruits are full in the early morning, causing immediate discolouration.

iv) Stems left on the fruit should be cut off closely because they can puncture other fruit, causing post harvest decay and fruit spoilage.

v) The tree should never be shaken to harvest the fruits. The fruits should not be allowed to fall on the soil to avoid the mechanical injury that makes fruit more prone to decay.

vi) After harvesting, the fruits should never be left in direct sunlight and must be kept in the shade.

vii) The contact of fruits with the soil should be avoided and should be kept carefully into padded field crates, well-ventilated plastic containers, or picking bags.

viii) Picking bags either should strapped around the waist or put over the shoulder.

ix) Picking bags should be designed to empty from the bottom so that fruits can roll out of the sack onto the bottom of a larger field container or atop fruits already present.
Post-harvest operations:

Improved post-harvest practices results in reduction in losses, improve overall quality, extend shelf life and higher profits for growers and marketers.

Normally, Mangoes do not need any post-harvest treatment for marketing in local markets, except simple washing with water to remove the latex and dust. On a commercial scale or for export purpose, they are sometimes dipped in hot water, containing fungicide for the control of diseases. However, hot water treatment (HWT) is an effective post-harvest treatment for Mangoes. Dipping newly harvested fruits in hot water minimizes fruit fly damage, anthracnose, and stem-end rot infections.

Curing, washing, grading, packaging, storage, transportation, processing and marketing etc are the important post-harvest operation.

Packaging:

Packaging fresh fruits and vegetables is one of the most important steps in the long and complicated journey from grower to consumer. Therefore, main purpose of packaging is to provide produce with attributes necessary to survive a number of different hazards that can be expected during storage, transportation and distribution. Bags, crates, hampers, baskets, cartons, bulk bins, and palletized containers are convenient containers for handling, transporting, and marketing fresh produce. Packaging of fruits in standard containers is one way to reduce cost, the trend in recent years has moved toward a wider range of package sizes to accommodate diverse needs of wholesalers, consumers, food service buyers, and processing operations.

Packaging of fruits is also required for efficient handling and marketing, better eye appeal and better shelf life by reducing mechanical damage and water loss. Proper packaging protects fruits from pilferage, dirt, physiological and pathological deterioration during further handling.

Packaging and packaging materials contribute a significant cost in marketing of the fruits, therefore it is important to have a clear understanding of the wide range of packaging options available in market. Proper packaging helps in efficient marketing of fresh fruits, as it protects them from mechanical damage, moisture loss, pilferage and dirt.

Types packaging:

Two types of packaging i.e. Conventional packaging and modern packaging are used in packaging of the fruits. Conventional packaging comprises of wooden boxes, bamboo boxes and jute gunny bags, baskets made of woven strips of leaves, while in modern packaging, card board, plastic crates, poly bags, flexible sacks made of plastic jute such as bags (small sacks) and nets (made of open mesh), Plastic crates Pallet boxes and shipping containers, wire bags, are generally used. But, C.A.P. (Controlled Atmospheric Packaging) is the best modern packaging method for packaging of fruits. It allows certain gaseous component from atmosphere to replace, released by the fruits or check the gaseous exchange around fruit pack and thus enhance shelf life of fruits.
Most popular containers used for packing Mangoes are baskets of various makes and crates and boxes.

Central Institute for Subtropical Horticulture, Lucknow has designed and developed CFB Boxes of 5 kg and 10 kg capacity for packing and shipping of Mango fruits successfully as an alternative to traditional nailed wooden boxes.

Experiments conducted by the Directorate of Marketing and Inspection show that wooden crates are better package material than others because these can withstand a longer transportation with less damages.

Use of CFB boxes for packaging for the domestic market is need of the hour due to scarcity of the wood and environmental concerns of the country. For export purposes, CFB boxes are already in extensive use. Paper scraps, newspapers, etc., are commonly used as cushioning material for the packaging of fruits, which prevent them from being bruised and spoiled during storage and transportation. Polythene (LDPE) lining has also been found beneficial as it maintains humidity, which results in lesser shrinkage during storage.

Wrapping of fruits individually (Unipack) with newspaper or tissue paper and packing in honeycomb nets helps in getting optimum ripening with reduced spoilage.

**Few facts about the packaging:**

- The use of steel trunks or tin containers is limited, and 4-5% of the total despatches of Mango from Ratnagiri and Vengurla are packed in such containers.
- Wooden crates are good containers, especially for expensive varieties, which are packed in mature condition.
- There is no standardization of weight for any pack and it may differ from place to place.
- Cost of containers for packing Mangoes also differs from place to place, depending upon availability of raw material and labour.
- Padding or cushioning material in packaging of Mangoes varies from grass, paddy or wheat straw, to paper shavings and leaves of Mango.
- At times, no padding material is used.
- In some places, newspapers are used as lining material in different packages.
- Ventilated wooden boxes with paper shavings in alternate layers, as cushioning material is ideal for transportation of ‘Dashehari’ and ‘Banganpalli’ varieties for long distance by rail.
- No sudden change in the existing system of package of this fruit seems to be possible.

**Preparation of fruits for packaging:**

Fruits should be checked prior to packing to ensure absence of blemishes, bruises, insect infestation and mechanical damage. Stem of fruit should be removed, while holding the fruit with stem end down. After removal of stem, fruits should be
placed on a de-sapping bench and allow sap to drain for 20-30 minutes. Fruits should also be washed in order to reduce the chances of any sap burn. Care should also be taken while handling fruits so that stems are not accidentally broken. Fruits should be packed with stem end down and convex curve up. This position prevents any sap that oozes after fruit has been packed from spoiling appearance of fruit.

**Qualities of packaging material:**

Packages act as a container, which offers accommodation to fruits for storage and transportation, therefore packages must have following basic qualities.

a) Package must have sufficient mechanical strength to protect the contents during handling, transport, and stacking.

b) Packaging material must be free of chemical substances that could be transferred to the produce and become toxic to man.

c) Package must meet handling and marketing requirements in terms of weight, size, and shape.

d) Package should allow rapid cooling of contents and prevent build up of heat

e) Mechanical strength of package should be largely unaffected by moisture content (when wet) or high humidity conditions.

f) Package should be reusable, and biodegradable.

g) Cost of package should be as low as possible.

h) It must prevent spoilage during transit and storage.

i) Labeling of package must indicate about quality, variety, date of packing, weight and price etc.

j) It must be convenient in handling operations and to stack.

k) It must be clean and attractive.

l) It should immobilize the fruits placed inside.

q) Quality and hygienic cushioning material must be used to protect fruits from impact, injury and compression.

r) It should offer good ambient conditions to fruits congenial for storage and transportation

s) It should meet optimum requirements of ventilation vis-à-vis temperature and relative humidity management.

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PRESERVATIVE TREATMENTS FOR CUT VEGETABLES

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ABSTRACT

Postharvest technologies have allowed horticultural industry to meet the demands of local and worldwide distribution of fresh produce that have high nutritional and sensory quality. Enzymatic browning is the major important cause for fresh cut vegetables deterioration and decay and quality loss. The preservatives which preserve the colour, flavour, texture by controlling microbial growth and deterioration of fresh cut vegetables. Enzymatic browning is main cause for quality loss in fresh cut vegetables. Methods to prevent browning are a great research in the field of food industry. The prevention of oxidation was mainly done by different methods of chemical, physical, controlled atmosphere and coating methods.

Keywords: Enzymatic browning, preservation, polyphenol oxidase.

Introduction

From the quality point of view, it is desirable to preserve the characteristics of fresh cut vegetables. Obviously, any food product should be safe for consumption, and fresh cut products are very sensitive to contamination. Among the limitations for shelf life of fresh cut vegetables are decay, desiccation, discoloration/ browning, microbial spoilage, textural changes and development of off flavours and off odour. The primary quality attributes of a food product include colour, texture, flavour and nutritional value.

While the conventional food processing methods extend the shelf life of vegetables, the minimal processing to which cut vegetables are highly perishable and requiring cool storage to enhance a shelf life. Preparation steps such as peeling, slicing, shredding etc. This is the main cause for where micro organisms enter into the internal tissues of produce and make that product is not available for consumption. Among the possible consequences of mechanical injuries to produce are an increase in respiration rate and ethylene production, accelerated senescence and enzymatic browning (Rosen and Kader, 1989).

Enzymatic browning

Mainly vegetables have more health benefits for consumers, due to their content of fiber, vitamins and antioxidant compounds. However, the antioxidant properties may change during the processing and storage of vegetables. These changes induce a great loss of the microbial and antioxidant qualities (Lindley, 1998). Thus preservation against oxidation in food during processing and storage has become an increasing priority in the food industry. In fact, oxidation is the important cause of food decay
after that induced by microbiological contamination. The enzymatic browning involves two oxido reductases enzymes *i.e.*, polyphenoloxidase (PPO) and peroxydase (POD). The browning occurs when the cutting, shock, loss of firmness lead to the starting of browning reactions which induce losses or changes of flavor, odor and nutritional value.

**Pre-harvest factors**

Several parameters may contribute to the development of enzymatic browning. Agricultural practices, soil, fertilizers, climate and harvesting conditions all affect the final quality of fresh cut products (Ahvenainen, 1996). High nitrogen levels have been related to a greater tendency to brown in potatoes (Mondy *et al.*, 1979). The susceptibility to brown may differ from cultivar to cultivar was explained in table 1.

**Table 1: Susceptibility of potato varieties to enzymatic browning after storage (of whole unpeeled tuber) at 5°C and 75% RH**

<table>
<thead>
<tr>
<th>Storage time</th>
<th>Browning index</th>
<th>var. Bintje</th>
<th>var. Van Gogh</th>
<th>var. Nicola</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 month</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 min</td>
<td>6</td>
<td>27</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>60 min</td>
<td>15</td>
<td>40</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>120 min</td>
<td>21</td>
<td>52</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td>5 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 min</td>
<td>16</td>
<td>26</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>60 min</td>
<td>23</td>
<td>56</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>120 min</td>
<td>30</td>
<td>78</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>8 month</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 min</td>
<td>10</td>
<td>28</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>60 min</td>
<td>32</td>
<td>74</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td>120 min</td>
<td>62</td>
<td>104</td>
<td>145</td>
<td></td>
</tr>
</tbody>
</table>

Browning evaluation was carried out on 5 mm slices cut from the centre of the tubers and left at 23°C for observation at n30 min, 60 min and 120 min after cutting (Mattila *et al.*, 1993).

**Post harvest and processing factors**

Processing operations such as washing, scrubbing, peeling, trimming, cutting, shredding etc carried out during the initial stages of fresh cut preparation cause mechanical injury to the plant tissues. Peel removal and loss of tissue integrity with cell breakage facilitate microbial contamination. In addition, exposure to air and release of endogenous enzymes that are put in contact with their substrates. Quality deterioration may result from increased ethylene production, which may induce higher cellular metabolism and enzymatic activity (Reyes, 1996). Among the enzymes that may have deleterious effects, polyphenol oxidase (PPO), can be the most damaging enzyme with regard to color deterioration of plant foods (Whitaker and Lee, 1995).

During peeling and cutting operations, the bruising and damage occurs in more tissue layers than intended when the dull knives and blades are used, thus the sharpness
of knife blades can significantly affect product storage life (Bolin et al., 1977). The tissue response to mechanical injury is expected to be more pronounced when extensive wounding is inflicted on the produce, such as the grating of carrots versus preparation of carrot sticks. Moreover, the direction of the cut also affects the tissue response to wounding (Zhou et al., 1992). The washed mushrooms had 15% less soluble phenolics, showed leaching of PPO and therefore less enzymatic activity, there was also water uptake during washing, and consequently a more rapid deterioration of mushrooms, due to microbial spoilage and mechanical damage (Choi and Sapers, 1994). Same as the rinsed and drained shredded lettuce may retain 0.5 – 1% water on the surface, a residual amount that can decrease product quality by facilitating decay, thus dewatering is carried out (Bolin et al., 1977). The tendency to brown of three potato varieties stored for different periods (Table 1) showed that Bintje stored for one month gave a maximum browning index of 10 as acceptable for fresh cut processing (Mattila et al., 1993).

Wounding and ethylene induce the activity of the enzyme phenylalanine ammonia lyase (PAL), a key enzyme for phenolic biosynthesis. The lettuce storage life is related to the activity of stress induced PAL (Couture et al., 1993). In fresh cut lettuce browning of pieces shows detrimental quality. Such as russet sprouting (RS), which is characterized by brown spots on lettuce midribs; browning of cut edges (LEB) and of the leaf surface (LSB). The harvested lettuce heads the stem tissue near the harvesting cut may develop browning, or so called but discoloration, when the cut stem initially becomes yellow, it later develops a reddish brown colour, and finally an intense brown pigmentation. PAL activity is induced by cutting the lettuce stem, with subsequent synthesis and accumulation of soluble phenolic compounds, supplying substrates for PPO.

**Control of enzymatic browning**

Enzymatic browning can be controlled by using of both physical and chemical methods. Physical methods include reduction of temperature and oxygen, use of modified atmospheric packaging or edible coatings, or treatment with gamma radiation or high pressure. Chemical methods utilize compounds which act to inhibit the enzyme, remove its substrates (oxygen and phenolics).

**Chemical treatments**

Various chemical treatments are used for limiting the oxidation phenomenon. They differ by their action depending on the used chemical agents antioxidant agent, chelating agent, firmness agent and acidifying agent.

**Antioxidant agents**

Antioxidants can prevent the initiation of browning by reacting with oxygen. They also react with the intermediate products, thus breaking the chain reaction and preventing the formation of melanin (Lindley, 1998). Their effectiveness depends on environmental factors such as pH, water activity (aw), temperature, light and composition of the atmosphere. The main antioxidants are hexylresorcinol E586, N-acetyl cysteine E920, cysteine hydrochloride E920, ascorbic acid E300 and glutathione.
Chelating agents

PPO requires copper ions to be active (Du et al., 2012). Thus, the presence of a substance capable of binding divalent cations present in the medium reduces the enzymatic activity of PPO. The principal chelating agents are kojic acid, citric acid E330 and EDTA E385. The EDTA can inhibit PPO, which is metalloenzyme containing copper in the active site.

Firmness agents

Calcium salts are the best known; they are used in the strengthening of cell walls. This prevents the destruction of cell compartments and also the contact of PPO with polyphenols in the vacuole (Khunpon et al., 2011). The firmness agents are calcium lactate E327, calcium propionate E282, calcium chloride E509, calcium ascorbate E302 and sodium chloride.

Acidifying agents

The optimum PPO activity is observed at pH 6.0-6.5, while little activity is detected below pH 4.5 (Whitaker, 1994). The main acidifying agents are citric acid E330, erythorbic acid E315, ascorbic acid E300 and glutathione.

Other anti browning agents

Sodium chloride (as other halides) is known to inhibit PPO; the browning control is possible by the produce which was dipped in the solutions that are acidic; pH 3.5 (Rouet-Mayer and Philippon, 1986). Proteases presumed that PPO inhibition was due to proteolysis or to binding at specific sites required for activation. As well as aromatic carboxylic acids (benzoic acid and cinnamic acid) also PPO inhibitors (Walker, 1975). It has been suggested that cinnamates and benzoates may undergo a slow but gradual conversion to PPO substrates.

<table>
<thead>
<tr>
<th>Product</th>
<th>Chemical agents</th>
<th>Results</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watermelon</td>
<td>2% sodium chloride</td>
<td>Preservation of the firmness of fresh cut tissue throughout storage</td>
<td>(Mao et al., 2006)</td>
</tr>
<tr>
<td>Brinjal</td>
<td>Calcium ascorbate or citrate (0.4%)</td>
<td>Calcium ascorbate was the best treatment to inactivate enzymes</td>
<td>(Barbagallo et al., 2012)</td>
</tr>
<tr>
<td>Artichoke</td>
<td>Ascorbic acid, citric acid, cysteine and their combination, ethanol, sodium chloride, 4-hexylresorcinol</td>
<td>Cysteine (0.5%) was the most effective treatment to prevent browning</td>
<td>(Amodio et al., 2011)</td>
</tr>
<tr>
<td>Potato</td>
<td>1% sodium acid sulfate + 1% citric acid and 1% ascorbic acid</td>
<td>Polyphenoloxidase actions and browning are reduced</td>
<td>(Calder et al., 2011)</td>
</tr>
</tbody>
</table>
Physical treatments

The most commonly used approaches to controlling enzymatic activity in fresh cut products is the use of low temperature during handling, processing and storage. Some of physical methods include modified/ controlled atmospheres and gamma radiation. Non thermal methods include high pressure treatment or high electric field pulses.

Modified atmospheric packaging

Modified or controlled atmospheres retards senescence and consequently extend storage life of products. It should be supplement to an adequate management of temperature and controlled humidity. The shredded iceberg lettuce was stored by using a moderate vaccum packaging with polyethylene (80 µm) at 5°C temperature, browning was inhibited over a 10 days period (Heimdal et al., 1995). Modified atmospheric packaging was also efficient in controlling microbial build up during storage (King Jr et al., 1991).

Edible coatings

Edible coatings are used as a semi permeable barrier that helps reduce respiration, retard water loss and colour changes, improve texture and mechanical integrity, improve handling characteristics, helps retain flavour compounds and reduce microbial growth. It is possible to create a modified atmosphere enrobing fresh cut produce in edible coating (Baldwin et al., 1995). A carboxy methyl cellulose based coating did not control enzymatic browning of potatoes, but when such a coating was combined with additives (antioxidant, acidulant) shows superior than dipping the fresh cut produce in solutions with the same additives (Baldwin et al., 1996).

Low temperature

Fresh cut products generally have higher respiration rates the same intact produce; the respiration increase may vary from a few percent to over 100 %. Moreover, the degree of respiration increase varies with temperature and commodity (Watada et al., 1996). A common practice in the preparation of fresh cut products is rinsing in cold water, which helps lower the temperature in addition to removing cellular exudates released during peeling and cutting of produce. Dewatering of rinsed products is normally required to control decay. This is done commercially through centrifugation, but can also be achieved with forced air. In conventional food processing, the most widely used methods for enzyme inactivation rely on heat application. Optimum PPO activity has been reported to vary with the source of the enzyme and reaction conditions (pH, substrate, etc). PPO from several plant sources exhibits maximum activity in the temperature range of 25-30°C. Moreover PPO thermostability is also influenced by cultivar, growing location and pH (Vamos-Vigyazo, 1981). The green pea PPO required 29 min at 80 °C, or 2.5 min at 90 °C, and only 1 min at 95 °C. Low temperature blanching may be effective in preventing or controlling enzymatic activity in fresh cut products. Within 24 hr of cutting, iceberg lettuce cut into 2 × 2 cm pieces showed a 6 to 12 fold increase in PAL activity. A heat shock treatment on cut iceberg lettuce for 90 seconds at 45°C prevented such increase in PAL activity (Saltveit, 2000).
Gamma radiation

Gamma radiation has been used for insect and disease disinfections, as well as retard ripening and sprouting. Irradiation applied to fresh cut carrots stored in micro porous plastic bags, resulted in limited respiration increase due to wounding, and ethylene production was also reduced (Chervin et al., 1992). Endive samples that were irradiated revealed longitudinal internal pink - brown lines, which progressed to the entire vegetable piece becoming pink – brown.

High pressure technology

Inactivation of deleterious enzymes has been achieved through application of high pressure technology (Hendrickx et al., 1998). While bacterial spores are highly resistant to pressure treatment, and over 1200 MPa is required to their inactivation, yeasts, molds, vegetative cells are pressure sensitive and can be inactivated by milder treatments at 300-600 MPa. High pressure has been considered as an alternative for irreversible inactivation of PPO (Hendrickx et al., 1998). PPO activation was also described in low pressure treatments of crude carrot extracts (Anese et al., 1995). As well as potato and mushroom requires much higher pressures (800 and 900 MPa).

Other colour changes

White blush in carrots

The bright orange colour of fresh carrots can disappear in stored fresh cut products, particularly when abrasion peeling. Carrots may develop white blush also known as white bloom, a discoloration effect which results in the formation of a white layer on the surface of peeled carrots, giving a poor appearance to the product. Knife peeled carrot surfaces appeared severely damaged, compressed and separated from underlying tissue, therefore prone to dehydration. Razor peeled carrot surfaces were cleaner and apparently only a thin layer of cells had been removed, resulting in a product that upon drying did not acquire whitish appearance (Tatsumi et al., 1991). At this stage, the quality defect can be reversed by dipping the carrots in water and allowing for dehydration. Carrots was peeled with coarse sand paper and dipped in a 2 % citric acid solution at 70 °C for 20 to 30 seconds and it was effective up to 5 weeks in cold storage; product taste was not affected by the treatment. When the application of edible coating, loss of carotene in fresh cut carrots results 50 % retention of β carotene was obtained after 28 days of storage, compared to 33 % retention in the control (Li and Barth, 1998). Edible coating emulsions containing caseinate-staeric acid were effective in reducing the white blush defect of carrots (Avena-Bustillos et al., 1994).

Yellowing and Greening

Reduction of green pigmentation and predominance of yellow pigments a common process in ripening and senescence of some vegetables accelerated by ethylene. Shredded iceberg lettuce darkens during storage, particularly at high temperatures (Bolin et al., 1977). The susceptibility of baby and romaine lettuce samples of photosynthetic tissue became lighter and mid rib discoloration during
storage. The visual quality of broccoli is lost when florets turn yellow, retention of
green colour has been attained with the use of modified atmospheric packaging and
storage at 10°C (Barth et al., 1993).

Conclusion

The different methods of preservation against enzymatic browning in vegetables
are in constant development. Instead of the non thermal treatments, the thermal
methods remain the most effective for protecting the foods against oxidation. So, more
research is required to preserve the quality of vegetables with novel techniques.

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ascorbate as inhibitors of browning and softening in minimally

packaging affects ascorbic acid, enzyme activity and market quality of


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ACHIEVEMENTS IN ROOTSTOCK BREEDING FOR TEMPERATE FRUIT CROPS

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Shalimar Campus, Srinagar (J & K)

Rootstocks are very essential components in today’s modern horticulture, as there implies many new challenges for need to develop new technologies and farming systems. The recent development is the clonally propagated rootstocks in different fruit crops and hence many new development projects work on this. However there are still less number of breeding programmes for rootstocks when compared to breeding programmes for scion cultivars. Also many number of rootstocks for different traits are still in evaluation phase and only few have been introduced. In apple, predominant rootstock is the M₉ and in the dwarf vigour group the ideal rootstock (e.g. easily propagated, dwarf, precocious, resistant to fire blight, scab, collar rot and woolly aphid) is still missing, albeit some promising new rootstocks are in introduction. For pear several dwarf Pyrus series are in testing stage, but by now none of them resulted in a breakthrough in pear rootstock usage. Rootstock research for stone fruits over the last decade has been focused more on rootstock evaluation than on breeding of new rootstocks. From the agronomic standpoint vigor is a key issue in order to establish high-density orchards. Other important agronomic traits include compatibility with a wide spectrum of cultivars from different species, good tolerance to root hypoxia, water use efficiency, aptitude to extract or exclude certain soil nutrients, and tolerance to soil or water salinity. Biotic stresses are also important: Resistance/tolerance to pests and diseases, such as nematodes, soil-borne fungi, crown gall, bacterial canker, and several virus, viroids, and phytoplasms. The implementation of molecular markers in order to give support to the phenotypic evaluation of plant breeding has great potential assisting the selection of new genotypes of rootstocks. Marker-Assisted Selection (MAS) can shorten the time required to obtain new cultivars and can make the process more cost-effective than selection based exclusively on phenotype, but more basic research is needed to well understood the molecular and physiological mechanisms behind the studied trait.

1. CHARACTERISTICS OF AN IDEAL ROOTSTOCK:

2. Freestanding
3. Precocious
4. Dwarfing
5. Graft compatible
6. Easy multiplication
7. Abiotic and biotic resistance
8. Widely adaptable
9. Longevity of plant
10. High yielding
11. High fruit quality
2. PRIMARY TARGETS OF ROOTSTOCK SELECTION:

Rootstock species are considered to be under going domestication because they are part of a mutualistic relationship between humans and plants that enhances the fitness of both the domesticator and the domesticate (Zeder, 2015). Although rootstock breeding clearly targets specific traits (Figure 1) to our knowledge no formal description of a ‘domestication syndrome’ exists for rootstock species. Further, few comparative morphological or genetic studies of rootstocks and their wild ancestorsexist to infer signatures of rootstock domestication. The primary traits targeted during rootstock selection are:

2.1 Graft Union Formation and Graft Compatibility

For the grafting to be successful and for the development of proper rooting system, the rootstock and scion need to graft compatible. Consequently, the primary selection factor for any root stock is its ability to form the tissue that serves as the junction between the rootstock and scion: the graft union.

2.2 Root Function and Structure

After a successful graft union, rootstocks are selected in part for traits in herent to the root system itself, resistance to biotic (insects, pathogens etc.) and abiotic stresssuch assalinity, drought, and flooding is considered.

2.3 Rootstock Modulation of Scion Phenotypes

In addition to the rootstock structure and function, rootstocks are also selected based on their effects on the scion, including precocity (early bearing), production, disease resistance, and fruit quality (Koepke and Dhingra, 2013).

In addition to altering tree architecture, rootstocks are also widely used to find resistance to pests and pathogens that affect the scion, including physiological disorders. Proper nutrient and water uptake and then transport by the rootstock to the scion cultivar is also thought to play a very important role in resistance to physiological disorders such as physiological pitting and stem-end browning in kiwi and stem-end rind breakdown in citrus (Thorpe et al. 2007).
Figure 1 Rootstocks used in perennial agriculture (A) have been selected from a pool of wild germplasm and bred for (B) their ability to graft to cultivated scions, (C) the root phenotype, and (D) their ability to impact the phenotype of the grafted scion (Warschefsky et al. 2016)

3. APPLE ROOTSTOCK BREEDING

3.1 Objectives
- Freestanding and free from suckering
- Precocious widely adaptable
- Good anchorage to reduce the cost of support system
- Easy to propagate
- Dwarfing
- Fully graft compatible
- Strong drought tolerance and resistance to weed competition for soil and water minerals
- Resistant to wholly apple aphid
- High resistance to severe winter cold
- Resistant to fire blight and collar rot
- Resistant to replant problem

3.2 Improvement

Horticulture Research International- East Malling (formerly East Malling Research Station) is one of the pioneering centres for the breeding and development of rootstocks for temperate fruits. In the 1920s, Drs. Wellington and Hatton, initiated work on apple rootstocks who verified distinct rootstocks and distributed them throughout the world as Types, Type I to Type IX. Later, further types were added to the original nine. Although distributed under type names, the apple rootstocks later rapidly became known under Malling (or M.) designations and eventually the Roman numerals were replaced by the more normal Arabic ones. Only two of these original Malling selections namely M.9 and M.7, are now used extensively.

3.2.1 Challenges with Current Apple Rootstocks

Over the last 60 years, growers worldwide have used the Malling series of rootstocks from England. However, their limitations are:
- lack of winter hardiness,
- lack of resistance to Phytophthora root rot,
- susceptibility to fire blight bacterial disease,
- burr knots,
- poor anchorage,
- root suckers,
- sensitivity to apple replant disease,
- brittle graft unions.
- lack of precocity.
3.2.2 Geneva Rootstocks

Geneva rootstocks are replant tolerant, (G.41, G.214, G.935, G.210, G.30, and G.890) precocious, and productive. See the following diagram to see Geneva rootstocks by tree size. EMLA are virus free rootstocks derived from a corresponding M or MM selection. They have comparable characteristics to the uncertified material, but tend to be 5-10% more vigorous (Figure 2).

![Geneva Rootstocks by Tree Size](image-url)

**Figure 2: Geneva rootstocks of apple**

Table 1: Some exotic rootstocks of apple

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>M₉ Pajam 1</td>
<td>French origin, good fruit setting, adapts to any density (1600-4000 trees/ha)</td>
</tr>
<tr>
<td>M₉ Pajam 2</td>
<td>French origin, increased productivity, winter hardiness</td>
</tr>
<tr>
<td>M₉ NAKB T337</td>
<td>From Holland, 30-35% size of seedlings</td>
</tr>
<tr>
<td>M₉ NIC 29</td>
<td>Belgian origin, size similar to M₉ 337, more survivability % in orchard planting</td>
</tr>
<tr>
<td>Budogovsky 9</td>
<td>30-40% of seedling size, resistant to collar rot, winter hardiness</td>
</tr>
<tr>
<td>Budogovsky 118</td>
<td>Russian bred rootstock, recommended on dry, sandy soils, replant sites</td>
</tr>
<tr>
<td>Geneva 11</td>
<td>Higher yield efficiencies, fire blight resistant, moderate woolly aphid resistant</td>
</tr>
<tr>
<td>Geneva 65</td>
<td>Resistant to collar rot and fire blight, same size as M27</td>
</tr>
<tr>
<td>Geneva 30</td>
<td>Similar size to EMLA 7, More flight blight resistant than EMLA7</td>
</tr>
<tr>
<td>EMLA 106</td>
<td>Semi dwarfing rootstock, good choice for spur type red delicious</td>
</tr>
<tr>
<td>EMLA 111</td>
<td>2/3 size of standard tree, well anchored, tolerant to drought</td>
</tr>
<tr>
<td>EMLA 7</td>
<td>50-60% size of seedling, winter hardy and well anchored</td>
</tr>
<tr>
<td>Ottawa series</td>
<td>Resistant to latent virus, more productive than MM106</td>
</tr>
<tr>
<td>MAC 1</td>
<td>Same size as M7, don’t sucker and well anchored</td>
</tr>
<tr>
<td>MAC 9</td>
<td>Size as M9, productivity as M9</td>
</tr>
<tr>
<td>Supporter 4</td>
<td>Frost resistant, better efficiency than both EMLA 26 and EMLA 106</td>
</tr>
<tr>
<td>P 22</td>
<td>Well anchored, resistant to crown gall, collar rot, canker, scab.</td>
</tr>
<tr>
<td>Breeding Programme/Countries</td>
<td>Series</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Polish apple rootstocks</td>
<td>Polish (P) series</td>
</tr>
<tr>
<td>Russian Breeding programme</td>
<td>Budagovskij (B) or Bud Series</td>
</tr>
<tr>
<td>USA rootstock breeding</td>
<td></td>
</tr>
<tr>
<td>Canada breeding programme</td>
<td></td>
</tr>
<tr>
<td>Germany rootstocks</td>
<td>Pillnitzer Supporter series</td>
</tr>
<tr>
<td>Sweden Breeding programmes</td>
<td>BM Series</td>
</tr>
<tr>
<td>The Czech Republic</td>
<td>JTE or JOH series</td>
</tr>
<tr>
<td>Japan</td>
<td></td>
</tr>
<tr>
<td>Research Institute Voinestia, Romania</td>
<td>Voinesti series</td>
</tr>
</tbody>
</table>
4. PEAR ROOTSTOCK BREEDING:  
4.1 Objectives:  
- Dwarfing and free standing of trees  
- Precocity and productivity of varieties  
- High yield efficiency  
- Positive influence to fruit quality and size  
- Efficient propagation ability  
- Compatibility  
- Cold hardiness  
- Tolerance to iron and calcium chlorosis  
- Resistance to fire blight  
- Resistance to pear decline  

4.2 Improvement  
Unlike the cultivated apple, which has a large number of clonal rootstocks offering wide range of tree vigor, pears have traditionally been hampered by a more limited number and a more limited range of tree vigor control among its rootstocks. Quinces, widely used in Europe, have given the best precocity and vigor control coupled with easy propagation via stool beds. Quince rootstocks also offer slightly greater tolerance to pear decline than *Pyrus* stocks. However their use is, often limited by their lack of cold hardiness, lack of adaptation to high pH soils and drought, and their limited graft compatibility. The latter has not been insurmountable in Northern Europe, as cultivars such as ‘Conference’ and ‘Comice’ are graft compatible with quince and the use of inter stock such as ‘Beurré Hardy’ has proven useful in overcoming graft incompatibility. There is also considerable genetic variation within *Cydonia oblonga*, with demonstrated variation in cold hardiness (Wertheim, 1997), susceptibility to fire blight (Bobev and Deckers, 1999), graft compatibility (Sotiropoulos, 2006) and tolerance to calcareous soils (Fideghelli and Loreti, 2009). Important pear rootstocks according to their size are given in Figure 3.

![Figure 3: Pear rootstocks](image-url)
Table 3: Some of exotic rootstocks of pear

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>OH X F 333</td>
<td>( \frac{1}{2} - \frac{2}{3} ) standard size, resistant to fire blight, collar rot, wooly pear aphids</td>
</tr>
<tr>
<td>OH X F 40</td>
<td>2/3 standard size, resistant to fire blight, precocious and well anchored</td>
</tr>
<tr>
<td>OH X F 513</td>
<td>Semi vigorous rootstock, precocious, resistant to crown rot, wooly pear aphid</td>
</tr>
<tr>
<td>OH X F 87</td>
<td>Semi dwarf, best among series, tolerant to decline and blight</td>
</tr>
<tr>
<td>OH X F 97</td>
<td>Vigorous pear rootstock, more productive, good anchorage</td>
</tr>
<tr>
<td>BP 1</td>
<td>Clonal stock from South Africa, fully compatible with all pear cultivars</td>
</tr>
<tr>
<td>Pyrodwarf</td>
<td>Excellent winter hardiness, used for poor soils, bearing: 4-5yrs</td>
</tr>
<tr>
<td>Quince C</td>
<td>Common in Europe, precocious and used in good fertile soils</td>
</tr>
<tr>
<td>Quince A</td>
<td>General purpose rootstock, suitable for most soils</td>
</tr>
</tbody>
</table>

Table 4: Active and in-active pear rootstock breeding programme

<table>
<thead>
<tr>
<th>Country</th>
<th>Institution</th>
<th>Genus/Species</th>
<th>Primary Trait</th>
<th>Rootstocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>B. Morrison</td>
<td><em>Pyrus communis</em></td>
<td>Yield efficiency</td>
<td>BM 2000</td>
</tr>
<tr>
<td>Belarus</td>
<td>Belorussian Research Institute for Fruit</td>
<td><em>Pyrus communis</em></td>
<td>Yield efficiency</td>
<td>Seedling rootstock</td>
</tr>
<tr>
<td>Germany</td>
<td>Fruit Genebank, Dresden-Pillnitz</td>
<td><em>Pyrus communis</em></td>
<td>Yield efficiency</td>
<td>Pi-Bu series</td>
</tr>
<tr>
<td></td>
<td>Geisenheim Research Institute</td>
<td><em>Pyrus communis</em></td>
<td>Dwarfing, precocity</td>
<td>Pyrodwarf, Pyroplus</td>
</tr>
<tr>
<td>Italy</td>
<td>CIV, Ferrera</td>
<td><em>Pyrus communis</em></td>
<td>Yield efficiency</td>
<td>Ct.214, Ct.214</td>
</tr>
<tr>
<td></td>
<td>Univ. of Bologna</td>
<td><em>Pyrus communis</em></td>
<td>High pH soil tolerance</td>
<td>Fox series</td>
</tr>
<tr>
<td>Poland</td>
<td>Poland Institute of Pomology and Floriculture</td>
<td><em>Pyrus communis</em></td>
<td></td>
<td>Elia, Belia, Doria</td>
</tr>
<tr>
<td>South Africa</td>
<td>Bion Donne Research Station</td>
<td><em>Pyrus communis</em></td>
<td>dwarf</td>
<td>BP1,Bossiar series RV.138,</td>
</tr>
</tbody>
</table>
CHERRY ROOTSTOCK BREEDING:

Compared to apple, cherry rootstock breeding is a relatively “young” field and systematic breeding projects can be traced back to the 1960-70s. Breeding projects applied “classical methods”, e.g. selection of crossing partners by chance or based on little knowledge of genetics and heritability of desired characteristics. Recognition and investigation of certain rootstock-scion interactions became possible due to evaluation of progenies. Thus, cherry rootstock breeding can be considered a typical example for stone fruits. The most promising rootstock groups are the vegetatively propagated P. cerasus clones and the new interspecific hybrids. P. cerasus breeding projects in

<table>
<thead>
<tr>
<th>Country</th>
<th>Institution/Institute</th>
<th>Species</th>
<th>Trait</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warsaw</td>
<td>Agricultural University</td>
<td>Pyrus communis</td>
<td></td>
<td>GK series - seedling</td>
</tr>
<tr>
<td>USA</td>
<td>MCAREC, Oregon State University</td>
<td>Pyrus communis</td>
<td>Yield efficiency</td>
<td>Horner series</td>
</tr>
<tr>
<td>UK</td>
<td>East Malling Research</td>
<td>Pyrus communis, Cydonia</td>
<td>Yield efficiency</td>
<td>708 series, C132 QR 193-16</td>
</tr>
<tr>
<td>France</td>
<td>INRA-Angers</td>
<td>Pyrus sp.</td>
<td>High pH soil tolerance</td>
<td>Pyriam, BA 29</td>
</tr>
<tr>
<td>Spain</td>
<td>IRTA</td>
<td>Pyrus sp.</td>
<td>High pH soil tolerance</td>
<td>Interspecific crosses</td>
</tr>
<tr>
<td>USA</td>
<td>USDA, ARS</td>
<td>Pyrus sp.</td>
<td>Yield efficiency, Fire blight resistance</td>
<td>OHF x US selections</td>
</tr>
<tr>
<td>China</td>
<td>Several institutes and universities</td>
<td>Pyrus (Asian)</td>
<td>Dwarfing</td>
<td>Several</td>
</tr>
<tr>
<td>Japan</td>
<td>Gifu University</td>
<td>P. bet &amp; P. call</td>
<td>Dwarfing</td>
<td>SPRB &amp; SPRC series</td>
</tr>
<tr>
<td>Lithuania</td>
<td>LIH-Babtai</td>
<td>Cydonia</td>
<td>Cold hardiness</td>
<td>K series</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Flueren</td>
<td>Cydonia</td>
<td>Yield efficiency</td>
<td>Eline</td>
</tr>
<tr>
<td>Poland</td>
<td>Institute of Pomology and Floriculture</td>
<td>Cydonia</td>
<td>Cold hardiness</td>
<td>S-1</td>
</tr>
<tr>
<td>Ukraine</td>
<td>Ukranian Academy of Agrarian</td>
<td>Cydonia</td>
<td>Drought tolerance, soil pH</td>
<td>IS, K&amp; R series</td>
</tr>
</tbody>
</table>
Advances in Horticultural Crops

Germany (Weiroot series), Italy (CAB series), and Denmark (DAN series) showed that it is possible to select non-suckering *P. cerasus* as rootstocks in a wide range of vigour and compatibility. At the present stage, cherry rootstock breeding programs have produced a wide range of rootstocks selected for vigour, precocity and productivity.

**Table 5 Some exotic rootstock of cherry**

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gisela 5</td>
<td>Popular German rootstock, rootstock of choice, good winter hardiness</td>
</tr>
<tr>
<td>Gisela 6</td>
<td>Large trees than Gizela 5, much less fussy about soil conditions</td>
</tr>
<tr>
<td>Gisela 12</td>
<td>Precocious and productive, early heavy crops, full production by 5th year</td>
</tr>
<tr>
<td>W. 13</td>
<td>Moderate to high vigour, good anchorage, no staking</td>
</tr>
<tr>
<td>W. 154</td>
<td>Moderate vigour, high yields and good fruit size, no support</td>
</tr>
<tr>
<td>W. 53</td>
<td>Weak growing rootstock, needs staking, good yields if managed properly</td>
</tr>
<tr>
<td>Charger</td>
<td>Trees intermediate in size between colt and F12/1, resistant to bacterial canker</td>
</tr>
<tr>
<td>M x M 60</td>
<td>Wide range of soil compatibility, resistant to phtophora and crown gall, more productive than mazzard, little to no suckering</td>
</tr>
</tbody>
</table>

**Table 6 Cherry rootstock breeding programmes**

<table>
<thead>
<tr>
<th>Country</th>
<th>Institution</th>
<th>Series</th>
<th>Species/genus</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>University of California Davis</td>
<td>UCMH series</td>
<td><em>Prunus mahaleb</em></td>
</tr>
<tr>
<td></td>
<td>Oregon Forest Grove</td>
<td>M xM series</td>
<td><em>Prunus mahaleb</em> x <em>Prunus avium</em></td>
</tr>
<tr>
<td></td>
<td>Michigan State University East Lancing</td>
<td>MSU series</td>
<td><em>Prunus cerasus</em> hybrids</td>
</tr>
<tr>
<td>Canada</td>
<td>PARC Summer Land</td>
<td></td>
<td><em>Prunus avium</em></td>
</tr>
<tr>
<td>Germany</td>
<td>TUM Weihenstephan</td>
<td>Weiroot series</td>
<td><em>Prunus cerasus</em></td>
</tr>
<tr>
<td></td>
<td>JKI Dresden</td>
<td>PI-KU series</td>
<td><em>Prunus hybrids</em></td>
</tr>
<tr>
<td></td>
<td>Justus Liebeg University Giessen</td>
<td>GISELA series</td>
<td><em>Prunus hybrids</em></td>
</tr>
<tr>
<td>Belgium</td>
<td>CRA Gambloux</td>
<td>GM series</td>
<td><em>Prunus hybrids</em></td>
</tr>
<tr>
<td>Czechoslovakia</td>
<td>Research and Breeding Institute of Pomology,</td>
<td>PH series</td>
<td><em>Prunus avium</em> x <em>Prunus cerasus</em></td>
</tr>
</tbody>
</table>
### 6. PLUM ROOTSTOCK BREEDING

#### 6.1 Objectives

- Easy vegetative propagation (hardwood or softwood cuttings, micropropagation in vitro),
- Good compatibility with a broad range of varieties,
- Cold hardiness,
- Tolerance to calcareous soils,
- Tolerance to wet and dry soil conditions,
- Stability and durability of the grafting combination,
- Resistance against important biotic environmental factors like nematodes, viruses, fungi, bacteria and phytoplasma

#### 6.2 Improvement

Different *Prunus* species such as *P. cerasifera*, *P. domestica*, *P. spinosa*, *P. salicina*, *P. besseyi*, *P. tomentosa*, *P. pumila*, *P. americana*, *P. armeniaca*, *P. persica* and *P. dulcis* and its hybrids can be used as rootstocks for plums. ‘Weito 6’ and ‘Weito..."
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226’ are selections of *P. tomentosa* made in Weihenstephan, Germany. These rootstocks are drought resistant and induce small, heavy cropping trees. However, they suffer in wet soils. Hybridization of *P. tomentosa* and *P. domestica* are not successful. However, hybridizations of *P. tomentosa* with *P. besseyi* and other species are possible (Kask, 1989). For instance, the hybrid ‘VVA-1’ (*P. tomentosa* X *P. cerasifera*) was introduced by Eremin as a dwarfing rootstock for plum and apricot as well as VVA-2, a seedling originating from open pollination of VVA-1, and VSV-1, a hybrid between *P. incisa* and *P. tomentosa* (Kask, 1989). Recently, a plum rootstock breeding programme was started at Technical University of Munich-Weihenstephan. The aim is to develop semi-dwarfing and dwarfing rootstocks, which are hypersensitive to PPV. Inter- and intra-specific hybridizations are carried out. If bud sticks which are latently infected with PPV are grafted upon rootstocks showing a strong hypersensitive response against PPV, the budstick will either not grow or die after a short period of growth. In this way it is guaranteed that only trees free from PPV will leave the nursery. Hypersensitive rootstocks could also be used for scions hypersensitive against PPV.

**Table 7 Important clonal rootstocks for plums and prunes**

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Species or Hybrid</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myrobalan B</td>
<td><em>P. cerasifera</em></td>
<td>UK</td>
</tr>
<tr>
<td>Myrobalan 29C</td>
<td><em>P. cerasifera</em></td>
<td>USA</td>
</tr>
<tr>
<td>Adara</td>
<td><em>P. cerasifera</em></td>
<td>Spain</td>
</tr>
<tr>
<td>Myrabi</td>
<td><em>P. cerasifera</em></td>
<td>France</td>
</tr>
<tr>
<td>Mariana GF 8/1</td>
<td><em>P. cerasifera</em> x <em>P. monsaniana</em></td>
<td>France</td>
</tr>
<tr>
<td>Mariana GF 2624</td>
<td><em>P. cerasifera</em> x <em>P. monsaniana</em></td>
<td>USA</td>
</tr>
<tr>
<td>Mariana GF 8-5</td>
<td><em>P. cerasifera</em> x <em>P. monsaniana</em></td>
<td>South Africa</td>
</tr>
<tr>
<td>Pixy</td>
<td><em>P. insititia</em></td>
<td>UK</td>
</tr>
<tr>
<td>St.Julian A</td>
<td><em>P. insititia</em></td>
<td>UK</td>
</tr>
<tr>
<td>Ishtara (Ferciana)</td>
<td><em>P. cerasifera</em> x <em>P. salicina</em></td>
<td>France</td>
</tr>
<tr>
<td>Julior (Ferdor)</td>
<td><em>P. insititia</em> x <em>P. domestica</em></td>
<td>France</td>
</tr>
<tr>
<td>GF 677</td>
<td><em>P. persica</em> x <em>P. amygdalis</em></td>
<td>France</td>
</tr>
<tr>
<td>Citation</td>
<td><em>P. persica</em> x <em>P. salicina</em></td>
<td>USA</td>
</tr>
</tbody>
</table>

7. PEACH ROOTSTOCK BREEDING

7.1 Objectives

- Resistance to rootknot nematodes.
- Tolerance to calcareous soil conditions.
- Tolerance to water-logged soil conditions.
Cold hardiness.

Tolerance to peach tree short life (PTSL) associated with the ring nematode

Resistance to various diseases and pests like powdery mildew, brown rot, leaf curl, Xanthomonasspp., and green aphid (the vector of PPV).

7.2 Improvement

In the last two decades, important progress has been achieved in rootstock breeding and new plant material has been released worldwide. Many peach-growing countries are running breeding programmes, mainly in research institutions with public funding, but also private nurseries are starting to emerge in this field. An increasing number of rootstocks are now available in the international market, and breeding programmes are active in North America, Europe, Asia and South Africa (Reighard, 2002) (Table 8). Although clonal rootstocks are used in the peach industry, peach seedling still dominates many cultivating areas in the world. An exception occurs in the Mediterranean countries, where the French almond x peach hybrid ‘GF-677’ dominates from the 70’s due to the predominant alkaline soils. In Spain, it still represents 47 per cent and in Italy 69 per cent of the rootstocks used. This is followed in use by peach seedlings, like ‘Montclar’ and ‘GF305’ used in both countries in soils without nematode problems and non-calcareous, accounting for 18 and 20 per cent of the total Spanish and Italian plantings, respectively (Fideghelli, 2003; Rubio-Cabetas et al., 2005), and 50 per cent in France (Loreti and Massai, 2006). ‘GF-677’ has started to be replaced by other interspecific hybrids such as ‘Cadaman’ and ‘Barrier’, together accounting for 8 per cent in Spain and one per cent in Italy. In Spain various plum selections, such as ‘Adesoto 101’, ‘Monpol’, and ‘Montizo’, are also widely used due to their better adaptability to heavy soils and they account for 18 and 20 per cent of the total Spanish and Italian plantings, respectively (Rubio-Cabetas et al., 2005). In Italy ‘MrS.2/5’, ‘Penta’ and ‘Tetra’ are used in heavy soils and together account for about 6 per cent (Fidegehelli, 2003). More recently, there has been a significant move towards the use of other almond x peach hybrids from a Spanish programme; ‘Monegro’, ‘Garnem’ and ‘Felinem’, because of their root knot nematode resistance, currently represents 17 per cent of the total rootstocks planted. In the North American peach industry, a completely different situation is found, where several peach seedlings of P. persica are almost exclusively used and constitute more than 95 per cent of the peach rootstock used (Reighard and Loreti, 2008). Some are resistant to RKN, like ‘Nemaguard’ and ‘Nemared’, and to ring nematodes, like ‘Guardian’. The situation in the Southern hemisphere is also quite different from the Mediterranean countries. In South Africa a representative 7 per cent of ‘GF-677’ and other interspecific hybrids can be found, mainly from American origin like ‘Viking’ and ‘Atlas’ (Zaiger Genetic). However, peach seedling is also widely used, around 69 per cent of the total production (Stassen, pers. commun.). In South America, mainly Chile and Argentina, ‘Nemaguard’ peach seedling dominates, together with ‘Flordaguard’. It is in those countries where replanting in peach orchards is an important fact now and has started to be substituted by hybrids having in his lineage ‘Nemaguard’: the GxN hybrids (Felipe, 2009) which have demonstrated a good performance in replanting conditions (Gómez Aparisi et al., 2000). Still, the replacement of a clonal rootstock is slow due to the long trials and evaluation cycles for...
rootstock programmes that may require 7-10 years to complete (Beckman and Lang, 2003). So adoption of a new rootstock is still an inherently slow process.

The introduction of novel genes for resistance to nematodes, soil root fungi, soil bacteria, soil sickness and Peach Tree Short Life (PTSL) has been successfully achieved in the last decade. Particularly noteworthy among recent releases has been the incorporation of Root Knot Nematode (RKN) resistance. Rootstocks have also been developed for replant sites to reduce the incidence of PSTL. Special emphasis has been placed on developing dwarfing rootstocks for high-density orchard systems. However, adaptation to other desirable soil properties, such as tolerance to salinity, alkalinity, waterlogging and drought is more complex (Table 9). As a consequence, many opportunities and challenges remain to be addressed in the adaptation to abiotic factors required for selecting the ideal rootstock for peach in the future, including graft compatibility, and rootstock influence on scion performance. Some research programmes are now aimed at understanding important biological phenomena in the roots.

Table 8 Main recent rootstock releases in the last two decades available for peach and main desirable traits introduced by the breeding programmes.

<table>
<thead>
<tr>
<th>Year</th>
<th>Rootstock</th>
<th>Country</th>
<th>Origin</th>
<th>Objective</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>Adafuel</td>
<td>Spain</td>
<td>Prunus hybrids: AxP</td>
<td>Calcareous soil</td>
<td>Cambra, 1990</td>
</tr>
<tr>
<td>1991</td>
<td>Flordaguard</td>
<td>USA</td>
<td>P. davidiana hybrids</td>
<td>Low chilling</td>
<td>Sherman et al., 1991</td>
</tr>
<tr>
<td>1995</td>
<td>Adesoto-101</td>
<td>Idem</td>
<td>Plum</td>
<td>Vigor control</td>
<td>Moreno et al., 1995</td>
</tr>
<tr>
<td>1996</td>
<td>Cadaman-Avimag</td>
<td>France</td>
<td>P. davidiana hybrids</td>
<td>RKN</td>
<td>Edin and Garcin, 1996</td>
</tr>
<tr>
<td>1997</td>
<td>Montizo</td>
<td>Idem</td>
<td>Plum</td>
<td>Waterlogging tolerance</td>
<td>Felipe et al., 1997</td>
</tr>
<tr>
<td>1997</td>
<td>Tetra</td>
<td>Italy</td>
<td>Europeam Plum</td>
<td>Waterlogging tolerance</td>
<td>Nicotra and Moser, 1997</td>
</tr>
<tr>
<td>1997</td>
<td>Guardian</td>
<td>Idem</td>
<td>P. persica</td>
<td>RKN, PTSL</td>
<td>Beckman et al., 1997</td>
</tr>
<tr>
<td>2002</td>
<td>Krymsk1-Krymsk-4</td>
<td>Russia</td>
<td>Prunus hybrids</td>
<td>Cold, Dwarfing</td>
<td>Eremin and Eremin, 2002</td>
</tr>
<tr>
<td>2000</td>
<td>Monegro</td>
<td>Spain</td>
<td>Prunus hybrids:</td>
<td>RKN</td>
<td>Felipe et al.,</td>
</tr>
</tbody>
</table>
Table 9 Tolerance of Peach Rootstocks to Stress.

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Rootknot Nematodes</th>
<th>Calcareous Soil</th>
<th>Water logging</th>
<th>Cold Hardiness</th>
<th>Peach Tree Short Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lovell</td>
<td>S</td>
<td>MS</td>
<td>S</td>
<td>Moderate</td>
<td>S</td>
</tr>
<tr>
<td>Halford</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>Moderate</td>
<td>S</td>
</tr>
<tr>
<td>Nemaguard</td>
<td>R</td>
<td>VS</td>
<td>S</td>
<td>Poor-Fair</td>
<td>S</td>
</tr>
<tr>
<td>Nemared</td>
<td>R</td>
<td>S</td>
<td>S</td>
<td>Fair</td>
<td>S</td>
</tr>
<tr>
<td>Guardian</td>
<td>R</td>
<td>MS</td>
<td>S</td>
<td>Moderate</td>
<td>R</td>
</tr>
<tr>
<td>Flordaguard</td>
<td>R</td>
<td>VS</td>
<td>S</td>
<td>Poor</td>
<td>S</td>
</tr>
<tr>
<td>Titan Hybrids</td>
<td>R</td>
<td>R</td>
<td>VS</td>
<td>Fair-Good</td>
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<td>Hansen</td>
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<td>VS</td>
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VS = very susceptible; S = susceptible; MS = moderately susceptible; R = resistant.

8. APRICOT ROOTSTOCK BREEDING

8.1 Objectives

- Tree characteristics (rootstocks, tree vigor, growth habit, and productivity)
- Floral biology (flowering date, intensity, and fertility)
- Fruit characteristics (maturity, size, firmness, color, taste),
- Disease resistance and climatic adaptation (cold hardiness, chilling requirement, and spring frost)
8.2 Improvement

New apricot rootstocks should be tolerant or resistant to nematodes, diseases, insects, edaphic factors, with good propagation efficiency and rooting ability. The evaluation for the interaction between the root system and the canopy of the scion cultivar must be optimized to increase tree efficiency. The selection of inter specific hybrids for rootstocks is one solution to meet complex objectives in a rootstock-breeding program (Dosba, 2003). One of the most intensely active areas of stone fruit rootstock breeding is the breeding for nematode resistance.

Many apricots (P. Armeniaca L) produced throughout the world are grown on seedling rootstocks of the same species (Crossa-Raynaud and Andergon, 1987). Often such seed may be a mixture collected from several cultivars such as Franco used in Italy which is derived from Canino, Reale d Imola, Baracca, Prete and San Castrese apricot cultivars. In contrast the seedling rootstock Manicot (GF 1236) which was produced by INRA in France, is the single cultivar and is much more homogenous. Others rootstocks of such type are A470 and A474 from France, Haggith from Canada and Millioner 1 and Millioner 11 from Germany. Peach seedling is still used occasionally as rootstocks for apricots and seedlings such as GF 305, Misour and Rancho resistant have been tested widely. Seedling of Myrobalan (P. Cerasifera) is also utilized and almost all apricot producing countries have their own selections. While selection of Myrobalan (e.g., Myrobalan B and Myrobalan 29 C) are also used in some countries.

9. WALNUT ROOTSTOCK BREEDING

9.1 Objectives

- Dwarfing rootstocks
- compatibility between stock and scion
- easy to propagate through vegetative means
- tolerant to blackline, Phytophthora rot etc
- greater yields
- precocity of production
- reduction in variability of orchards

9.2 Improvement

Superior clonal Paradox rootstock selections have been identified and are in retesting or field trials. These include an extremely vigorous individual that appears to tolerate nematode (Pratylenchus vulnus) infestation, but is not having resistant per se. five selections of a vigorous black line-tolerant hybrid (J. hindsii × J. regia) × J. regia, three clones that are less damaged than others by Phytophthora citricola in greenhouse tests, and one clone that exhibits limited gall formation when challenged by (Agrobacterium tumefaciens) are in preliminary tests. Genetic engineering through gene silencing has also resulted in clones that do not exhibit crown galls after inoculation in vitro (McGranahan et al., 2004).
Much more work is needed on rootstocks. Since the hybrids appear to have the most vigor, it is important to evaluate the performance of different species in hybrid combinations. One that is readily available in S. America and hybridizes easily with *J. regia*is *J. australis* Griseb. from Argentina. Other possibilities are *J. neotropica* Diels (northwestern S. America), *J. olanchara* Standl. & L. O. Williams (Mexico and Guatemala) and *J. cathayensis* Dode (East Asia, China). In California, we have approached the blackline problem, caused by the cherry leafroll virus, through both cultivar hypersensitivity to the virus and rootstock tolerance. The latter, a short-term solution, is aimed at developing a rootstock combining the *J. regia* response to blackline disease with the vigor and other attributes of Paradox. This can be achieved, in theory, by selecting vigorous, tolerant individuals among seedlings of a backcross generation (*J. hindsii × J. regia*) × *J. regia*. In 1988, 13,000 Paradox offspring from 17 source trees were planted in a randomized complete block design with six blocks in Phytophthora infested soil. Between 1992 and 1994, they were screened for vigor and tolerance to the virus. Five seedlings were selected in 1994, but it has taken until recently to establish grower trials to compare their performance in the field to Paradox and *J. regia* rootstocks because of the challenges of clonal propagation. Breeding efforts have focused on identifying sources of resistance among *J. hindsii* and other wild species of black walnut and crossing them with *J. regia* to develop new clonally propagated, disease-resistant Paradox rootstocks (Hackett et al., 2010). For example, R x 1 (*J. microcarpa × J. regia*) is resistant to Phytophthora crown and root rot (Browne et al., 2010). A transgenic approach has also been used (Hackett et al., 2010), specifically to engineer rootstocks for RNAi-mediated resistance to crown gall (e.g., RR4 11A).

10. ALMOND ROOTSTOCK BREEDING

10.1 Objectives

- Should impart high to medium vigour to support maximum nut yield.
- Possess adoption to diverse soil types and have good anchorage.
- Resistant to diseases and pests.

10.2 Improvement:

Almond seedlings have been the traditional rootstocks used under non irrigated and well-drained soil conditions. Advantages include easy propagation from seed, excellent compatibility with almond cultivars, deep rooting ability, and high tolerance to drought and calcareous soils. However, almond rootstocks perform poorly on excessively wet soils during active growth. The most significant commercial plum rootstocks for almond are the Marianna’ hybrids, a group of clones arising from a breeding line believed to be *Prunus myrobalan x P. hortulana* of this group, ‘Marianna 2624’ is an important rootstock for almond in California for use in finely textured soils with poor drainage and where oak root fungus has occurred. ‘Marianna 2624’ is also nematode-resistant. Some almond cultivars including the major cultivar ‘Nonpareil’ can be incompatible on ‘Marianna 2624’ and related clones, however almond x peach hybrids show outstanding characteristics as rootstock for almond. All self-fruitful
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almond tested have grown vigorously and produced consistently higher yields when grafted on the peach x almond hybrid rootstock GF 677.

CONCLUSION

Rootstocks and interstocks are the integral part of commercial fruit cultivation and needs equal focus. The effect of rootstocks and inter-stocks pertaining to growth, flowering, fruit set, yield efficiency and fruit quality attributes of fruit crops are complex and poorly understood. In India, development of rootstocks is not adequate. The existing new rootstocks and interstocks are mostly obtained from exotic sources and adopted after testing. More emphasis on collection of local or indigenous wild germplasm in different tree and vine fruit crops. Local rootstocks for apple, pear, cherry, peaches, plum, almond etc. need to be standardized. The potential to produce new rootstocks by either conventional means or in combination with modern technologies is substantial and demonstrated. There is an urgent need to evolve rootstocks tolerant to biotic and abiotic stresses in different temperate fruit crops.

REFERENCES


ORIGIN, AREA, PRODUCTION, VARIETIES, PACKAGE OF PRACTICES FOR RIDGE GOURD

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Ridge Gourd (Luffa acutangula Roxb.) \((2n = 26)\) (Hindi : Ghia tori) &
Smooth Gourd (Luffa cylindrica Roem.) \((2n = 26)\) (Hindi: Kali tori)

Both ridge or ribbed gourd and smooth or sponge gourd belong to genus *Luffa*. Genus name was derived from the product “Loofah” used as bathing sponges, scrubber pads, doormats, pillows, mattresses, cleaning utensils, etc. Both species contain a gelatinous compound called luffein.

Both crops are cultivated on a commercial scale and grown in homesteads for its immature fruits which are used as cooked vegetable. Fibre of mature dry fruits is used as a bath sponge. As tender fruits are easily digestible and appetizing, it is prescribed for those who are suffering from malaria and other seasonal fevers.

Origin and distribution
Origin of ridge gourd is not known. Smooth gourd may be a native of South Asia or Africa or Australia.


**Varieties–Sponge gourd**: Pusa Supriya, Pusa Sneha, Pusa Prajakta, Rajendra Nenua-1

Climate and soil
Like bitter gourd, ridge gourd and smooth gourd are typical warm season crops and come up well during summer and rainy seasons. Optimum temperature required is 25-27 °C. Ideal soil is fertile well drained loam rich in humus.

Cultivation practices
Both ridge and smooth gourd are grown during summer and rainy season by sowing seeds during January – February and June – July, respectively. Seeds are sown in raised beds, furrows or pits @ 3.5-5.0 kg/ha for ridge gourd and 2.5-5.0 kg/ha for sponge gourd. Since seeds are with hard seed coat, it is advisable to soak seeds overnight in water. A row-to-row distance of 1.5-2.5 m and hill to hill distance of 60-120 cm is required for both crops under bower or trellis system. When it is trailed to ground under pit system, a row-to-row spacing of 1.5-2.0 m and pit-to-pit distance of 1.0-1.5 m are recommended for both crops.

Manure and fertilizer requirements, irrigation and intercultural operations are same as that of bitter gourd.
Harvesting

Crop is ready for harvest in about 60 days after sowing. Both crops are picked at immature tender stage. Fruits attain marketable maturity 5-7 days after anthesis. Over-mature fruits will be fibrous and are unfit for consumption. To avoid over-maturity, picking is done at 3-4 days interval. Harvested fruits are packed in baskets to avoid injury and can be kept for 3-4 days in a cool atmosphere.

Yield: 7.5 – 15.0 t/ha.

Pests and Diseases of Cucurbits

Cucurbits are affected by a large number of insect pests, nematodes and diseases. Major pests and diseases affecting cucurbit vegetables are discussed below:

Pests

Fruit fly, red pumpkin beetle and epilachna beetle cause damage to most of cucurbits. In addition, insects like gall fly; aphids, leaf hopper, ants, worms, underground semi loopers, leaf miners, fruit borers and mites affect specific cucurbits. Intensity of infestation varies from place to place.

Fruit fly (Bactrocera cucurbitae)

This is a major pest of majority of cucurbits especially that of bitter gourd, snake gourd, pointed gourd, muskmelon, oriental pickling melon, watermelon, tinda and pumpkin. Adult fly has reddish brown body with transparent and shiny wings, bearing yellow-brown streaks. It lays eggs singly or in clusters of 4-12 in flower or developing fruits or ripening fruits with the help of sharp ovipositor of females. Eggs hatch in 2-9 days and maggots feed on internal contents of fruits causing rotting. Pupation is in ground at a depth of 1.5-15.0 cm. Infestation is more during rainy season.

Adopt following package for control of fruit fly:

1. Cover developing fruits with paper cover or polythene cover immediately after anthesis and pollination.

2. Collect and destroy affected fruits by dipping in hot water or insecticide solution. Do not leave infested fruits on gourd.

3. Use light trap and poison baits during night. Spray a bait solution containing 200 g gur or sugar and 20 ml Malathion 50 EC in 20 l of water as coarse droplets on lower surface of leaves.

4. Spraying on under surface of leaves of maize plants grown in rows at a distance of 8-10 m in cucurbit field is also effective as flies rest on such tall plants.

5. Hang baits containing sex attractants like pheromones or protein hydrolysate with Furadan granules. Hanging coconut shells with pieces of fully ripened fruits of “Mysore poovan” banana or toddy or molasses along with Furadan granules also attract and kill fruit flies.
Red Pumpkin Beetle (*Aulacophora foveicollis*)

Beetle attacks most of cucurbits especially melons, bottle gourd, pumpkin, cucumber, water melon etc. Bitter gourd is not seen attacked by beetle. Beetles eat the leaf lamina causing defoliation particularly at cotyledon stage of crop. Grubs feed on underground stem and root portion of plants causing holes / galleries and result in drying up of plants. As insects pupate in the soil, deep ploughing soon after the crop exposes and kills grubs and pupae.

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Application of Furadan 3 G granules 3-4 cm deep in soil near base of just germinated seedlings will take care of young seedlings from attack of beetle.

Epilachna beetle (*Epilachna seplima*)

Epilachna beetle is a serious pest of bitter gourd and snake gourd. Adult flies feed on foliage causing holes and defoliation. A large number of yellow coloured thorny grubs are seen on under surface of leaves and feed on chlorophyll resulting in skeletonisation of leaves. Mechanical control by way of collection and destruction of egg masses and
grubs are very effective as they are seen as a colony. It can also be controlled by spraying Carbaryl (0.2%) or Metacystox (0.15%).

**Aphids (Aphis gossypii)**

Aphids suck sap from leaves of cucurbits like ash gourd, snake gourd, mush melon, water melon, cucumber etc. causing crinkling of leaves. It also transmits mosaic virus. Control aphids by spraying Malathion (0.1%) or tobacco decoction

**Leaf hopper (Amrasca biguttula biguttula)**

During summer months, jassids cause heavy loss to bitter gourd crop. Green coloured hopper and its nymphs are seen in large numbers on under surface of leaves and suck sap causing typical hopper burn symptoms. Initially neem oil garlic mixture at fortnightly interval is effective for control of hopper. Spraying of Acetaf, Imidachloprid etc. control hoppers effectively.

**Red spider mites (Tetranychus sp.)**

Larvae, nymphs and adults of mites lacerate leaves from under surface and suck sap resulting in production of white patches between veins in Cucurmis melo. Infested leaves turn yellow and fall of prematurely. In severe cases, intense webbing occurs giving a dusty appearance to under surface of leaves. Mites can be controlled by spray of neem oil garlic mixture or Kelthane or Dicofol on under surface of the leaves.

**Leaf miner (Lyriomyza trifolii)**

This polyphagous pest causes characteristic white twisting lines in ash gourd, Cucurmis sativus and Cucurmis melo. Severe leaf mining accelerates leaf drop and retards growth and yield of plants. For control of miner, trap adults to yellow cards applied with adhesives. Burning infested dried leaves will help in reduction of population. Spraying neem oil garlic mixture early in morning before sunrise will be an effective control.

**Gall fly (Lasioptera falcate)**

Gall flies, having shape of mosquitoes, lay eggs in soft stem of bitter gourd, snake gourd, coccinia etc. Emerging larva feed inside stem. Since large numbers of larvae are seen inside stem, affected portion becomes bulged and subsequent growth of stem is arrested. Restrict irrigation and nitrogen fertilizers once infestation is noticed. Cutting and removal of galls also should be practiced regularly. Spray systemic insecticides under sever infestation.

**Diseases**

**Fusarium wilt (Fusarium oxysporum)**

Fusarium wilt is a serious disease water melon, musk melon, bottle gourd etc. In young seedlings, cotyledons drop and wither. Older plants wilt suddenly and vascular bundles at the collar region show brown discolouration. Being a soil borne disease, chemical control is very difficult. Cultivation of resistant varieties and crop rotation with resistant crops are viable methods for overcoming the disease. To some extent, the disease can be checked by hot water treatment of seeds at 55°C for 15 minutes and by drenching soil with carbendazim.
**Collar rot** (*Rhizoctonia solanii*) / **Pythium rot** (*Pythium sp.*)

Characteristic symptom of the disease is appearance of dark brown water-soaked lesions girdling the base of stem at soil level followed by death of plants. It is more serious under water logged conditions and during rainy seasons. Treating seeds with Thiram @ 3 g/kg of seed before sowing, sowing of seeds on raised beds, drenching vines with Redomyl (0.2%) or Carbendazim (0.1%) are recommended for control of the disease.

**Powdery mildew** (*Sphaerotheca fuliginea*)

This disease is more destructive in pumpkin, squashes, bottle gourd, melon and cucumber, that too, during rain free periods. Symptoms appear as white to dirty grey spots or patches on leaves which become white powdery as they enlarge. Powdery coating covers entire plant parts and causes defoliation. Fortnightly spray of Karathane (0.5%) or Calixin (0.05%) or Carbendazim (0.1%) are recommended for control of powdery mildew.

**Downy mildew** (*Pseudoperonospora cubensis*)

Disease is prevalent in areas of high humidity, especially during rainy season, on crops like bitter gourd, snake gourd, melon, bottle gourd and ridge gourd. Symptoms appear as water soaked lesions on under surface of leaf lamina and angular spots on upper surface corresponding to the water-soaked lesions on under surface. Disease spreads very fast.

Plucking and destruction of affected leaves and spraying Dithane M-45 (0.2%) on under surface of leaves give effective control.

**Anthracnose** (*Colletotrichum lagenarium*)

This disease is endemic in warm and humid conditions where rainfall and humidity are high. Cucurbits like watermelon, bottle gourd, cucumber and snake gourd are more susceptible to disease. Different types of symptoms are observed on leaves, petioles, stem and fruits. Symptoms on young fruits appear in the form of numerous water soaked depressed oval spots, which coalesce covering large areas. Under humid conditions, pink masses of spores can be seen in centre of these spots. Pink gummy exudation may also be seen on lesions due to exudation of spores. Symptoms on vines occur as brownish specks which grow into angular to circular spots. Girdling of affected portion leads to general blight symptoms. Clean cultivation and crop rotation minimize disease incidence. Treating seeds with Carbendazim @ 25 g/kg of seed and spraying crop at 10 days intervals with Indofil M-45 (0.35%). Benomyl or Carbendazim (0.1%) gives effective control.

**Alternaria blight and fruit rot** (*Alternaria cucumerina*)

This is a serious disease under warm and humid conditions in crops like musk melon, water melon, bottle gourd, snake gourd, cucumber and pumpkin. Symptoms appear as yellow spots on leaves which turn brown and finally turn black on aging. They usually start from margins and produce concentric rings. Severely affected vines look like burnt charcoal. Use of disease free seeds, clean cultivation and crop rotation are effective for
control of disease. Spray of 0.25% Indofil M-45 at 10-15 days interval is effective for disease control.

**Mosaic**

Viral disease are causing extensive damage to different cucurbits like pumpkin and squashes, water melon, ridge gourd, bitter gourd, ash gourd, melon, cucumber and coccinia. Viral diseases are becoming serious due to intensive and continuous cultivation of a crop with indiscriminate use of plant protection chemicals. Several viruses like aphid transmitted cucumber mosaic virus, watermelon mosaic viruses like aphid transmitted cucumber mosaic virus, watermelon mosaic virus, mechanically transmissible tobacco virus group, non sap transmissible but white fly transmissible yellow vein mosaic virus etc. cause malformation and damage to plants. Symptoms expressed by host plant vary with virus and crop. Mosaic mottling, curling and twisting of leaves, shortening of internodes, stunted growth are common symptoms and vegetative growth, flowering and productivity are adversely affected once crop is infected.

Complete control of the diseases is not possible. Adoption of practices like collection of seeds from healthy virus free plants, seed treatment with hot air (70°C for 2 days) or hot water (55°C for 60 minutes), clean cultivation and removal of alternate hosts particularly weeds, avoiding relay cropping of susceptible crops, prophylactic spray of organic pesticides, control of vectors by spraying insecticides, use of biocontrol agents, cultivation of tolerant / resistant varieties, avoiding cropping during mosaic prone season and areas, either alone or in combination have to be tried for raising a mosaic free crop. Selection of methods for control of viral diseases should be based on intensity of infection, mode of transmission, etc.

**Nematodes**

Cucurbits are highly susceptible to nematode infestation particularly of root knot nematode *Meloidogyne incognita acrita*. Symptoms include premature leaf fall, wilting and decline in growth and fruit production. Roots of infected plants show typical galls / knots. Cultivation of resistant varieties, crop rotation with non-host plants, successive deep ploughing during hot weather, soil solarization with polythene sheets and soil fumigation with nematicides are advocated for control of root knot nematode.

**Application of fertilizers in Tamil Nadu**

Apply 10 kg of FYM, 100 g of NPK 6:12:12 g mixture as basal per pit and N @ 10 g per pit 30 days after sowing.
RECENT DEVELOPMENT IN POMEGRANATE

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The pomegranate has been grown since ancient times for its delicious fruits and as an ornamental garden plant for its red, orange or occasionally, creamy yellow flowers. The pomegranate (Punica granatum L.) belongs to the punicaceae family. It is also known as the Chinese apple or Apple of Carthage or Apple with many seeds. Pomegranate is known as a super fruit of next generation and is a native of Iran to Himalayan region and is extensively grown in Iran, Spain, India and USA as well as in most Near and Far East countries. In India, pomegranate is considered as a crop of the arid and semi arid regions because it withstands different soil and climate stresses. It thrives best under hot dry summer and cold winter provided irrigation facilities are available. Owing to its low maintenance cost, tolerant to biotic and abiotic stresses, high yielding potential, better keeping quality and higher nutraceutical fruit value, popularity of pomegranate is increasing among the growers and consumers worldwide. It is found growing wild in the hills of Himalayas covering the entire hilly tract of Jammu and Kashmir, Himachal Pradesh and parts of Uttar Pradesh. The main pomegranate growing states in India are Maharashtra, Karnataka, Gujarat, Rajasthan, Uttar Pradesh, Andhra Pradesh and Tamil Nadu. India ranks first in the pomegranate production (8.07 lakh tonnes) in the world, on an area of 1.09 lakh hectares with productivity of 7.40 t/ha (Anonymous, 2010). Maharashtra, a pomegranate basket of India, covers 0.82 lakh ha area (75%) with the production of 5.50 lakh tones (68 % of the total pomegranate production in the country). More than 90 percent of the fresh produce is utilized for domestic fresh consumption and export. Spain (45%) and Iran (15%) competes the India in International market.

1. Pomegranate Fruit Quality Characteristics

Pomegranate fruits are irregular round in shape with coriaceous rinds that vary from yellow, green or pink to bright deep red, depending on the variety and stage of ripening (Holland et al., 2009). The fruit, a false berry, balausta type, is internally having multi ovule chambers separated by membranous walls (septum) and a fleshy mesocarp. The chambers are filled with shiny red seeds encased in a succulent and edible red pink pulp called arils. The arils develop from the outer epidermal cells of the seed and elongates to a very large extent in a radial direction. The colour of arils varies from white to deep red depending upon the variety. Fruit quality depends largely on sugar and acid content of the juice. The edible portion of the portion of pomegranate is an excellent dietary source as it contains a significant proportion of organic acids, soluble solids, polysaccharides, vitamins, fatty acids and mineral elements of nutritional significance.
2. Therapeutic Properties of Pomegranate

Pomegranate is a very promising and emerging crop for its refreshing arils, juice and its chemo preventive properties having medicinal value (Hertog et al., 1997). The pomegranate has been regarded as a food medicine of great importance for therapeutic purposes like colic, colitis-diarrhea, dysentery, leucorrhea, paralysis and headache It finds wide application in the traditional Asian medicines both in Ayurvedic and Unani systems. The therapeutic properties are reported to be due to the presence of betulic and urosolic acids and different alkaloids such as pseudo pelletierine, pelletierine and some other basic compounds.

commercial farming of the pomegranates globally, due to the potential health benefits of the fruit such as its high antioxidant, anti-mutagenic, anti-hypertension activities and the ability to reduce liver injury.

3. Pomegranate Processing

Ongoing global drive for a healthier diet has led to a rise in demand for convenient and fresh food produce, with high nutritional value and free of additives (James Celeb et al., 2011). Pomegranate indicates the great scope for the processing into value added products having extended shelf life. The fruit disorders such as sun burnt husks, splits and cracks and husk scald on whole fruit reduces marketability and consumer acceptance. The new sector of pomegranate processing allows the use of the fruits with low quality fruits that cannot be commercialized, for the preparation of the new products. Despite of great potential for pomegranate derived products, the industrial processing of pomegranate is scarce due to peeling difficulties and lack of technological development for industrial processing of pomegranate.

4. New Technologies for Pomegranate Storage

The pomegranate is classified as a nonclimacteric fruit. In spite of the non climacteric nature of the fruit, quantitative and qualitative loss still occur due to postharvest handling processes, resulting in chilling injuries, husk scalding, weight loss and decay of pomegranate (Kader et al., 1984). The new physical treatment applications have been reported to prolong the shelf life of the fresh pomegranates. These treatments modifies the environmental conditions of pomegranate storage, effecting the fruit physiology and biochemistry and inhibiting the development of microorganisms contaminating the fruit surface, keeping the original physico-chemical quality recommended a fast pre-refrigeration using forced air as one of the simplest ways to extend the commercial life of pomegranate up to 2-3 months by keeping storage temperature around 50C. Artes and Tomas-Barberan (2000) reported the applications of controlled and modified atmospheres (CO2 enriched and / or reduced O2), use of the thermal treatments for fruit conditioning and curing and intermittent warming during the cold storage to avoid fungal developments and physiological disorders that develops below 50C.
5. Pomegranate Juice Processing

Pomegranate contains 48 to 52 per cent of edible part on the whole fruit basis, which comprises of 78 percent juice and 22 percent seed. The seeds along with arils are crushed and juice is extracted and marketed as a fresh juice due to its excellent flavour, attractive fragrance, delicious taste and high nutritive and medicinal value. Production of juice from the pomegranate arils proved to be one of the important methods of value addition. The juice can be processed possible into the squash, syrup, nectar, jelly, concentrate and such other products. Pomegranate juice can be used as an ingredient providing colour to the other products. The pomegranate juice is a rich source of polyphenols. The phenolic constituents of pomegranate such as the anthocyanins give the colour and other polyphenols such as flavonoids and some non flavonoids are responsible of antioxidant properties, astringency and bitterness to juice.

6. Packaging of Pomegranate Juice

Packaging material selection as well as processing influences the quality of foods, altering colour and nutrient composition during storage as a result of contact with oxygen and light transmission through them. Paperboard cartons with low density polyethylene (LDPE) coating or glass containers are commonly used materials of juices. Oxygen and lighthave destructive effect on the anthocyanin during storage. So the packaging material also plays an important role in the colour stability of stored pomegranate product. Perez-Vicente et al. (2004) assessed the influence of packaging material on colour and bioactive compounds of pasteurized pomegranate juice during storage at 24/18 0C and 40-50% RH. They opined that the organoleptic quality of juice could be altered by packaging material, even if nutritional quality is not influenced suggesting that the oxygen permeability of the packaging material (which is the more damaging factor than light for pomegranate juice) should be minimized to avoid the detrimental effects on the retention of colour and some bioactive compounds. Glass containers were found to be better as compared to high density polyethylene or polyvinyl chloride containers with regards to retention of anthocyanins, vitamin C and organoleptic quality of the fruit juices.

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MATURITY AND MATURITY INDICES OF FRUITS AND VEGETABLES

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The principles dictating at which stage of maturity a fruit or vegetable should be harvested are crucial to its subsequent storage and marketable life and quality. Fruits harvested too early may lack flavour and may not ripen properly, while produce harvested too late may be fibrous or have very limited market life. Similarly, vegetables are harvested over a wide range of physiological stages, depending upon which part of the plant is used as food. For example, small or immature vegetables possess better texture and quality than mature or overmature vegetables. Therefore harvesting of fruits and vegetables at proper stage of maturity is paramount importance for attaining desirable quality. The level of maturity actually helps in selection storage methods, estimation of shelf life, selection of processing operations for value addition etc.

Post-harvest physiologists distinguish three stages in the life span of fruits and vegetables: maturation, ripening, and senescence. Maturation is indicative of the fruit being ready for harvest. At this point, the edible part of the fruit or vegetable is fully developed in size, although it may not be ready for immediate consumption. Ripening follows or overlaps maturation, rendering the produce edible, as indicated by taste. Senescence is the last stage in the ontogeny of the plant organ, characterized by natural degradation of the fruit or vegetable, as in loss of texture, flavour, etc. (senescence ends at the death of the tissue of the fruit).

Maturity is the attainment of a particular size or stage after which ripening takes place is called maturity. It is also defined as the stage of development at which the produce has completed its natural growth and is ready for harvest. This stage would ensure proper completion of ripening process.

The term maturity is derived Latin word 'Maturus' which means ripen. It is that stage of fruit development, which ensures attainment of maximum edible quality at the completion of ripening process.

The maturity has been divided into two categories i.e. physiological maturity and horticultural maturity.

1. **Physiological maturity:** It is the stage at which a plant or plant part continues ontogeny (complete developmental history of an organism from egg/spore/bud etc. to an adult individual) even if detached from the parent plant or the point of origin. It can also be defined as the stage at which a plant or plant part is capable of further development or ripening when it is harvested i.e. ready for eating or processing. Ex. A French bean pod or okra pod is at its physiological maturity when the seeds are fully developed and the pod is lignified which will dehisce with little pressure.
2. Horticultural maturity / Harvest maturity: It may be defined as the stage at which a plant or plant part possesses all the prerequisites for use by consumers for a particular purpose, i.e. local, distant, export market (shipping maturity) or exhibition or processing (processing maturity), culinary maturity, desert maturity etc. Ex. A pod vegetable is matured when it is tender with maximum size. Horticultural maturity stage of tomato if harvested for long distance transportation would be the “turning stage of skin from green to red”, while the optimum stage of harvesting of the same crop for home use or local markets would be “when the fruits have attained full red colour”. Maturity indices are important for deciding when a given commodity should be harvested to provide some marketing flexibility and to ensure the attainment of acceptable eating quality to the consumer. Generally, a single maturity index is not considered to be reliable. In most of the crops more than one or two indices should be made use of while determining the exact stage of optimum maturity. Fruits picked at the wrong stage of maturity may develop physiological disorders in storage and may exhibit poor defect quality. Fruit size is also sacrificed by harvesting too early. For selecting the harvest maturity of fruits or vegetables it should be kept in mind that harvested commodity has its peak acceptable quality (Non-toxic, size, appearance and flavour with adequate shelf life).

Importance of maturity indices:
- Ensure sensory quality (flavour, Colour, aroma, texture) and nutritional quality.
- Ensure an adequate post harvest shelf life.
- Facilitate scheduling of harvest and packing operations
- Facilitate marketing over the phone or through internet.

Determination of harvest maturity can be done by different methods:

1. Computation methods: (1) calendar date, (2) Days From Full bloom to Harvest, (3) Mean heat units (4) T – stage.

2. Physical methods: (1) Fruit retention strength, (2) Fruit size and surfacemorphology, (3) Weight, (4) Specific gravity, (5) Colour, (6) Flesh firmness, (7) Total soluble solids (TSS), (8) Juice content and (9) oil content


4. Physiological methods: (1) Respiration rate and (2) Ethylene evolution rate

Determination of maturity: Parameters which are considered for the determination of maturity indices are: Chronological age, size, shape, surface characteristics, color, firmness, soluble solids, sugars, starch presence, sugar to acid ratio, oil content etc. In recent years much work has been done on developing non-destructive methods for the measurement of fruit and vegetable characteristics, using principles of NMR (nuclear magnetic resonance), X-rays, sonics and ultra sonic waves, delayed light emission and light reflectance. Maturity indices must be set for each region and variety.
MICROWAVE DRYING OF FRUITS AND VEGETABLES

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ABSTRACT

Drying is one of the most common food preservation techniques which involve removal of moisture from the food product. Drying offers a means of preserving foods in a stable and safe condition as it reduces water activity and extends shelf-life much longer than that of fresh fruits and vegetables. The growing resistance of consumers to the use of chemicals for the preservation of food and the increasing demand for the good quality of fast dried foods has increased the rapid expansion of market for the additive free dehydrated alternatives. Hence, there is a need to develop dried products of high quality, which has potential to attract consumers thus expanding the market for such products.

Keywords: Drying; Quality attributes; colour; rehydration ratio.

INTRODUCTION

Fruits and vegetables are rich sources of important dietary nutrients such as vitamins, minerals and fibres. They are considered as highly perishable commodities as they contain high moisture contents of about 80% (Orsat et al., 2006). There are different ways of keeping products fresh for a longer time and maintaining its quality. However, most of the preserving techniques require low temperature which is difficult to maintain throughout the distribution chain. Drying is considered as one of the oldest method of preservation. It reduces the water activity and increases the shelf life of fresh fruits and vegetables to a longer period of time (Zhang et al., 2006). It has been found that more than 20% of the world perishable crops are preserved by drying to increase the shelf life and promote food security (Grabowski et al., 2003). There are some other objectives of drying like quality enhancement, ease of handling, further processing, sanitation (Duan et al., 2010). At present, the demand for dehydrated fruits and vegetables has increased in the global market (Villagran et al., 2003). These dehydrated vegetables are high in nutrient content, free of chemicals and preservatives, have an improved appearance and taste (Lakshmi and Vimala, 2000) and have an indefinite storage life (Rockstrom, 2000). The preservation of fruits and vegetables by drying through sun or solar drying causes poor quality and contamination of food. The most applicable method of drying includes freeze, vacuum, osmotic, cabinet or tray, fluidized bed, spouted bed, Ohmic, microwave and combination thereof (George et al., 2004). Fluidized bed drying has been considered as one of the best method of drying with faster and uniform drying. During this process, hot air is blown at a high velocity in fluidized bed chamber in order to keep food particles in suspension (Doymaz, 2004). The application of microwave energy to the fluidized bed drying process is called as microwave assisted fluidized bed drying (MWFBD). Microwaves have frequencies
range from 300 MHz to 30 GHz, with 915 MHz and 2450 MHz being the most commonly used for dielectric heating, which reflects commercial emphasis on home microwave ovens (Venkatesh and Raghavan, 2004). Use of microwave in drying of fruits and vegetables has become widespread as it minimizes quality degradation and provides rapid and effective heat distribution in the materials (Diaz, 2003). Furthermore, high quality product is obtained via microwave drying in addition to the decline in drying period and energy conservation. MW-related combination drying takes advantages of conventional drying methods and microwave heating, leading to better processes than MW drying alone.

**Effect of microwave drying on quality attributes**

During drying of fruits and vegetables, number of changes takes place on quality parameters. Majority quality parameters associated with dried food products include color, visual appeal, shape of product, flavour, microbial load, retention properties, water activity, freedom from pests, insects and other contaminants, preservatives (Ratti, 2005). These quality parameters can be divided into four major groups: i) physical, ii) chemical, iii) microbial and iv) nutritional.

Physical changes that influence the quality of final dried product include case hardening, collapse, pore formation, rehydration, caking and stickiness. Chemical changes include browning, lipid oxidation, colour loss and change of flavour (Salunkhe et al., 1991). These changes are undesirable because these produce undesirable colour and flavour. Pretreatments such as osmotic dehydration, blanching, sulphur treatment are given to avoid these undesirable changes. The dried products are considered safe with respect to microbial hazard. Different microbes are having different water activity. Usually, no growth of microbes occurs below $a_w 0.62$ (Sablani, 2006a). Fruits and vegetables are rich source of vitamins, minerals and fibres. However, these nutrients are lost during the process of drying. A number of vitamins such as vitamin A, C and thiamine are heat sensitive. About 80% decrease in the carotene content occurs if they are dried without enzyme inactivation. Microwave drying can reduce the drying time and improve the quality (Beaudry et al., 2003).

**Effect of microwave drying on colour of fruits and vegetables**

Colour of a foodstuff is an important quality attribute and plays a significant role in its appearance, processing, and acceptability. The discolourization and browning of fruits and vegetables are the results of various reactions, including Maillard condensation of hexoses and amino components (Cornwell and Wrolstad, 1981), phenol polymerization and pigment destruction (Abers and Wrolstad, 1979). The color measurements of food materials can be used in an indirect way to determine the color change, since they are simpler and faster than chemical analysis. Hunter color parameters ($L$ whiteness=darkness; $a$, redness=greenness; and $b$, yellowness=blueness) have previously proved valuable in describing visual color deterioration and providing useful information for quality control in fruits and vegetables. Dadali et al. (2007), studied color change kinetics of okra undergoing microwave drying. The color change of okra using the $L$, $a$, $b$ system totally explained the real behavior of okra samples undergoing microwave drying. The final values of $L$, $a$, $b$, total color change (DE), chroma and hue angle were influenced by microwave drying. The values of Browning...
index showed that microwave drying caused more brown compound(s). This result was supported by the increase in a value. The zero-order and first-order kinetic models were used to explain the color change kinetics and it was observed that L, b, chroma, and Browning index were fitted to a first order kinetic model. On the other hand, a, total color change (DE), and hue angle followed a zero-order kinetic model. As a function of power/sample amount, the data for L, a, and b, total color change (DE), chroma, hue angle, and Browning index were fitted to a quadratic model. The total color change (DE), chroma, and Browning index increased, and hue angle decreased when the power/sample amount value was increased. For calculation of the activation energy for color change kinetic parameters, the exponential expression based on Arrhenius’s equation was used, and it was observed that the Arrhenius model described well the power/sample amount dependence of the estimated kinetic parameters for all the color parameters considered.

**Effect of microwave drying on rehydration characteristics**

Rehydration is a complex process which aims to restore fresh product properties when the dried material is in contact with the rehydration solution. Rehydration characteristics of the dried products were used as a quality index and they indicated the physical and chemical changes that occurred during the drying and were influenced by processing conditions, sample compositions, sample preparation and extent of structural and chemical disruptions induced by drying (Krokida and Maroulis 2001). The rehydration properties, rehydration rate, and rehydration capacity are important characteristics of many products, related to their later preparation for consumption (Krokida and Maroulis, 2000). Dehydrated products readily take up moisture when immersed in a liquid medium, leading to significant changes in their thermophysical properties. It is generally accepted that the degree of rehydration is dependent on the degree of cellular and structural disruption. Predrying treatments, subsequent drying and rehydration induce many changes in structure and composition of plant tissue and thus result in impaired reconstitution properties (Lewicki, 1998). Hence, rehydration can be considered as a measure of the degree of alterations to the material caused by drying and predehydration treatments. During drying, irreversible cellular rupture and dislocation, resulting in loss of integrity and, hence, a dense structure of collapsed, greatly shrunken capillaries with reduced hydrophilic properties, as reflected by the inability to imbibe sufficient water to rehydrate fully is observed (Jayaraman et al., 1990). Jokic et al. (2009) studied the influence of drying procedure on colour and rehydration characteristic of wild asparagus. Wild asparagus samples were dried using convective (40°C, 50°C, 60°C, and 70°C at the airflow velocity of 2.75 m/s), natural, and freeze (–20°C and –40°C) drying procedures. The best rehydration ratio was achieved when the samples were freeze dried at –40°C. Naturally dried asparagus samples resulted in a very low rehydration ratio compared to the other procedures investigated. The rehydration and appearance of the dried asparagus are two important physical factors that need special attention when designing or selecting a drying procedure. In the case of convective drying, with the increase of the drying temperature the rehydration ratio for the may have been due to the fact that the rate of the moisture removal at a higher drying temperature is very fast and causes less shrinkage of the dried samples. The rehydration ratio with the naturally dried samples
was the lowest. Freeze drying at –40°C resulted in the highest rehydration ratio. The study showed that a first-order kinetic model can describe the water uptake during rehydration of fruits and vegetables. The influence of temperature was examined by embodying them to the rehydration constant and the equilibrium moisture content after rehydration. The water temperature was found to influence the rehydration rates and the equilibrium moisture content in a positive way. The rehydration ability appeared to show a hysteresis during rehydration due to cellular and structural disruption that take place during dehydration. The structural model satisfactorily described the changes in the structural properties during the rehydration of all the dehydrated products examined. Apparent density, porosity, and specific volume appeared to show a hysteresis during rehydration, apparent density being lower and porosity and specific volume higher during rehydration than during dehydration (Krokida and Philippopoulos, 2005).

CONCLUSION

Many new dimensions came up in drying technology to reduce the energy utilization and operational cost. Among the technologies, osmotic dehydration, vacuum drying, freeze drying, microwave drying and spray drying are offering great scope for the production of best quality dried products and powders. Due to high cost, using single unit operation to dry the produce is not cost effective. Therefore, cost effective alternate systems like combination of microwave with other drying should be promoted to reap the advantage of sophisticated drying systems with minimum cost and simple technologies.

REFERENCES


Integrating Nutrient Management (INM) with Special Reference to Floricultural Crops

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Floriculture is a branch of horticulture concerning cultivation of flowering and ornamental plants for gardens and floristry. It includes cut flowers, cut greens, bedding plant, houseplants, flowering garden and potted plants etc. The rising living standards and unabated urbanization in the present day the world has led to growing demand of flowers and their products thereby making the floriculture an important commercial trade. Commercial floriculture has higher potential per unit area than the field crops and is therefore evolving as a lucrative business all over the world (Misra and Sudip, 2016). The area under floriculture in India are about 253.65 thousand hectare with production of 1.652 million tonnes loose flowers and 76.73 million tonnes cut flowers (NHB, 2012). Indian floriculture industry stands 2nd in world production (Shilpa and Narpat, 2016) and occupies 511st in terms of exports and contributes rupees 455 crores which is 0.06 percent of global trade (De and Singh, 2016). There is as such an urgent need of scientific approach and wise use to promote the relevant management practices, improvement of flower germplasm, balanced nutrient management, modern production technology, quality planting material, precision farming etc., for conservation and commercialization of the floriculture industry and diversification from the traditional field crops due to higher returns per unit area. The overall strategy for increasing crop yields and sustaining them at high level must include integrated approach to the management of nutrients. The sustainability in agriculture system is a global issue. Integrated nutrient management program is a critical component of the type of integrated farming systems (Edwards et al., 1990). The program involves maximize biological inputs to crop production and minimize the use of inorganic amendments so as to create a much more sustainable pattern of crop production, not only ecologically but also environmentally (National Research Council, 1991). Since the nutrient turnover in soil plant system is considerably high in intensive farming, integrated approach of chemical, organic and biological sources can achieve sustainable production. Practice of INM is the better option for the improvement of physical, chemical and biological properties of soils (Das et al., 2015). To maintain productivity and reduce dependence on chemical fertilizers alone is increasingly becoming important to flower growers. It is important to exploit the potential of organic manures, composts, crop residues, biofertilizers and their synergistic effect with chemical fertilizers for increasing balanced nutrient supply (Wani et al., 2016). This kind of intervention is of paramount importance in horticulture in general and ornamentals in particular. The use of biofertilizers reduces per unit consumption of inorganic fertilizers and increase the quality and quantity of flower (Syamal et al., 2006). The growth and quality of flower are greatly influenced by numerous environmental factors like soil
type and nutrient availability being the most essential factors for appropriate growth (Tariq et al., 2012). The quality and production of cut flowers is primarily a varietal trait, it is greatly influenced by climatic, geographical and nutritional factors. The quality and quantity of applied fertilizer are the key factor affecting the growth, yield and quality of the cut flower (Dufour and Gue\;rin, 2005). The quality of flowers is influenced both by quantity and source of nutrients as well.

In India, there is a profitable production system for standard crops like gladiolus, mums, carnations, tuberose and roses. The domestic flower consumption as well as market, though not nearly as demanding as the international market, has incredible potential for expansion. (1) The quality and quantity of applied fertilizer are the key factor affecting the growth, yield and quality of the cut flower. (2) Use of high yielding varieties and other management practices aimed at higher production from unit area involves a high application rate of nutrients and excess amount of fertilizer that leaches from the soil affects quality for both the environment and human health. (3) The sustainability in agriculture system is a global issue. Practice of INM is the better option for the improvement of physical (structure and water retention capacity), chemical (nutrients and cation exchange capacity) and biological (microflora and microfauna) properties. (4) Further, it has been proved time and again under a limited range of soil organic matter contents, the crops yield for a given soil increases with the increase in soil organic matter. (5) To maintain productivity and reduce the application of chemical fertilizers is increasingly becoming important to flower growers. However, little information is available concerning flower production using organic fertilizer, even now when the concern is being raised more often (Jayoti et al., 2014).

WHAT IS INM?

“Integrated nutrient management means combined application of different sources of plant nutrients like organics, inorganic and bio fertilizers for sustainable crop production without degrading the natural resources on long term basis.”

The basic concept underlying the integrated nutrient management system (INMS), nevertheless, remains the maintenance and possible improvement of soil fertility for sustained crop productivity on long term-basis and also to reduce inorganic (fertilizer) input cost. The three main components of INMS as defined by FAO, 1998 are:

1. Maintain or enhance soil productivity through a balanced use of fertilizers combined with organic and biological sources of plant nutrients.
2. Improve the stock of plant nutrients in the soils.
3. Improve the efficiency of plant nutrients, thus, limiting losses to the environment.

Thus, integrated nutrient supply/management (INS) aims at maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of benefit from all possible sources of plant nutrients in an integrated manner (Roy and Ange, 1991).
Requirement of a crop for a nutrient is decided by the rooting behaviour and its mining ability, the native soil status, the potential yields as decided by the soil-agro climatic situations, the targeted yields and nutrient management.

While fertilizer misuse can contribute to environmental contamination, it is often an indispensable source of the nutrients required for plant growth and food production. Unless all the soil nutrients removed with the harvested crops are replaced in proper amounts from both organic and sustained; soil fertility will decline. If in the past, the emphasis was on increased use of fertilizer; the current approach should aim on educating farmers to optimize use of organic, inorganic and biological fertilizer in an integrated way. Plant nutrition in the present day requires judicious and integrated management of all sources of nutrients for sustainable agriculture.

Therefore, an INMS is the most efficient and practical way to mobilize all the available, accessible and affordable plant nutrient sources in order to optimize the productivity of the crops/cropping systems and economic return to the farmer. Three years data collected from 267 sites in India under different crops convincingly show a 22% increase in yield by following INM rather than farmer’s practice (Govil and Kaore, 1997).

IMPORTANCE OF INM

The aim of Integrated Nutrient Management (INM) is to integrate the use of natural and man-made soil nutrients to increase crop productivity and preserve soil productivity for future generations (FAO, 1995a). Rather than focusing nutrition management practices on one crop, INM aims at optimal use of nutrient sources on a cropping-system or crop-rotation basis. This encourages farmers to focus on long-term planning and make greater consideration for environmental impacts.

INM relies on a number of factors, including appropriate nutrient application and conservation and the transfer of knowledge about INM practices to farmers and researchers. Boosting plant nutrients can be achieved by a range of practices covered in this guide such as terracing, alley cropping, conservation tillage, intercropping, and crop rotation. Given that these technologies are covered elsewhere in this guidebook, this section will focus on INM as it relates to appropriate fertilizer use. In addition to the standard selection and application of fertilizers, INM practices include new techniques such as deep placement of fertilizers and the use of inhibitors or urea coatings (use of area coating agent helps to reduce the activity and growth of the bacteria responsible for denitrification) that have been developed to improve nutrient uptake.

Key components of the INM approach include:

1) Testing procedures to determine nutrient availability and deficiencies in plants and soils. These are:
(i) Plant symptom analysis – visual clues can provide indications of specific nutrient deficiencies. For example, nitrogen deficient plants appear stunted and pale compared to healthy plants.

(ii) Tissue analysis and soil testing – where symptoms are not visible, post-harvest tissue and soil samples can be analysed in a laboratory and compared with a reference sample from a healthy plant.

2) Systematic appraisal of constraints and opportunities in the current soil fertility management practices and how these relate to the nutrient diagnosis, for example insufficient or excessive use of fertilisers.

3) Assessment of productivity and sustainability of farming systems. Different climates, soil types, crops, farming practices, and technologies dictate the correct balance of nutrients necessary. Once these factors are understood, appropriate INM technologies can be selected.

4) Participatory farmer-led INM technology experimentation and development. The need for locally appropriate technologies means that farmer involvement in the testing and analysis of any INM technology is essential.

**COMPONENTS OF INM:**

**MANURE**

- **Bulky organic manure**
  - a. FYM
  - b. Compost
  - c. Night soil
  - d. Green manure

- **Concentrated organic manure**
  - a. Blood meal
  - b. Oil cakes
    - i. Sunflower cake
    - ii. Groundnut cake

**GREEN MANURES**

- In-situ green manures
- Ex-situ green manures

**BIO-FERTILIZERS**

- Azotobactor
- Rhizobium
Azolla
Azospirillum

**CHEMICAL FERTILIZERS**

- Urea
- Ammonium Sulphate
- DAP
- SSP
- Muriate of Potash
- Zinc sulphate

**Manures**

- Manures are the organic materials which improve soil fertility when incorporated into the soil.
- They are made up of animal remains and dead plants and contain more than one nutrient element.
- Concentration of nutrient in organic manure is low.

**Advantages of manure:**

1. They improve soil physical properties like structure, water holding capacity.
2. To increase availability of nutrients.
3. They prevent the loss of nutrients by leaching or erosion.
4. Manures supply plant nutrients including micro-organisms.

**I. Bulky organic manure:**

Bulky organic manures contain small percentage of nutrients and they are applied in large quantities. Farmyard manure (FYM), compost and green-manure are the most important and widely used bulky organic manures.

**II. Concentrated organic manure:**

Concentrated organic manures have higher nutrient content than bulky organic manure. The important concentrated organic manures are oilcakes, blood meal, fish manure etc. These are also known as organic nitrogen fertilizer. Before their organic nitrogen is used by the crops, it is converted through bacterial action into readily usable ammoniacal nitrogen and nitrate nitrogen. These organic fertilizers are, therefore, relatively slow acting, but they supply available nitrogen for a longer period.
## Nutrient Contents of Organic Manures

<table>
<thead>
<tr>
<th>Organic Manure</th>
<th>N %</th>
<th>P2O5 %</th>
<th>K2O %</th>
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</thead>
<tbody>
<tr>
<td><strong>Bulky organic manures</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Cattle dung</td>
<td>0.40</td>
<td>0.20</td>
<td>0.17</td>
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<tr>
<td>Poultry manure</td>
<td>3.03</td>
<td>0.63</td>
<td>1.40</td>
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<tr>
<td>Farmyard manure</td>
<td>0.50</td>
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</tr>
<tr>
<td>Rural compost</td>
<td>0.75</td>
<td>0.20</td>
<td>0.50</td>
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<tr>
<td>Urban compost</td>
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<td>1.00</td>
<td>1.50</td>
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<tr>
<td>Vermicompost</td>
<td>3.00</td>
<td>1.00</td>
<td>1.50</td>
</tr>
<tr>
<td><strong>Concentrated organic manure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Castor cake</td>
<td>4.37</td>
<td>1.85</td>
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<td>Coconut cake</td>
<td>3.00</td>
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<td>Neem cake</td>
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<td>Blood meal</td>
<td>12.00</td>
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<td>1.00</td>
</tr>
<tr>
<td>Groundnut cake</td>
<td>7.30</td>
<td>1.50</td>
<td>1.30</td>
</tr>
<tr>
<td>Pressmud</td>
<td>2.10</td>
<td>4.40</td>
<td>0.80</td>
</tr>
</tbody>
</table>

## Green Manure

Green undecomposed material used as manure is called green manure. It is obtained in two ways: by growing green manure crops or by collecting green leaf (along with twigs) from plants grown in wastelands, field bunds and forest.

## Green manuring

Green manuring is the practice of growing in the field, plants usually belonging to leguminous family and incorporating into the soil after sufficient growth. The plants which are grown for green manure are known as green manure crops. The most important green manure crops are sunnhemp, dhaincha, *Pillipesara*, clusterbeans and *Sesbania rostrata.*
Green leaf manuring

Application of green leaves and twigs of trees, shrubs and herbs collected from elsewhere is known as green leaf manuring. Forest tree leaves are the main sources for green leaf manure. Plants growing in wastelands, field bunds etc., are another source of green leaf manure. The important plant species useful for green leaf manure are neem, mahua, wild indigo, Glyricidia, Karanji (*Pongamia glabra*) calotropis, avise (*Sesbania grandiflora*), subabul and other shrubs.

Advantages of green manure:

i. Green manuring improves soil structure, increases water holding capacity and decreases soil loss by erosion.

ii. Growing of green manure crops in the off season reduces weed proliferation and weed growth.

iii. Green manuring helps in reclamation of alkaline soils. Root knot nematodes can be controlled by green manuring.

Bio-fertilizers

Bio-fertilizers may be defined as preparations containing living cells or latent cells of efficient strains of microorganisms that help crop plants’ uptake of nutrients by their interactions in the rhizosphere when applied through seed or soil. They accelerate certain microbial processes in the soil which augment the extent of availability of nutrients in a form easily assimilated by plants.

Very often microorganisms are not as efficient in natural surroundings as one would expect them to be and therefore artificially multiplied cultures of efficient selected microorganisms play a vital role in accelerating the microbial processes in soil.

Use of bio-fertilizers is one of the important components of integrated nutrient management, as they are cost effective and renewable source of plant nutrients to supplement the chemical fertilizers for sustainable agriculture. Several microorganisms and their association with crop plants are being exploited in the production of biofertilizers. They can be grouped in different ways based on their nature and function.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Groups</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>N2</td>
<td>fixing Bio-fertilizers</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Free-living</td>
<td><em>Azotobacter, Beijerinkia, Clostridium, Klebsiella, Anabaena, Nostoc,</em></td>
</tr>
<tr>
<td>2.</td>
<td>Symbiotic</td>
<td><em>Rhizobium, Frankia, Anabaena azollae</em></td>
</tr>
<tr>
<td>3.</td>
<td>Associative</td>
<td><em>Azospirillum</em></td>
</tr>
</tbody>
</table>
Advances in Horticultural Crops

<table>
<thead>
<tr>
<th>Symbiotic</th>
</tr>
</thead>
</table>

**P Solubilizing Bio-fertilizers**

1. **Bacteria**
   - *Bacillus megaterium* var. *phosphaticum*, *Bacillus subtilis*
   - *Bacillus circulans*, *Pseudomonas striata*

2. **Fungi**
   - *Penicillium* sp, *Aspergillus awamori*

**P Mobilizing Bio-fertilizers**

1. **Arbuscular mycorrhiza**
   - *Glomus* sp., *Gigaspora* sp., *Acaulospora* sp.,
     *Scutellospora* sp. & *Sclerocystis* sp.

2. **Ectomycorrhiza**
   - *Laccaria* sp., *Pisolithus* sp., *Boletus* sp., *Amanita* sp.

3. **Ericoid mycorrhizae**
   - *Pezizella ericae*

4. **Orchid mycorrhiza**
   - *Rhizoctonia solani*

**Biofertilizers for Micro nutrients**

1. **Silicate and Zinc solubilizers**
   - *Bacillus* sp.

**Plant Growth Promoting Rhizobacteria**

1. **Pseudomonas**
   - *Pseudomonas fluorescens*

**Advantages of bio-fertilizers:**

i. They are biodegradable.

ii. They do not Pollute soil and water resources.

iii. They are less expensive.

iv. Increase the grain yields by 10-40%.

v. Improve texture, structure and water holding capacity of soil.

vi. No adverse effect on plant growth and soil fertility.

vii. Replace 25-30% chemical fertilizers.

**Bio-fertilizers used in floriculture:**

- **Azospirillum**: Azospirillum is applied in several crops such as Marigold, Rose, Tuberose, Gladiolus, Chrysanthemum, Dahlia, etc.

- **Azotobacter**: Azotobacter is being applied in flower crops including Marigold, Rose, Gladiolus, Chrysanthemum, Dahlia, etc.

- **Phosphate Solubilising Bacteria**: PSB is applied in Rose, China Aster, Gladiolus, Tuberose, etc.
Vesicular-arbuscular Mycorrhizae (VAM): VAM is applied in flower crops such as Crossandra, China Aster, Marigold, Gladiolus, Chrysanthemum, Tuberose, etc.

**Fertilizers**

A fertilizer is any material of natural or synthetic origin that is applied to soils or to plant tissues (usually leaves) to supply one or more plant nutrients essential to the growth of plants.

Fertilizer is a rich source of nutrient and applied in order to supply a particular nutrient in which the soil is deficient.

**Chemical composition of major fertilizers:**

<table>
<thead>
<tr>
<th>FERTILIZER</th>
<th>N (%)</th>
<th>P (%)</th>
<th>K (%)</th>
<th>S (%)</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea</td>
<td>46</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ammonium sulphate</td>
<td>20.6</td>
<td>-</td>
<td>-</td>
<td>24</td>
<td>-</td>
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<tr>
<td>DAP</td>
<td>18</td>
<td>46</td>
<td>-</td>
<td>-</td>
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<tr>
<td>SSP</td>
<td>-</td>
<td>16</td>
<td>-</td>
<td>12</td>
<td>18(Ca)</td>
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<tr>
<td>MOP</td>
<td>-</td>
<td>-</td>
<td>60</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Zinc sulphate</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>17</td>
<td>36(Zn)</td>
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</table>

**STEPS OF INTEGRATED NUTRIENT MANAGEMENT:**

According to Singh and Biswas (2000), there are certain steps which are being followed in INM, which includes:

- To assess on farm and off farm resources
- Fixing yield target
- Estimation of nutrient requirement
- Integration of nutrient resources available with farmers to finalize probable best combination to meet nutrient requirement
- To determine time, method, mode of application considering type of crop
- To adopt efficient soil and water conservation measures to check soil erosion, soil organic carbon and nutrient losses and to facilitate in situ moisture availability
- Monitoring of soil fertility in terms of soil physical, chemical & biological properties & process

**ADVANTAGES OF INTEGRATED NUTRIENT MANAGEMENT:**

- Provides balance nutrition to the plants.
• Helps in the improvement of soil physical properties.
• Acts as reservoir of soil nutrients.
• Minimizes soil deterioration.
• Availability of soil nutrients to the plants.

EFFECT OF INM ON SOME FLOWERS

• Singh (2007) reported application of FYM + remaining required dose of NPK by chemical fertilizers with Azotobacter gave better growth, flowering & yield.
• Waheeduzzama et al. (2007) proved Panchagavya at 4% foliar spray + RDF is optimum for growth & yield of Anthurium.
• Shankar et al. (2010) revealed Single Tuberose when grown with vermicompost & PSB @ 1kg/m² & 2g/bulb, respectively produced highest spike length, maximum number of spikes/plant, weight of bulbs/plant & longevity of spikes.

RESEARCH GAPS

• INM practices remain unexplored for use by the farmers, due to lack of proper guidance and trainings.
• Most of the researches are not based on soil testing reports.
• Lack of nutrient balance analysis.
• Bio-fertilizers should be adopted as a part of integration.

FUTURE LINE OF WORK

• More emphasis on INM research with flower crops.
• Benefits of INM to be quantified.
• Awareness and popularising about various INM practices.
• Development of various INM models for flower production.

CONCLUSION

INM is an integrated process of combining various sources of nutrients for providing a balanced nutrition to the plants. As a result of adoption of INM,

• Helps in both enhanced and sustainable production.
• Integration protects and improves soil health & crop productivity.
  • More and more intensive research on varied INM components needed.
METHODS AND TECHNIQUES OF ESSENTIAL OIL EXTRACTION: A REVIEW

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INTRODUCTION

Aromatic plants are defined as those plants which possess essential oil in them. These essential oils are the odoriferous steam volatile constituents of the aromatic plants. The special kind of plants owe their fragrant compounds to present in the traces of essential oil in different parts(Youis et al., 2008). The large number of fragrance materials would be present in the parts of roots, stems, barks, leaves, flowers, fruits and heartwood. This essential oil content of plant material is low, typically 1 to 3% of the plant weight. They are thus low-volume, very high value products. There are several methods of extraction being practiced in the aromatic industry like Distillation, enfleurage, maceration, expression, solvent extraction and fluid extraction. Application of these methods depends upon nature of material and essential oil are absolute intended to be recovered based on its use in single or combination form. The worldwide market for essential oil growth rapidly and nowadays a lot of scientific research presently focused on the industrial development together with environmental preservation by used different techniques as Hydrodistillation (HD), Supercritical Fluid Extraction (SFE), Ultrasound-assisted extraction (UAE) and Microwave-Assisted Hydrodistillation (MAHD) (Hesham et al., 2016).

Importance of essential oil industry in India:

1. Use of aromatic plants and their products is as old as our history that distillation of rose flowers is mentioned in Charaka and SushricSamhitas believed to have been written in Indian 1000 years B.C.

2. The aromatic plants and aroma chemicals contained in them play a vital role in our day to day living. More and more common and middle class people are using perfume and perfumed products, which were previously used by affluent and rich people only as these are falling with the reach of more and more.

3. Historically, India has enjoyed a pre eminent position as the supplier of natural perfumes to the world over. This is still true in the case of sandal wood oil, lemongrass oil, palmarosa oil, vetiver oil and cedarwood oil.

4. Though more than a thousand of Indian flora have been reported to contain odoriferous materials, only half a dozen has been systematically studied and cultivated.
5. Current production of essential oil is 16,000-18,000 tonnes in India as against the world production of 80,000 tonnes (i.e. 20-25%).

6. Our country is earning a foreign exchange of Rs. Around 130 crores per annum by way of export of aromatic essential oil. However, its contribution in world export is only 1.1% and in import 0.7%.

7. India ranks 28th position in import and 14th position in global trade of essential oil and India is the largest producer of Mints and Basils. Whereas, the countries like China, Brazil and Indonesia are the toughest competitors for India in essential oil industry.

8. India’s share of essential oil in the world market can be improved greatly if some of the bottlenecks that prevail now are removed. They are:
   a) Adoption of age old technology is still being followed in essential oil production.
   b) Wide fluctuation in quality and price.
   c) Available of low priced synthetic substitutes.

Methods and techniques of Essential oil extraction:

   Essential oils are used in a wide variety of consumer goods such as detergents, soaps, toilet products, cosmetics, pharmaceuticals, perfumes, confectionery food products, soft drinks, distilled alcoholic beverages (hard drinks) and insecticides (Wang and Weller, 2006). The world production and consumption of essential oils and perfumes are increasing very fast. Production technology is an essential element to improve the overall yield and quality of essential oil. Essential oils are obtained from plant raw material by several extraction methods (Dick and Starmans, 1996).

Traditional methods of Essential oil extraction:

   There are several by the numbers methods of extraction behavior of essential oils. The timid technologies about essential oils processing are of abundant significance and are still overused in copious parts of the globe. Distillation, Enfleuarge, Maceration, Solvent extraction and Expression are the roughly traditional and generally used methods.

1. Distillation:

   It can be defined as separation of components of a mixture of two or more liquids by virtue of difference in their vapor pressure. The bulk of essential oils are produced by distillation. There are three types of distillation:

   i) Hydrodistillation: It is one of the oldest, simplest and still being widely practiced method for oil extraction (Meyer-Warnodet et al., 1984). In this method, the material to be distilled comes in direct contact with boiling water. It may float on the water or be completely immersed depending on its specific gravity. The method is advantageous for certain materials especially when they are in finely powdered form. But it is not good for material containing saponifiable or high boiling point constituents.
ii) **Hydro-steam distillation:** This is an improved method in which the plant material is suspended on a perforated grid at some distance above the bottom of the still and the lower part of the still is filled with water to a level below the grid. When heated, the wet steam of rises through the material at low pressure (Fahlbuschet et al., 2003). This method gives better results of oil with the materials like seeds, roots and etc.

iii) **Steam distillation:** In this method of distillation, no water is kept in the bottom of stills, but saturated or superheated steam is introduced through open or perforated coils below the charge or above the grid. This method is commonly employed in the extraction of essential oils from herb and leaf materials. It is a most efficient method and gives higher yields. However, it is not generally practiced to delicate flowers (Rai R. and Suresh B., 2004).

![Diagram of distillation process]

2. **Enfleurage (Extraction from cold fat):**

   This method of extraction of essential oil is used when the distillation process may have deleterious effects on an essential oil through hydrolysis, polymerization and resinification. And also where the delicate oils become lost in large volumes of water and where the flowers continue to produce fragrance after the harvest. Here, fat can readily absorb fragrant from flowers and when such principle is used on large scale constitutes enfleurage. When the flowers come in direct contact with the fat loses their fragrance. In 24 hours’ time, when the flowers have emitted most of their oil and start to wither, they are removed and fresh flowers are again place in the fat. This process will continue for days till the fat is saturated with the flower oil and processes the typical fragrance (Arnouldet et al., 1981). The perfumed fat is then removed and this final product is called as pomade. The pomade is then subjected to alchololic extract (with high quality alcohols) in order to get rid of the fat and finally the material (oil, alcohol and small quantity of fat) is distilled in vacuum at low temperature to obtain a concentrated flower oil free from alcohol called as the ‘absolute of enfleurage’.
3. **Maceration (Extraction from hot fat):**

When the physiological activity of flowers is stopped after harvest and do not continue developing fragrance. Since no further oil develops in the flowers, the long and complicated method of enfleurage would become costly and ineffective. Hence maceration or hot fat extraction is practiced whereby a medium actually penetrates the plant tissue and dissolves all the flower oil present in the oil glands (Singh 2008). Here, a batch of hot fat is systematically treated with several batches of flowers until it becomes saturated with the flower perfume. The fragrant fat thus obtained depending upon the flowers used is called ‘orange pomade’ or ‘pomade rose’ and etc. It may be treated further to sold by washing it with strong alcohol.
4. Extraction from volatile solvents:

The principle of extraction is same with maceration is just simple and quite old one. This method was once developed and has been quickly adopted for processing all types of perfumes from the flowers that do not continue to produce fragrance once they are harvested. The fresh flowers would be charged into specially built extractors and treated with purified solvent like petroleum ether by adjusting to its room temperature. The solvent penetrates the flower and dissolves the natural flower perfume together with some waxes and other albuminous and coloring matters (Chrissie et al., 1996). This solution is subsequently pumped into an evaporator and concentrated at a low temperature. After the solvent is completely driven off in vacuum, the flower oil is obtained. Since there would be no supply of heat at any stage in the procedure, the oil is saved from harmful effects of higher temperatures and therefore it produces the most appropriate perfume as present in the flowers (Dawidowicz et al., 2008).

The solvent should have some of the particular qualities:

i) It should be completely and quickly dissolve all the odoriferous principles of the flowers.

ii) It should have low boiling point for its easy removal and yet not too low, as this would evaporate it at room temperature.

iii) The solvent must not dissolve water.

iv) It must be chemically inert.

v) It should be cheap and non-flammable.
5. Expression:

This method of extraction will be usually practiced in certain special cases. In general, it involves squeezing of any plant material at high pressures in order to press out the oils are other liquids. This process would be carried out with the hand operated pressers or crushers in particular perfumery industries. The oil is then separated from the liquids by centrifuging (Handa et al., 2008).

Non-Traditional methods of Essential oil extraction:

Traditional methods of extraction of essential oils have been discussed and these are the methods most widely used on a commercial scale. However, with technological advancement, new techniques have been developed which may not necessarily be widely used for commercial production of essential oils but are considered valuable in certain situations, such as the production of costly essential oils in a natural state without any alteration of their thermosensitive components or the extraction of essential oils for micro-analysis. The quality of extracted Essential oils is therefore extremely damaged particularly if the extraction time is long. Therefore, Novel methods and techniques, for example, abide by green extraction concept and principles have constantly emerged in recent years for obtaining natural extracts with a similar or better quality to that of official methods. New extraction techniques must also reduce extraction times, energy consumption, solvent use and CO\textsubscript{2} emissions.

1. Supercritical Fluid Extraction (SFE):

It is the most recent method of extraction of oil process when the fragrance and flavor ingredients resembles to their natural source. Supercritical carbon dioxide is used as the solvent in this method. The raw materials are kept in the enclosed cylindrical containers. Temperature and pressure are opted above its critical temperature at 31\textdegree C and pressure 73.8 bar according to the material and desired end product (Rozzi et al., 2002). Super-critical CO\textsubscript{2} circulates through the material and dissolves the active ingredient (Pourmortazavi et al., 2007). The solvent solute mixture is circulated into a separator and the pressure is maintained below the super-critical point and the CO\textsubscript{2} becomes gaseous and the solutes precipitate and collected. The gaseous CO\textsubscript{2} is taken into a heat exchange where it cooled and liquified which can be used in the extraction unit again (Capuzzo et al., 2013).
2. **Solvent-free microwave extraction (SFME):**

Solvent-free microwave extraction (SFME) is in the extraction procedure of essential oil which is cloaca by the in site water of the plant material without added any solvent (Lucchesi *et al.*, 2007). Developed this method by Cheat and co-workers (Lucchesi *et al.*, 2004a,b). Based on the integration of dry distillation and microwave heating energy. It consists on the microwave dry-distillation at atmospheric pressure of plant without adding water or any organic solvent (Filly *et al.*, 2014). In a model SFME procedure, the plant material was moistened before to extraction by soaking in a certain amount of water for 1 to 2 h and then draining off the excess water. After that, the moistened materials were subjected to the microwave oven cavity and a condenser was used to collect the extracted essential oils in a pre-setting procedure. The irradiation power, temperature and extraction time were controlled by the panel in the instrument. The separated essential oil was dried over anhydrous sodium sulphate and stored at 4°C in the dark.
3. Ultrasound-assisted extraction (UAE):

Ultrasound-assisted extraction (UAE) is a good process to achieve high valuable compounds and could involved to the increase in the estimate of some food by-products when used as sources of natural compounds or plant material (Bhaskaracharya et al., 2009). The major importance will be a more effective extraction, so saving energy, and also the use of mean temperatures, which is beneficial for heat-sensitive combinations. This technique was developed in 1950 at laboratory apparatus (Vinatoruet al., 2001). Ultrasound allows selective and intensification of essential oils extraction by release from plant material when used in combination with other techniques for example solvent extraction and hydrodistillation. Ultrasound technology has been featured as a valuable method in food engineering processes and plants (Bhaskaracharya et al., 2009), and become this field from the techniques active. In these applications the power ultrasound increases the surface wetness evaporation average and causes oscillating velocities at the interfaces, which may affect the diffusion boundary layer and generate rapid series of alternative expansions of the material, affecting cluster transfer (Garcia-Perez et al., 2006).

The plants raw material is immersed in water or another solvent (Methanol or ethanol or anyone from the solvents) and at the same time, it is subjected to the work of ultrasound (Karim et al., 2012). This technique has been used for the extraction of many essential oils especially from the flower, leaves or seeds (Sereshiti et al., 2012).
4. Microwave hydro diffusion and gravity (MHG):

Is a new green technique for the extraction of essential oils. This green extraction technique is an original microwave blend microwave heating and earth attraction at atmospheric pressure. MHG was conceived for experimenter and processing scale applications for the extraction of essential oils from different kind of material plants (Abertet al., 2008).

Microwave hydro diffusion and gravity (MHG) become clear not only as economic and efficient but also as environment-friendly, not require solvent or water and as it does require less energy (Chematet al., 2004). The performances and advantages of this technique are a reduction of extraction time (in the case of hydro- distillation it takes 90min or more but in this technique only 20 min) and reducing environmental impact and power saving (Vianet al., 2008).
5. Microwave-Assisted Hydrodistillation (MAHD):

Microwave-assisted hydrodistillation is an advanced hydrodistillation technique utilizing a microwave oven in the extraction process. (Golmakani et al., 2008) reported some recently published studies have successfully utilized a microwave oven for the extraction of active components from plants. The efficiency of Microwave-assisted hydrodistillation is strongly dependent on the dielectric constant of water and the sample (Brachet et al., 2002).

Conventional techniques for the extraction of active constituents are time and solvent consuming, thermally unsafe and the analysis of numerous constituents in plant material is limited by the extraction step (Mandal et al., 2007). High and fast extraction performance ability with less solvent consumption and protection offered to thermolabile constituents are some of the attractive features of this new promising microwave-assisted hydrodistillation technique. Application of Microwave-assisted hydrodistillation in separation and extraction processes has shown to reduce both extraction time and volume of solvent required, minimizing environmental impact by emitting less CO2 in atmosphere (Lucchesi et al., 2004; Ferhat et al., 2006) and consuming only a fraction of the energy used in conventional extraction methods (Farhat et al., 2009). The use of Microwave-assisted hydrodistillation in industrial materials processing can provide a versatile tool to process many types of materials under a wide range of conditions. Microwave-assisted hydrodistillation is a current technology to extract biological materials and has been regarded as an important alternative in extraction techniques because of its advantages which mainly are a reduction of extraction time, solvents, selectivity, volumetric heating and controllable heating process. The principle of heating using Microwave-assisted hydrodistillationis
Storage and packing of essential oils:

The distilled oil should be left to stand for a few hours. Anhydrous sodium sulphate (Approximately 3%) may be added to remove moisture. It has to be ensured that oil should not contain any moisture before packing. Then the oil would be stored in the completely closed containers made up of stainless steel or aluminium drums kept in dark and cool cellars. Essential oil thus stored should not be exposed to air and sunlight otherwise there will be a deterioration in the quality of oil where aromatic essences become less intense, grow darker and more viscous, by developing a bleaching effect and subsequently changes into brown odorless resin.

Conclusion:

Essential oils are natural products which consist of many volatile molecules. They have been used for several applications in pharmaceutical, cosmetic, agricultural and bioactivity example flowers. Extraction of essential oils could be carried out by various techniques. Have Innovative methods avoid shortcomings of content optional techniques to reduced chemical risk, extraction time and high energy input and obtain yield quality of essential oils. Despite their numerous application, except if essential oils are very sensitive to environmental factors used as such.
REFERENCES:
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INTRODUCTION

The diverse soil types and climatic conditions in our country encourage the growth of a broad spectrum of grassy (monocot) and broad leaf (dicot) weeds. All weeds harm the crops and environment in more than one way. Generally, there are two types of weeds, one that emerge before or after the crop emerges and are less competitive and can be controlled easily and the other that emerge simultaneously with the crop and are more difficult to control. Weeds have peculiar characteristics that help them compete successfully with the crops. They have short life cycles compared to crops in which they occur and complete 3-4 life cycles before the crops come to flowering. They have an inherent capacity to produce innumerable number of seeds armed with good dispersal mechanisms, e.g., *Parthenium hysterophorus* L., *Achyranthes aspera* L. and *Bidens pilosa* L. Some weeds of perennial nature are blessed with vegetative propagation characteristics like underground nuts (*Cyperus* spp.), stolons (*Cynodon dactylon* Pers.).

• Weed: weed is a plant growing out of place and time. They are unwanted not useful, persistent and prolific, effectively competing with the beneficial and desirable crop plants for space, nutrients, sunlight and water, interfere with agricultural operations and thereby reducing the yield and quality of produce.

• Weed is defined as the unwanted, undesirable plant, growing out of their proper place, which interfere with the utilization of natural resources, prolific, persistent, competitive, harmful and even poisonous in nature and can grow in adverse climatic conditions.

• Weediness: Weediness is defined as the state or condition of a field, flower bed, lawn and so forth in which there is an abundance of weeds.

Characteristics of weeds:

1) Weeds have rapid seedling growth and ability to reproduce when young e.g. Redroot Pigweed can flower and reproduce when it is less than eight inches tall.

2) Weeds have quick maturation period or take only a short time in the vegetative phase e.g. Canada thistle can produce mature seeds in two weeks after flowering and Russian thistle seeds can germinate very quickly between 280 -110 °F in late spring.
a. Weeds have environmental plasticity. Many weeds are capable of tolerating and growing under a wide range of climatic and edaphic conditions.

b. If a weed is cross pollinated, this is accomplished by non-specified flower visitors or by wind.

c. Weeds resist detrimental environmental factors. Most crop seed rot, if they do not germinate shortly after planting whereas, and weed seeds resist decay for long periods in soil and remain dormant for longer duration.

d. Weed seeds exhibit several kinds of dormancy and escape the rigors of environment and germinate when conditions are more favorable for their survival. Many weeds have no special environment requirements for germination.

e. Each weed plant is capable of producing large number of seeds per plant and seed is produced over a wide range of environmental conditions.

f. Roots of some weeds are able to penetrate and emerge from deep in the soil, while most roots are in the upper foot of the soil Canada thistle roots routinely penetrate 3-6 feet and field bindweed roots up to 10 feet deep. Roots and rhizomes are capable of growing many feet per year.

3) Roots and other vegetative parts of perennial weeds are vigorous with large food reserves, enabling them to withstand environmental stress.

4) Perennials have bitterness in the lower stem nodes or in rhizomes and roots and, if severed vegetative organs will quickly regenerate in to whole plant.

5) Weeds have great competitive ability for nutrients, light and water and can compete by special means (e.g. Rosette formation, climbing growth and allelopathy)

**CLASSIFICATION OF WEEDS:** Out of 2,50,000 plant species, weeds constitute about 250 species, which are prominent in agricultural and non-agricultural system. Under world conditions about 30000 species are grouped as weeds which are classified as follows:

**I. Based on life span:** Based on life span (Ontogeny), weeds are classified as Annual weeds, Biennial weeds and Perennial weeds.

A. Annual Weeds: Weeds that live only for a season or a year and complete their life cycle in that season or year are called as annual weeds. These are small herbs with shallow roots and weak stems. Produces seeds in profusion and the mode of propagation is commonly through seeds. After seeding, the annuals die away and the seeds germinate and start the next generation in the next season or year following.

Most common field weeds are annuals. The examples are:

a. Monsoon annuals: *Commelina benghalensis, Boerhavia erecta*

b. Winter annuals: *Chenopodium album*

B. Biennials Weeds: They complete the vegetative growth in the first season, flower and set seeds in the succeeding season and then die. These are found mainly in non-cropped areas.
e.g. *Alternanthera echinata*, *Daucus carota*

**C. Perennials Weeds:** Perennials live for more than two years and may live almost indefinitely. They adapt to withstand adverse environmental conditions. They propagate not only through seeds but also by underground stems, roots, rhizomes, tubers etc. and hence they are further classified into

i. **Simple perennials:** Plants propagated only by seeds e.g. *Sonchus arvensis*

ii. **Bulbous perennials:** Plants which possess a modified stem with scales and reproduce mainly from bulbs and seeds e.g. *Allium sp.*

iii. **Corm perennials:** Plants that possess a modified shoot and fleshy stem and reproduce through corm and seeds e.g. Timothy (Phleum pratense)

iv. **Creeping perennials:** They reproduce through seeds as well as with one of the followings:

a. **Rhizome:** Plants having underground stem – *Sorghum halepense*

b. **Stolon:** Plants having horizontal creeping stem above the ground – *Cynodon dactylon*

c. **Roots:** Plants having enlarged root system with numerous buds – *Convolvulus arvensis*

d. **Tubers:** Plants having modified rhizomes adapted for storage of food – *Cyperus rotundus*

**II. Based on ecological affinities:**

a. **Wetland weeds:** They are tender annuals with semi-aquatic habit. They can thrive well under waterlogged and in partially dry conditions. Propagation is chiefly by seed

   e.g. *Amm annia baccifera*, *Eclipta alba*

b. **Garden land weeds (Irrigated lands):** These weeds neither require large quantities of water like wetland weeds nor can they successfully withstand extreme drought as dryland weeds

   e.g. *Trian thema portulacastrum*, *Digera arvensis*

c. **Dry lands weeds:** These are usually hardy plants with deep root system. They are adapted to withstand drought on account of mucilaginous nature of the stem and hairiness.

   e.g. *Tribulus terrestris*, *Argemone Mexicana*

**III. Based on soil type (Edaphic)**

(a) **Weeds of black cotton soil:** These are often closely allied to those that grow in dry condition e.g. *Aristolochia bracteata*

(b) **Weeds of red soils:** They are like the weeds of garden lands consisting of various classes of plants e.g. *Commelina benghalensis*

(c) **Weeds of light, sandy or loamy soils:** Weeds those occur in soils having good drainage.
e.g. Leucas aspera

(d) Weeds of laterite soils: e.g. Lantana camara, Spergula arvensis

IV. Based on place of occurrence

(a) Weeds of crop lands: The majority of weeds infests the cultivated lands and cause hindrance to the farmers for successful crop production. e.g. Phalaris minor in wheat

(b) Weeds of pasture lands: Weeds found in pasture / grazing grounds.

- e.g. Indigofera enneaphylla

(c) Weeds of waste lands: Corners of fields, margins of channels etc., where weeds grow in profusion e.g. Gynandropsis pentaphylla, Calotropis gigantean etc.

(d) Weeds of playgrounds, road-sides: They are usually hardy, prostrate perennials, capable of withstanding any amount of trampling. e.g. Alternanthera echinata, Tribulus terestris

V. Based on Origin

(a) Indigenous weeds: All the native weeds of the country come under this group and most of the weeds are indigenous. e.g. Acalypha indica, Abutilon indicum

(b) Introduced or Exotic weeds: These are the weeds introduced from other countries. These weeds are normally troublesome and control becomes difficult.

- e.g. Parthenium hysterophorus, Phalaris minor, Acanthospermum hispidum

VI. Based on cotyledon number

Based on number of cotyledons they can be classified as dicots and monocots.

(a) Monocots e.g. Panicum flavidum, Echinochloa colona

(b) Dicots e.g. Crotalaria verucosa, Indigofera viscosa

VII. Based on soil pH: Based on pH of the soil the weeds can be classified into three categories.

(a) Acidophile – Acid soil weeds e.g. Rumex acetosella

(b) Basophile – Saline & alkaline soil weeds e.g. Taraxacum sp.

(c) Neutrophile – Weeds of neutral soils e.g. Acalypha indica

VIII. Based on morphology: Based on the morphology of the plant, the weeds are also classified in to three categories. This is the most widely used classification by the weed scientists.

(a) Grasses: All the weeds which come under the family Poaceae are called as grasses which are characteristically having long narrow spiny leaves. The examples are Echinocloa colonum, Cynodon dactylon.

(b) Sedges: The weeds belonging to the family Cyperaceae come under this group. The leaves are mostly from the base having modified stem with or without tubers. The examples are Cyperus rotundus, Fimbrystylis miliaceae.
(c) **Broad leaved weeds:** This is the major group of weeds. All dicotyledon weeds are broad leaved weeds. The examples are *Flavaria australacica, Digera arvensis, Tridax procumbens.*

**IX. Based on nature of stem:** Based on development of bark tissues on their stems and branches, weeds are classified as woody, semi-woody and herbaceous species.

(a) **Woody weeds:** Weeds include shrubs and under shrubs and are collectively called brush weeds e.g. *Lantana camera, Prosopis juliflora.*

(b) **Semi-woody weeds:** e.g. *Croton sparsiflorus.*

(c) **Herbaceous weeds:** Weeds have green, succulent stems and are of most common occurrence around us e.g. *Amaranthus viridis.*

**X. Based on specificity:** Besides the various classes of weeds, a few others deserve special attention due to their specificity.

a. **Poisonous weeds:** The poisonous weeds cause ailment to livestock resulting in death and cause great loss. These weeds are harvested along with fodder or grass and fed to cattle or while grazing the cattle consume these poisonous plants e.g. *Datura fastuosa, D. stramonium* and *D. metel* are poisonous to animals and human beings.

b. **Parasitic weeds:** The parasite weeds are either total or partial which means, the weeds that depend completely on the host plant are termed as total parasites while the weeds that partially depend on host plant for minerals and capable of preparing its food from the green leaves are called as partial parasites. Those parasites which attack roots are termed as root parasites and those which attack shoot of other plants are called as stem parasites. The typical examples are;

- **Total root parasite** – *Orabanche cernua* on Tobacco
- **Partial root parasite** - *Striga lutea* on sugarcane and sorghum
- **Total stem parasite** - *Cuscuta chinensis* on lucerne and onion
- **Partial stem parasite** - *Loranthus longiflorus* on mango.

c. **Aquatic weeds:** Unwanted plants, which grow in water and complete at least a part of their life cycle in water are called as aquatic weeds. They are further grouped into four categories as submersed, emersed, marginal and floating weeds.

- **Submersed weeds:** These weeds are mostly vascular plants that produce all or most of their vegetative growth beneath the water surface, having true roots, stems and leave e.g. *Utricularia stellaris, Ceratophyllum demersum.*

- **Immersed weeds:** These plants are rooted in the bottom mud, with aerial stems and leaves at or above the water surface. The leaves are broad in many plants and sometimes like grasses. These leaves do not rise and fall with water level as in the case of floating weeds e.g. *Nelumbium speciosum, Jussieua repens.*

- **Marginal weeds:** Most of these plants are immersed weeds that can grow in moist shoreline areas with a depth of 60 to 90 cm water. These weeds vary in size, shape and habitat. The important genera that comes under this group are; *Typha, Polygonum, Cephalanthus, Scirpus, etc.*
• **Floating weeds**: These weeds have leaves that float on the water surface either singly or in cluster. Some weeds are free floating and some rooted at the mud bottom and the leaves rise and fall as the water level increases or decreases. e.g. *Eichhornia crassipes*, *Pistia stratiotes*, *Salvinia sp.*, *Nymphaea pubescens*.

**EFFECTS OF WEEDS:**

1) **Harmful effects of weeds**: Weeds have serious impacts on agricultural production. It is estimated that in general weeds cause 5% loss in agricultural production in most of the developed countries, 10% loss in less developed countries and 25% loss in least developed countries. In India, yield losses due to weeds are more than those from pest and diseases. Yield losses due to weeds vary with the crops. Every crop is exposed to severe competition from weeds. Most of these weeds are self-sown and they provide competition caused by their faster rate of growth in the initial stages of crop growth. In some crops, the yields are reduced by more than 50% due to weed infestation.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Reduction in yields due to weeds (%)</th>
<th>Reduction in yield due to weeds (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>41.6</td>
<td>Groundnut</td>
</tr>
<tr>
<td>Wheat</td>
<td>16.0</td>
<td>Sugarcane</td>
</tr>
<tr>
<td>Maize</td>
<td>39.8</td>
<td>Sugar beet</td>
</tr>
<tr>
<td>Millets</td>
<td>29.5</td>
<td>Carrot</td>
</tr>
<tr>
<td>Soybean</td>
<td>30.5</td>
<td>Cotton</td>
</tr>
<tr>
<td>Gram</td>
<td>11.6</td>
<td>Onion</td>
</tr>
<tr>
<td>Pea</td>
<td>32.9</td>
<td>Potato</td>
</tr>
<tr>
<td>Okra</td>
<td>45.5</td>
<td>Tomato</td>
</tr>
<tr>
<td>Cabbage</td>
<td>55.2</td>
<td>Cauliflower</td>
</tr>
</tbody>
</table>

The yield loss due to unchecked weeds varies from 34.0 to 71.7 per cent in fruit crops, 10-95 per cent in vegetables, and 25-80 per cent in tuber crops

• Weeds compete with crops for water soil, nutrients, light, and space, and thus reduce the crop yields. An estimate shows that weeds can deprive the crops 47% N, 42% P, 50% K, 39% Ca and 24% Mg of their nutrient uptake. Weeds also act as alternate hosts that harbor insects, pests, diseases and other microorganisms.

**Table: Alternate hosts of some of the pest and diseases are as given below**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Pest</th>
<th>Alternate host</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet potato</td>
<td>Sweet potato weevil</td>
<td><em>Convolvulus arvensis</em></td>
</tr>
<tr>
<td>Potato</td>
<td>Stalk borer, beetles and cutworms</td>
<td><em>Chenopodium album</em></td>
</tr>
</tbody>
</table>

Some weeds release inhibitors of poisonous substances into the soil that may be harmful to the crop plants, human beings and livestock.
**Table: Health problems caused by weeds to humans**

<table>
<thead>
<tr>
<th>Health problem</th>
<th>Weed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hay fever and Asthma</td>
<td>Pollen of <em>Ambrosia</em> and <em>Franseria</em> sp</td>
</tr>
<tr>
<td>Dermatitis</td>
<td><em>Parthenium, Ambrosia</em></td>
</tr>
<tr>
<td>Itching and Inflammation</td>
<td><em>Utrica</em> sp</td>
</tr>
<tr>
<td>African sleeping sickness</td>
<td>Brush weeds</td>
</tr>
<tr>
<td>Malaria, encephalitis and filaria caused by mosquito</td>
<td>Aquatic weeds like <em>Pistia lanceolata</em>, <em>Salvinia auriculata</em></td>
</tr>
</tbody>
</table>

- Weeds reduce the quality of marketable agricultural produce. Contamination of weed seeds of *Datura sp, Argemone sp, Brassica sp* etc., is harmful to human health and weed seeds present in the produce cause odd odour sometimes.

- Weeds not only reduce yield but also interfere with agricultural operations. Weeds make mechanical sowing a difficult process and render harvesting difficult, leading to increased expenditure on labour, equipment and chemicals for their removal.

- Weeds are also a nuisance and a fire hazard along railway lines, roads, right-of-ways, airports, forests and industrial sites.

### 2. Beneficial effects of weeds

In spite of all the difficulties caused by weeds, they can offer some beneficial properties, particularly when occurring at low densities. These aspects should be utilized in the farming system, although this may make organic management more complicated than chemical based systems. Some of the potential benefits of weeds are listed below:

- Helping to conserve soil moisture and prevent erosion. A ground cover of weeds will reduce the amount of bare soil exposed helping to conserve nutrients, particularly nitrogen which could otherwise be leached away, especially on light soils.

- Food and shelter can be provided for natural enemies of pests and even alternative food sources for crop pests. The actual presence of weed cover may be a factor in increasing effectiveness of biological control of pests and reducing pest damage.

- Weeds can also be valuable indicators of growing conditions in a field, for example of water levels, compaction and PH.

- Weeds can be an important source of food for wildlife, especially birds. Bird populations have been declining on farmland over the last few decades and leaving weeds as a resource has been shown to help revive bird populations.

**Weed management:** weed management in horticultural and plantation crops constitutes a major input in their production. Losses due to weeds are highest in least developed crop production systems and lowest in most highly developed ones. The following are some weed control methods followed in orchards.
I. Cultural Method of Weed Control: Any weed management program on farmland essentially begins with adoption of good crop husbandry practices leading to a sturdy crop which could overpower the weeds and make their subsequent control easy and more economical. Some important good crop husbandry practices which can bring about effective suppression of weeds in farming systems are as follows.

1. Proper crop stand: Gapy and under population crops are prone to heavy weed infestations which become difficult to control later. Therefore, practices like selection of proper seed, right method of sowing, adequate seed rate, protection of seed from soil borne pests and diseases, etc., are very important to obtain proper and uniform crop stand capable of offering initial competition to the young weeds.

2. Crop rotation: Many of our weed problems exist with us because of practicing monocultures i.e. growing of same crop year after in the same field. Parasitic weeds, as well as the crop associated weeds, can be discouraged by adopting well conceived crop rotations.

3. Summer tillage: There is a clear cut solar energy-rich, dry period of summer available, which should be utilized for desiccation of rhizomes, tubers and roots of the perennial weeds to death.

4. Solarisation: In this method the soil temperature is further raised by 5-10°C by covering a pre-soaked fallow field with thin, transparent plastic sheet. The plastic sheet checks the long wave back radiation from the soil and also prevents loss of energy by hindering moisture evaporation.

5. Mulching: Black plastic mulches of about 1000 gauge thickness have proved very useful in suppressing weeds and conserving soil moisture at the same time. The use of plastics in agriculture for different purposes, including for mulching, has been named plasticulture.

II. Mechanical Weed Control: In the method of mechanical weed control, various tools and implements are used. They are as follows:

1. Hand hoe: Hand hoeing is the most common mechanical method of weed control in India. The shape and size of the hoe varies from place to place. Hoeing loosens the soil surface and produces mulch.

2. Spade: Spade is shaped like a hand hoe but bigger in size. Digging can be done in between the crop inter row space with spade. Wherever wider row space is available, spade is used instead of hand hoe. Depending on the regions, the shape and size of the blade varies.

3. Country plough: It is used for opening the soil, removal of weeds, preparing seed bed and also covers the manure spread on the land.

7. Blade harrow: It is a bullock drawn row cultivation implement. Its cutting tool is a sharp blade, which works almost like sweep of a cultivator. It cuts the weed below the ground and leaves them on soil surface as mulch without causing inversion of the soil. It is the common row weeding implement on heavy black soils in India. This is locally called as ‘Guntaka’.
III. Chemical Weed Control: A herbicide is a chemical used to kill some target plants.

Following different chemical herbicide are used to control the weed in horticulture crops are as fallows

<table>
<thead>
<tr>
<th>Crop</th>
<th>Recommended herbicide</th>
<th>Dose (kg/ha)</th>
<th>No. of sprays</th>
<th>Time of spray</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango</td>
<td>Diuron or</td>
<td>2.25</td>
<td>1</td>
<td>Just after sowing seeds</td>
</tr>
<tr>
<td></td>
<td>Atrazine or</td>
<td>4.00</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oxyfluorfen</td>
<td>4.00</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Paraquat</td>
<td>12.00</td>
<td>2</td>
<td>5-6 months after pre-emergent spray and tri-monthly.</td>
</tr>
<tr>
<td>Banana</td>
<td>Diuron or</td>
<td>2.25</td>
<td>1</td>
<td>Just after planting suckers</td>
</tr>
<tr>
<td></td>
<td>Simazine or</td>
<td>4.00</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oxyfluorfen</td>
<td>4.00</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Paraquat or</td>
<td>12.00</td>
<td>2</td>
<td>6 months after pre-emergent spray</td>
</tr>
<tr>
<td></td>
<td>Glyphosate</td>
<td>6.00</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Pineapple</td>
<td>Bromacil +</td>
<td>2.25</td>
<td>1</td>
<td>10-15 days after planting</td>
</tr>
<tr>
<td></td>
<td>Diuron</td>
<td>2.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grape</td>
<td>Oxyfluorfen or</td>
<td>4.00</td>
<td>1</td>
<td>Just after planting</td>
</tr>
<tr>
<td></td>
<td>Atrazine or</td>
<td>4.00</td>
<td>1</td>
<td>Just after pruning during</td>
</tr>
<tr>
<td></td>
<td>Diuron</td>
<td>2.25</td>
<td>1</td>
<td>April</td>
</tr>
<tr>
<td></td>
<td>Paraquat or</td>
<td>12.00</td>
<td>2</td>
<td>As and when weeds</td>
</tr>
<tr>
<td></td>
<td>Glyphosate</td>
<td>6.00</td>
<td>1</td>
<td>emerge and become 15-25cm</td>
</tr>
<tr>
<td>Papaya</td>
<td>Fluchloralin or</td>
<td>4.00</td>
<td>1</td>
<td>One week after transplanting</td>
</tr>
<tr>
<td>Citrus</td>
<td>Diuron</td>
<td>5.00</td>
<td>1</td>
<td>After sowing seeds and transplanting</td>
</tr>
<tr>
<td>Guava</td>
<td>2, 4-D</td>
<td>2.00</td>
<td>1</td>
<td>Established orchards</td>
</tr>
<tr>
<td></td>
<td>Paraquat</td>
<td>3.00</td>
<td>2</td>
<td>Twice yearly during rainy and winter season</td>
</tr>
<tr>
<td>Cabbage</td>
<td>Oxyfluorfen or</td>
<td>1.00</td>
<td>1</td>
<td>Just after transplanting</td>
</tr>
</tbody>
</table>
### Advances in Horticultural Crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Herbicide</th>
<th>Rate</th>
<th>Application</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cauliflower</td>
<td>Fluchloralin</td>
<td>2.00</td>
<td>1</td>
<td>24 hr after transplanting</td>
</tr>
<tr>
<td></td>
<td>Oxyfluorfen or</td>
<td>1.25</td>
<td>1</td>
<td>24 hr after transplanting</td>
</tr>
<tr>
<td></td>
<td>Pendimethalin</td>
<td>2.00</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Radish</td>
<td>Butachlor</td>
<td>3.00</td>
<td>1</td>
<td>24 hr after sowing</td>
</tr>
<tr>
<td></td>
<td>Alachlor</td>
<td>4.00</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Okra</td>
<td>Fluchloralin</td>
<td>3.00</td>
<td>1</td>
<td>After sowing</td>
</tr>
<tr>
<td>Tomato</td>
<td>Alachlor</td>
<td>3.00</td>
<td>1</td>
<td>One day after transplanting</td>
</tr>
<tr>
<td></td>
<td>Fluchloralin</td>
<td>3.00</td>
<td>1</td>
<td>One day after transplanting</td>
</tr>
<tr>
<td>Brinjal</td>
<td>Fluchloralin</td>
<td>1.50</td>
<td>1</td>
<td>One day after transplanting</td>
</tr>
<tr>
<td>Chilli</td>
<td>Alachlor or</td>
<td>2.00</td>
<td>1</td>
<td>24 hr after transplanting</td>
</tr>
<tr>
<td></td>
<td>Butachlor or</td>
<td>2.00</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fluchloralin</td>
<td>2.00</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Onion</td>
<td>Fluchloralin</td>
<td>2.00</td>
<td>1</td>
<td>After transplanting</td>
</tr>
<tr>
<td>Cucumber, bottlegourd, ridgegourd, ashgourd, bittergourd, pumpkin and squash</td>
<td>Alachlor or</td>
<td>3.00</td>
<td>1</td>
<td>24 hr after seed sowing</td>
</tr>
<tr>
<td></td>
<td>Butachlor or</td>
<td>3.00</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fluchloralin</td>
<td>3.00</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Potato</td>
<td>Metribuzin</td>
<td>1.00</td>
<td>1</td>
<td>24 hr after planting</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>Napropamide</td>
<td>2.00</td>
<td>1</td>
<td>24 hr after transplanting</td>
</tr>
</tbody>
</table>

**References:**

CONVENTIONAL APPROACHES FOR CROP IMPROVEMENT IN CITRUS

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ABSTRACT

Citrus is a third important fruit crop in India; the long history of Citriculture and richness of germplasm has benefited genetics and breeding research. Tools used for the genetic improvement of Citrus were categorised as conventional (introduction, selection, hybridisation and mutation). Despite, fact that citrus breeding is very challenging, different breeding programs throughout the world have made significant progress in the application of conventional and modern approaches to genetic improvement and cultivar development. Important breeding goals exist in citrus with respect to both scions and rootstocks (Cameron and Frost, 1968).

The Selections of seedless and early- or late-ripening varieties are two important breeding goals at present. Conventional methods for disease resistance improvement of Citrus were bottleneck due to inadequate and lengthy breeding procedures. However, non-conventional methods, such as mutation breeding and protoplast fusion, have been routinely utilised for the production of disease resistant germplasm (Raufet al. 2013). The presence of a large number of seeds in citrus fruits is a big hindrance in consumer acceptability even if fruit posses high organolaptic properties. Seedy cultivars are accepted only if seedless cultivars are not present or they are much superior in fruit characteristics than seedless cultivars (Hasnainrazaet al. 2003). Recovery of triploid hybrids has become an important breeding strategy to develop new seedless citrus varieties and several of them have been already released from citrus breeding programs worldwide. Despite the undisputable importance of polyploidy in plant species, their genetics are much less well known than those of their diploid counterparts.

INTRODUCTION

Citriculture is the third largest component of the fruit industry next to mango and banana in respect to cultivated area and production in India. Citrus is a commercially important fruit crop of India and grown across its length and breadth with a production of 10 million tonnes from an area of 1.04 million hectares (Anonymous, 2016). The commercially grown crops are mandarin (Citrus reticulata Blanco), sweet orange (C. sinensis (L.) Osbeck), grapefruit (C. paradisiMacf.), pummel (C. grandisOsbeck), acid lime (C. aurantifoliaChristm.) and lemon (C. limon (L.) Burm. f.) etc. The major citrus growing states in India are Uttar Pradesh, Andhra Pradesh,
Maharashtra, Punjab, Himachal Pradesh, Tamil Nadu, Rajasthan, West Bengal, Sikkim and North-Eastern states.

Indian citrus industry has been grown up in respect to area and production. But, the productivity of citrus fruit is still very low i.e. 8.8 tonnes/ha, which is very low as compare to USA (35.11 tonnes/ha), Brazil (21.66 tonnes/ha), Spain (19.8 tonnes/ha) and Italy (17.76 tonnes/ha). This lower productivity of citrus is due to use of inferior genetic stocks, inadequate supply of quality planting materials of improved varieties/rootstocks, lack of high density planting, high incidence of insect-pests (citrus psylla, aphids), diseases (citrus canker, Phytophthora, greening etc), incidence of viruses and virus like organism (tristeza, exocortis, porosis, viroids etc.) and citrus decline, poor orchard management practices (poor water management, improper fertilization) etc.

The most important commercial citrus cultivars in India are the mandarin (Citrus reticulate), followed by sweet orange (Citrus sinensis) and acid lime (Citrus aurantifolia). Most of the Citrus species are originated in India. Therefore, it is considered natural home of many Citrus species. The development of new and improved citrus cultivars by conventional methods is a slow and costly process. It may take as long as 20–35 years or longer to release a new cultivar from the time of making the cross. The first formal citrus breeding programme was started by USDA in Florida in 1893 which is still expanding. University of California established the Citrus Research Center, Riverside in 1907. In India, Central Citrus Research Station was established at Nagpur in 1985 under Indian Institute of Horticultural Research, Bangalore.

Origin and taxonomy

Citrus and its related genera originated in the tropical and subtropical regions of South-East Asia, North-Eastern India, Southern China, the Indo-Chinese peninsula and the Malay Archipelago, and then spread to other continents (Webber, 1967). According to Tanaka (1961), the citrus may have originated in north-eastern India and Burma. China should be considered only a secondary centre of distribution. Calabrese (1998) indicated that the primordial genetic nucleus of citrus originated in China and the citrus slowly passed from its original location to other oriental regions. The citron (C. medica L.) is probably native to India. It is reported that some of the indigenous and wild mandarin types are found in south India, where as Hil柠檬 (Galgal) C. pseudolimon and Attani (C. rugulosa) are prevalent in the foot Hills of Himalayas in the north-west part of the country (Singh, 2001) As early as 1950 Vavilov reported the occurrence of sweet orange (C. sinensis Osbeck), mandarin (C. reticulate Blanco), citron (C. medica L.), sour lime (C. aurantifolia Blanco), Jenerutenga (C. nobilis lour), Rangpur lime (C. limonia Osbeck) and lemon (C. limon Burnn.) all are cultivated and found wild form in the NEH region of India.

Citrus belongs to sub family Aurantioidae. Rutaceae is one of the 12 families in the Geranineae suborder and the Aurantioidae subfamily – one of the seven belonging to the Rutaceae (Engler, 1931). Aurantioidae, the Orange’ subfamily, has been subdivided by Swingle into two tribes: Clauseneae with five genera and Citreae with 28 genera including Citrus and related genera, i.e. Fortunella, Poncirus, Eremocitrus, Microcitrus and Clymenia. Two different classification systems are commonly accepted


for the citrus taxonomy: the system of Swingle (1943) and that of Tanaka (1961). Understanding taxonomy, phylogenetic relationships, and genetic variability in citrus is critical for determining genetic relationships, characterizing germplasm, controlling genetic erosion, designing sampling strategies or core collections, establishing breeding programs, and registering new cultivars.

**Objectives**

The objective of citrus breeding relate to the characters of tree, rootstock and fruit. The Tree should be compact, Productive, resistant to Disease, Insect pests and adaptable to different soil and climatic Conditions with early maturing cultivars. The main goal of scion breeding are the amount and regularity of the crop, fruit with good size, high quality, attractive appearance and color, very low seed content and easy peeling. The breeding objective differs according to region. Resistance for biotic and abiotic stresses like cold hardy, salt tolerance and resistance against *Phytophthora parasitica*, citrus nematodes *Tylenchulus semipenetrans*, Tristeza virus are of prime importance in citrus breeding.

**Major problems in citrus breeding**

- Incompatibility and cross incompatibility
- Cultivars of *Citrus grandis* are self-incompatible (Soost, 1964).
- Cultivars of *C. limon*, *C. sinensis* and *C. reticulata* exhibit cases of self-incompatibility.
- 'Washington Navel' orange and 'Satsuma' mandarin are mostly pollen sterile and if not cross-pollinated with viable pollen, they yield parthenocarpic fruits.
- Many of the commercial cultivars are practically seedless (2 to 4 seeds)

**Objective of scion breeding**

Table. 1. Tree, fruit and post harvest objective of Scion breeding

<table>
<thead>
<tr>
<th>Tree performance</th>
<th>Fruit characteristic</th>
<th>Post harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>Exterior appearance</td>
<td>Handling for fresh market</td>
</tr>
<tr>
<td>Cold hardiness</td>
<td>Size and shape</td>
<td>Economic and cultural importance</td>
</tr>
<tr>
<td>Adaptation to adverse climatic and soil conditions</td>
<td>Quality (TSS/acid ratio), juice content, flavor/ colour</td>
<td>Processing quality</td>
</tr>
<tr>
<td>Adaptation to mechanical harvest</td>
<td>Ease of peeling</td>
<td>Storage life</td>
</tr>
<tr>
<td>Disease and pest resistance</td>
<td>Seedlessness, Ripening season</td>
<td>Juice content and composition</td>
</tr>
</tbody>
</table>

The scion breeding programs are mainly aimed at improving the fruit color, size, shape, flavor, and yield, as well as low seed content, easy peeling, and disease
resistance. The main breeding aims for scion cultivars vary with species and localities. The first step in scion breeding involves selection of parental types with favorable heritable characteristics/traits. Often those seed parents are selected that produce only zygotic progeny. Hence monoembryonic parents are preferred for scion breeding. It is traditionally achieved by controlled crossing. They are not amenable to sexual hybridization as a genetic improvement strategy. Hence, selection of useful variations following induction via mutagenic treatment of seeds and axillary buds, from spontaneously occurring nucellar seed or bud mutations, or somaclonal variation (Gmitter et al. 1992), have been the only effective approaches to cultivar development in these cultivar groups. The irradiated seeds of ‘Hudson’ grapefruit gave rise to ‘Star Ruby’ grapefruit, which had deep red flesh and reduced seediness. A low–seeded, grapefruit-like hybrid (USDA 77-19) was also developed.

**Rootstock breeding**

The need for dependable new rootstocks is of primary concern as they affect all aspects of fruit quality. However, choice of rootstock is not usually based on fruit quality considerations alone; disease tolerance, soil type and effects on yield are more often overriding considerations. Reduction of tree size without affecting yield or scion health is desirable (Soost and Roose, 1996). Rapid growth and lack of branching are desirable characters for convenient and economical nursery production of rootstock seedlings (Soost and Roose, 1996).

Many commonly used rootstocks have not been products of planned breeding programs; rather they have been selected over time through grower experience. These include selections of various citrus species such as sour orange (C. aurantium), rough lemon (C. limon), Cleopatra mandarin (C. reticulata), Rangpur lime (Citrus limonia Osbeck), and numerous others. A hybrid ‘US-852’ obtained from sexual hybridization of C. reticulata and P. trifoliata was found to exhibit outstanding effects on sweet orange fruit yield, producing fruit with high soluble solids on medium-size trees (Bowman et al. 1991).

**Germplasm resources**

Exotic collection of citrus germplasm was started in 1940. Kinnow mandarin was one of the collections which are now a leading cultivar in North – Western India. Besides, other exotic collections were Valencia Late, Washington Navel, Jaffa, Malta Blood Red, Pineapple, Ruby orange, Satsuma, Dancy Tangerine, Climentine, and Cleopatra, wilking ,Temple, Duncan, Marsh seedless, Lisbon lemon, Trifoliate orange, Dancy, Lisbon lemon and Trifoliate orange. More than 650 accessions are being maintained at CHES, Chethali, Bangalore, CHES, Ranchi, RFRS, Abhor, NRC on citrus, Nagpur, Horticultural Experiment Station, Bathinda, IARI, New Delhi, MPKV, Rahuri, Citrus Improvement Project, Tirupati, Citrus Experiment station, Nagpur, HC&RI, Periyakulam, and Citrus Experiment Station, Tinsukia, Assam.

During 1988 as a result of systematic exploration by NBPGR in North-Eastern region, C. indica and many endangered species were collected for conservation. North-Eastern region is a hunting ground of biodiversity of Citrus species. Chakraware et al. (1988) identified two promising clones of acid lime Vikram and Pramalini in
Maharashtra. At Nagpur, seedless Santra has been selected which gives high yield and quality fruits. The Seedless form of Santra (Mudkhed Seedless) was selected from the variability of the local cultivar (Chakrawar and Rane 1977).

**Important species and cultivars**

1. **Mandarin Group**

<table>
<thead>
<tr>
<th>No.</th>
<th>Species</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Citrus reticulata</em></td>
<td>Loose skinned orange, though mandarin and tangerine are names used more or less interchangeably to designate the whole group, tangerine is applied more strictly to those varieties which produce deep orange or scarlet fruits.</td>
</tr>
</tbody>
</table>
| 2   | **Calamondin**  
(*C. madurensis*): | Tanaka has recognized it as loose skinned orange group. It is very cold resistant for a true citrus fruit as hardy as Satsuma. Fruit colour is orange to deep orange, smooth and glossy surface, pitted shape, oblate, deep orange, and size small with flattened base having 7-10 segments. |
| 3   | **Clementine**  
(Algerian Tangerine) | It is a tangerine and is probably an accidental hybrid of the mandarin and sour orange which is considered to be originated in Algeria. Fruit colour deep orange, shape globose to elliptical, size medium with depressed apex, rind thick, segments 8-12 adhered slightly. It is an early variety |
| 4   | **Cleopatra**  
(*C. reshni*) | It is originated in China. Plant is thornless with dense top. Fruits are produced singly or in clusters, fruit colour dark orange red, shape oblate flattened at both ends, size small and segments 12-15. |
| 5   | **Coorg mandarin** | It is an important variety of South India particularly in Coorg and Wynad tracts. Fruits are medium to large, bright orange colour, oblate to globose in shape, finely papillate and winkled, glossy, segments 9 – 11. |
| 6   | **Khasi mandarin** | Swingle believed the king mandarin as a tangor, a hybrid between mandarin and sweet orange. King mandarin was first introduced from Cochin China to California in 1882. King mandarin is cultivated in Assam. This is a prolific bearer, frost resistant and produces high quality fruit. |
| 7   | **King mandarin**  
(*C. nobilis*) | This is believed to be a hybrid between mandarin and sweet orange, and cultivated in Assam. It is a prolific bearer, frost resistant and produces high quality fruit. Willow leaf mandarin (*C. deliciosa*), the tree is willowy in growth, almost thornless, and fruits usually borne singly at the tip of slender branches. Fruit colour orange, surface smooth, glossy frequently slightly lobed, necked base, apex depressed, wrinkled, rind thin with 10-12 segments. It is an early variety |
| 8   | **Kinnow mandarin** | It is a first generation hybrid between the king and willow leaf mandarin and developed by H.B. Frost at the California Citrus Experiment station in 1915. It was introduced into Punjab from USA. |
Tree is vigorous, large, top erect, dense symmetrical with few scattered thorns. Fruit colour resembles of king, deep yellowish orange, surface, smooth, glossy, very shallow pitted, shape slightly oblate, size medium with flattened base, rind thin, peel tough and leathery, segment 9-10 easily separable, seed 12-24. It is a late variety

| 2. | **Nagpur Santra**
|---|---
| This variety occupies prime position in Indian market and is one of the finest mandarins grown in the world. It is also known as Ponkan. Tree is large, vigorous, and spineless with compact foliage. Fruit size is medium, cadmium colour, smooth surface, and glossy, rind thin, soft, and slightly adhered with 10-12 segments. |  

2. **Lemon (C. limon)**

The lemon is a small evergreen tree native to Asia. The lemon fruits are used for both culinary and non-culinary purposes throughout the world. In India lemons are grown only in a limited extent in homestead gardens, mainly found in Uttar Pradesh, Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Rajasthan, Punjab, Assam and North Eastern region. It’s primarily used for its juice and pickles, also used as a Squash, citric acid, pectin, lemon oil, lemon cakes and lemon ice; apart from these the pulp and rind are used for cooking and baking. The lemon juice is used for cleaning and medicinal uses. The lemon juice content 5 to 6 percent citric acid, which gives sour in taste.

3. **Acid lime (C. aurantifolia)**

It is native of India and widely cultivated in the tropics. Tree medium sized, hardy, semi vigorous, upright growth, thorny, fruit round to oblong, yellow apex rounded and slightly nipped, base round, rind thin, papery segments 8-10, seeds 8-10.

4. **Tahiti lime (C. latifolia)**

It is large fruited acid lime. The plants are large, spreading, cold resistant, thornless, fruit large in size, seedless triploid, and produce non-viable pollen. It is considered as hybrid between lime and lemon. Fruit colour orange yellow, smooth surface, segments 8-10. It is a late variety.

5. **Rangpur lime (C. limonica)**

It is indigenous to India and is commonly used as root stock. Rangpur lime is mainly grown for home consumption and ornamental purpose. It is also known as Marmalade orange. It has loose rind, easily separable segments and pulp is light orange yellow.

6. **Sweet lime (C. limetoides)**

Generally, sweet lime is grown as a root stock for its non acidic fruits.
### Table 2. Important species and their cultivars

<table>
<thead>
<tr>
<th>Fruit type</th>
<th>Species</th>
<th>Sub types</th>
<th>Representative varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet orange</td>
<td><em>C. sinensis</em> (hybrid, origin) Native: China</td>
<td>Common sweet orange</td>
<td>Pera, Hamlin, Pineapple, Shamouti Itabora, Westin, Katol gold</td>
</tr>
<tr>
<td>Mandarin</td>
<td><em>C. reticulate</em> (True species) Origin: China</td>
<td>Common</td>
<td>Dancy, Pixie, Fairchild, Ponkan, Kinnow, Imperial, Nagpur seedless, Nagpur mandarin, Coorg mandarin</td>
</tr>
<tr>
<td>Satsuma</td>
<td>Okitsu, Wase, Owari, Aoshima, Clausellina</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clementine</td>
<td>Fina, Oroval, Nules, Marisol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sour orange</td>
<td><em>C. aurantium</em> (hybrid, origin) Native: China</td>
<td>Seville</td>
<td></td>
</tr>
<tr>
<td>Grapefruit</td>
<td><em>C. paradisi</em> (hybrid, origin) Native: Barbados</td>
<td>White-fleshed</td>
<td>Marsh, Duncan, Oroblanco</td>
</tr>
<tr>
<td>Pummelo</td>
<td><em>C. maxima</em> (true species)</td>
<td></td>
<td>Kao Panne, Kao Phuang, Thong Dee, Banpeiyu, Chandler, Reinking</td>
</tr>
</tbody>
</table>

**Source:** www.enotes.com/citrus-fruit-reference/citrus-fruit.

**Floral biology**

They are small, spiny shrubs or trees with alternate, usually evergreen, leaves, which are shiny and leathery and dotted with oil glands. The stems are mostly winged and jointed with the leaves and there is usually a spine on the twigs at the attachment of each stem. The calyx is cup-like with five sepals. The ovule is anatropous with micropyle facing the axis of ovary. Although seasonal conditions may cause citrus to bloom at various times, the main blooming period of citrus trees in subtropical climates is in the spring (Erickson 1968). The environmental and endogenous control of flower bud differentiation is quite complex and varies considerably from one species to another (Spiegel-Roy and Goldschmidt 1996). The induction of flower buds begins with a cessation of vegetative growth during the winter rest period in subtropics or dry periods in tropical regions (Davies and Albrigo 1994). To induce a significant number of flower buds, temperature below $20^\circ$C or drought periods longer than 45–50 days are required. Induction of flowering by low temperatures or water stress was correlated with an increase in leaf ammonia content (Verreynne and Lovatt 2009).
Pollination and fertilization

Pollen is of sticky, adherent type. Honeybees are very effective for crosspollination, but wind is a minor factor in its transfer from flower to flower. Development follows the usual course for angiosperm pollen. The commercially important citrus species do not require cross-pollination generally (Davies and Albrigo, 1994). Self-pollination can easily occur because of the proximity of anthers to stigma. Some types are parthenocarpic, fruit setting and maturing commercial crops of seedless fruit without fertilization and seed set.

The germination and growth rates of the pollen grains which have landed on the stigma are enhanced at high temperatures (25–30°C). Low temperatures (<20°C) reduce or totally inhibited pollen germination. The arrangement and percentage of the planting of the pollinizer variety within the orchard are also important for successful pollination (Davies and Albrigo, 1994). The pollen tube germinates and penetrates the embryo sac in the ovule. Fertilization occurs by fusion of a sperm (pollen) nucleus with an egg nucleus. Two microgamete’s are produced by the generative nucleus of the pollen. One microgamete fuses with the egg nucleus producing the zygote, while the other fuses with the two polar nuclei initiating the endosperm. Fertilization of the egg cell occurs 2 or 3 days after pollination under favorable conditions (Spiegel-Roy and Goldschmidt, 1996).

Inheritance

Single-gene inheritance is rarely found in citrus (furr,1969). Trifoliate leaf character of citrus shows complete dominance over the monofoliate. Purple Anthocyanin coloration of young leaves in some lemon character in controlled by dominant gene. Nucellarembryony appearance is controlled by dominant genes.Crosses between monoembryonic cultivars X polyembryonicnucellar ones gives hybrid of both types in ratio 1:1(Soost and Cameron, 1975).Maheshwari and rangawamy reported that polyembryony to be a recessive character controlled by series of multiple genes. Characters like thorniness, pubasence and presence of oil glands are dominant. Reduction of necatarins and scaliness of flower buds are recessive. Resistance to CTV is controlled by Dominant allele at single locus (Ctr). Levels of acidity in citrus fruits are also inherited. Soost and Cameron (1961) obtained hybrids of relatively low acidity from crosses of a low-acid pummelo by medium-acid pollen parents of several varieties. Thorniness is controlled by more than one gene.

Genomics

Citrus species have small genomes. The size of the Citrus sinensis haploid genome is estimated to be 372 Mb (Arunuganathan and Earle, 1991).The largest and smallest genomes were respectively Citrus medica L. (the citron, with an average value of 398 Mb/haploid genome) and Citrus reticulate (the mandarin, with an average value of 360 Mb/haploid genome).Counting length of sweet orange is 320.5 Mb. 29,445 of protein-coding loci with 44,387 transcripts and 23,421 gene models were allocated in nine pseudo chromosomes. More than a half million citrus ESTs (Expressed Sequence Tags) have been obtained and deposited to public databases in recent years (Delseny et al., 2010). The frequency of female 2n gametes ranges from rates below 1 % to over 20
% probably due to the abortion of the first meiotic division or second meiotic division in the megaspore (Luro et al., 2004).

Polyembryony

The formation of multiple embryos is quite common in many citrus cultivars. They may be the result of multiple zygotic embryos, produced by the fission of one fertilized egg or from two or more functional embryo sacs in a single ovule. However, the predominant cause of multiple embryo formation is nucellarembrony, the development of vegetative embryos from the nucellus. These embryos are the outgrowths of the nucellus and develop asexually by mitotic division of the cells of the nucellus. As the male gamete does not contribute to their formation, they are the product of vegetative reproduction having a genetic constitution identical to that of the female (seed) parent.

The plants arising from nucellar seedlings are generally free of viruses. Citrus are almost universally propagated by budding onto seedling rootstocks. Uniformity of the rootstock genotypes is essential for reliable performance following budding and orchard establishment. Nucellarembrony allows fixing the genotype of a superior variety, and hence seed can be produced for many generations without loss of vigor or genotype segregation, circumventing any need to produce hybrid seeds for rootstock production (Garcia et al., 1999).

Breeding

Selection of new citrus and related cultivars has been occurring for many years by selection of superior phenotypes from the wild for cultivation. However, systematic, mission-oriented breeding programs first began in Florida in 1893 with Swingle and Webber (Davies and Albrigo, 1994). Since then, numerous programs have been developed worldwide with a variety of objectives. Due to its heterozygous nature, sexual hybridization to create new genotypes results in substantial variation of the characters in the progeny as they produce widely variant sexually derived progeny. Nucellar embryos, on the other hand, give rise to genetically and phenotypically uniform progeny. A long period of juvenility is characteristic of citrus seedlings and is evidenced by the presence of thorns, vigorous upright growth, delay in fruiting, and alternate bearing. It takes 5 or more years for the first flowering to occur in citrus seedlings. There is a lack of knowledge regarding genetic mechanisms controlling the inheritance of agriculturally important traits. Only a few important traits show single gene inheritance (Gmitter et al., 1992). Conventional hybridization has given rise to a few new citrus cultivars and rootstocks (Gmitter et al., 1992).

Although it takes only minutes to effect pollination, the difficult nature of citrus breeding lies in the elimination of undesirable hybrids and the evaluation of selections (Sykes, 1987). Despite the fact that citrus breeding is very challenging, different breeding programs throughout the world have made significant progress in the application of conventional and modern approaches to genetic improvement and cultivar development. Important breeding goals exist in citrus with respect to both scions and rootstocks.
Achievements in breeding through various approaches

Introduction

Taking a genotype or a group of genotypes in to a new place or environment where they were not grown previously. Thus introduction may involve new varieties of a crop already grown in that area, a wild relative of the crop species or totally a new crop species for that area.

Table 3. Introduced cultivars of sweet orange.

<table>
<thead>
<tr>
<th>Sr.no</th>
<th>Variety</th>
<th>Special feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Washington Navel</td>
<td>Introduced from USA, fruits round seedless, early in maturity</td>
</tr>
<tr>
<td>2</td>
<td>Valencia</td>
<td>Introduced from USA, world's most important variety. But alternate bearing.</td>
</tr>
<tr>
<td>3</td>
<td>Jaffa</td>
<td>It is a seedless clone of Palestine, introduced from USA. Fruit are small to medium,</td>
</tr>
<tr>
<td>4</td>
<td>Mosambi</td>
<td>Originates from Mozambique. Popular in MH &amp;AP, it has prominent streaks on the rind fruit is subglobose in shape.</td>
</tr>
<tr>
<td>5</td>
<td>Hamlin</td>
<td>Its chance seedling, early seedless variety.</td>
</tr>
</tbody>
</table>

Selection

Most of commercial varieties cultivated are of selection only. Few important selections in India are Yuraj blood red from blood red. Mudkedh seedless mandarin was selected as mutant from Nagpur mandarin. Pramalini and vikram, acid lime varieties were selected at Marthwada Agricultural University, Parbhani. PKM-1 was developed at Periyakulam. A seedless selection of acid lime was also made at Himachal Pradesh. DabwaliBaramasi and Pau selections were made in Lemon.

Table 5. Successful acid lime cultivars developed through selection

<table>
<thead>
<tr>
<th>Sr.no</th>
<th>Variety</th>
<th>Special feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PDKV lime</td>
<td>Maximum yield, superior quality with attractive fruits, resistant to citrus canker.</td>
</tr>
<tr>
<td>2</td>
<td>PDKV Chakradhar</td>
<td>Thornless and seedless variety, round fruit.</td>
</tr>
<tr>
<td>3</td>
<td>PDKV Bahar</td>
<td>Released by Dr.PDKV, Akola. Big fruit, Yield: 30-35 t/ha.</td>
</tr>
<tr>
<td>4</td>
<td>Vikram</td>
<td>Developed by VNMKV, Parbhani, fruits cluster bearing. Chakrawar et al. (1988).</td>
</tr>
<tr>
<td>5</td>
<td>Pramalini</td>
<td>Developed by VNMKV, Parbhani, fruit medium size, cluster bearing. Tolerant to canker. Chakrawar et al. (1988).</td>
</tr>
</tbody>
</table>
Table 8. Successful sweet orange cultivars developed through selection

<table>
<thead>
<tr>
<th></th>
<th>Cultivar</th>
<th>Released by</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Katol gold</td>
<td>Dr. PDKV, Akola</td>
<td>Attractive golden yellow colour, more production than Nucellor (122 q/ha)</td>
</tr>
<tr>
<td>2</td>
<td>Youraj blood</td>
<td></td>
<td>It is clonal selection of blood red.</td>
</tr>
</tbody>
</table>

Table 9. Successful mandarin cultivars developed through selection

<table>
<thead>
<tr>
<th></th>
<th>Cultivar</th>
<th>Selected from</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mudkhed seedless</td>
<td>Nagpur mandarin</td>
<td>it is bud mutant of Nagpur Mandarin (Chakrawar and Rane, 1977).</td>
</tr>
<tr>
<td>2</td>
<td>N4</td>
<td>Clone of Nagpur mandarin at NRCC, Nagpur, seedless cultivar.</td>
<td></td>
</tr>
</tbody>
</table>

Hybridization

Much of hybridization in citrus is interspecific than intraspecific hybrids are reported for the first time between the genera *Citrus* L. and *Citropsis* (Engl.) Conventional hybridization using the recently described species *Citrus wakonai* and *Citropsis gabunensis* (Engl.) resulted in high rates of fruit set and seed formation.

Some of the citrus varieties developed through hybridization are,

1. **Tahiti lime**: - It is hybrid between lime and lemon, fruit large and seedless. It is triploid.
2. **Rasaraj**: - hybrid variety, canker resistance developed by IIHR, Bangalore. It is cross between Kagzi lime x Nepali oblong lemon.
3. **Kinnow**: - It is cross between king x willow leaf by H.B. Frost in 1935. Popular in North India.
4. **Encore**: - It is a cross of King and Willow leaf by H.B. Frost, but it’s an alternate bearing habit.
5. **Wilking**: - It is a cross between king x willow leaf
6. **Page**: - Hybrid of minneala tangelo x Clementine.

Poyploidy

Polyploids such as triploids, tetraploids, pentaploids, hexaploids and octaploids are found spontaneously in *Citrus*. Among polyploids, triploids are of almost importance as they produce seedless fruits and vegetables. Well known are for instance tetraploid Hongkong wild kumquat, triploid Tahiti lime and tetraploid Triphasia desert lime. Triploids show more vigor than tetraploids and have thick round leaves. Triploids obtained from Citrus breeding were found themost resistant to low temperature. The Crossing of diploid plants using female parents that are genetically able to produce a high percentage of unreduced megaspores is a method to get triploids. The problem of
citrus embryo abortion in 2n x 4n crosses has been a limitation for recovering triploids by this method (Esen and Soost, 1971). Triploids of citrus can also be produced by crossing tetraploid seed parent with diploid pollen parent (Cameron & Burnett, 1978). It was also observed that 4n x 2n crosses had higher seed set than that of reciprocal crosses (Cameron and Burnett, 1978).

**Mutation**

Citrus and its related genera are extremely prone to mutations’. Several important commercial Citrus varieties, such as Washington navel orange, Marsh grapefruit, Shamouti Orange, and Salustiana orange, have arisen as bud “sprout” mutation. Inducing mutations by Gamma-rays has been effectively used with several species of *Citrus*. A red color of flesh and juice mutant derived from 80Gy gamma irradiation of *Citrus paradisi* cv. Ruby Red was released as cultivar Rio Red in 1984. Bud woods of two Indonesian local commercial mandarin (*Citrus reticulata* L. Blanco) cv. SoE and Garut, and pummelo (*Citrus grandis* L. Osbeck) cv Nambangan were exposed to Gamma-ray doses of 20, 40 and 60Gy, and irradiated bud woods were then budded onto rootstocks cv. Japanche Citroen.

**Breeding for drought and saline stress tolerance**

Citrus, like most fruit trees, is relatively salt sensitive. The deleterious effects of salt stress lead to reduction in fruit yield and quality. The common citrus rootstocks differ in their tolerance to salinity (Bernstein, 1969) and citrus trees can withstand relatively moderate salinity levels depending on the climate, scion cultivar, rootstock, and irrigation-fertilizer management. In many studies Cl− exclusion from leaves served as a reliable criterion for salt tolerance leading to a decreasing order of salinity tolerance in rootstocks: Cleopatra mandarin > Sour orange > Sweet orange = Swinglecitrumelo > Rough lemon > *Poncirus trifoliata*.

The activity of some of the anti-oxidant enzymes has been correlated with salt tolerance. In extracts of lemon cell cultures, an additional superoxide dismutase (SOD) isozyme was observed in the selected salt-tolerant culture as compared with the salt-sensitive one, following a separation on iso-electric focused gels (Piqueras et al., 1996). Attempts to regenerate salt-tolerant citrus plants via in vitro production of salt-tolerant callus or mutagenesis have been rather limited and as yet not in use. Therefore, in addition to conventional breeding based on the availability of limited salt-tolerant rootstocks, efforts should be invested to identify traits/genes that have a key role in tolerance to salt.

**References**


**TECHNIQUES OF FLOWER DRYING AND THEIR VALUE ADDITION**

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**ABSTRACT**

Drying of flowers makes value economically because fresh flowers will last only about a few days to weeks, but charm of dried flowers and foliages can be maintained for a few months to years with lesser cost if proper care took during the drying process. Drying of flowers is a pleasing experience because it is easy to do and flowers usually dry well. Flowers can be preserved by different drying methods like Air drying, Water drying, Embedding techniques (Sand, Borax, silica gel etc.), Microwave oven drying, Hot air drying, Pressing and gelcerenig etc. of all the methods, embedding in sand, silica gel and borax is economically and commercially viable the flowers dried in embedding techniques were used for three dimensional flower arrangements. Flowers dried by Pressing method are used for greeting cards and bookmarks and other creative arts. Drying at higher temperature (Microwave, oven and solar drying) shows quicker results as compared to a lower temperature (room). Value addition results in more acceptable quality products for the domestic and export market and hence ensure high premium to the producer. Moreover, value addition technology can help in avoiding wastage during the glut period and farmers involved in flower cultivation can earn better remuneration. Preparation of value added products helps in employment generation at the producer level, wholesaler level or at industrial level. Value addition is a good source for income generation by self employment. Various types of value added products which can be prepared either by practice or by obtaining training of these products.

**Keywords:** Drying and value addition

**INTRODUCTION**

Dry flowers and plant materials have tremendous potential as substitute for fresh flower and foliage for interior decorations as well as other aesthetic and commercial uses. India has rich biodiversity comprising of wide variety of ornamental trees, shrubs, climbers, etc. which are not being used as fresh flowers but their branches, twigs, flowers, fruits, cones, stems, rocks, bark, etc. can be dehydrated to preserve their beauty and for utilization in dry flower industry.

In recent times revolutionary changes are seen in the floriculture industry. One component contributing to this revolution is dry flower industry. Dry flower industry has tremendous export potential. Indian dry flower exports contributing to about 70-
80% of the floral exports during the last decade. Dry flower exports comprised of Rs. 385.49 crore out of the total floricultural exports worth of Rs. 548.79 crore, during the year 2016-17.

**Drying:** Process of removing moisture in the product up to certain threshold value.

**Dehydration:** Process of removal of moisture by the application of artificial heat under controlled conditions of temperature, relative humidity and air flow.

**Advantages of dry flower**
- Dry flowers are cheaper to the consumer as once purchased can be used for a long period
- Not dependent on weather or season
- Year round availability of raw material
- Eco friendly and degradable
- Utilized in preparation of many products like dried flower arrangement, greeting cards, potpourris etc

**Features of dry flower industry**
- Labour intensive
- Job opportunities for thousands of workers
- Self employment
- Subsidiary industries can be associated

**Type of crop and variety suitable for drying**

Selection of a suitable crop for drying purpose is very important for the success of the industry. Some of the flowers lose their ornamental value after drying like Sweet pea, helichrysum etc. The quality of dry flowers also varies with cultivar of a particular crop.

**Tips for collecting plant materials are as follows:**
- Avoid collecting material when they are wet or moist from dew.
- Use a sharp knife or pruning shears to cut flowers and plant materials.
- Select plant materials that are without insect or disease problems.
- Place stems in water while harvesting to prevent wilting.
- Some flowers may hold colour better if allowed to stand in water for a few hours. Start the drying process as soon as possible after cutting.
- Be mindful of where you collect plant materials; never remove unlawful or endangered plants.

**Harvesting stage of flowers for drying**

The stage of harvesting for different flowers varies according to the species and the form of flower desired. Usually flowers are harvested just before they are fully open and the colour has not faded. Flowers harvested at fully open stage took lesser time for drying than those harvested at tight bud and half open stage. Faster dehydration may be due to the reason that flowers lose moisture as harvesting time is delayed due to sensitivity of the flower tissues to ethylene, or other hydrolyzing enzymes and senescence also.
Moisture content after drying

Moisture content in the flowers after drying influences flower shape. The lower moisture content provides rigidity and results in uniform cell contraction in the flowers while the higher moisture content in dried flowers lead to flaccid flowers. A range of 8-11.5 per cent moisture content in the dried flowers will ensure good quality and firmness and maintains keeping quality for more than six months. Excessive drying of flowers resulted into petal shedding during handling.

Methods of drying or dehydration

1. Air Drying: It is oldest, simple and inexpensive method of drying also referred as ‘Upside Down’ or ‘Hang and Dry’ method of drying. The only disadvantage is that the flowers are not able to retain their original colour and their petals also shrink. Air drying is 2 types

i. In situ drying

Drying of flowers or plant parts naturally while attached to the plant.

E.g. Cassia, Albizzia, Koelreutaria, Pride of India, Bael, Pine, Reetha, etc.

ii. Vertical/hanging drying

Drying can be done either by hanging the flowers upside down or by placing them vertically on the racks. Strip excess leaves up to 1/4th stem length and then tie small flowers of similar type into one small bundle (maximum 10 flowers) whereas large flowers are dried individually with rubber bands. Bunches of flowers hang upside down with the help of thread over a rope or bamboo split in a dark warm place to preserve the colour. Leave the flowers hanging for 3-4 weeks for complete drying depending upon the weather conditions. Relative humidity of the drying area should be less than 75 per cent as they encourage the mould growth which spoils the flowers.

E.g.: Rose buds, Gompherena, Golden rod, Limonium, Gypsophilla, Paper flower, Straw flower, Bougainvillea etc.

2. Press Drying

Pressing is either using herbarium press or books with weight. Keep the flowers or leaves or floral parts in two folds of blotting paper and place the same inside the herbarium press and put a layer of corrugated paper over the blotting paper and make 3-4 layers in same manner and fasten the bolts of herbarium press. On alternate days, turn the side of flower as well as blotting paper according to the requirement, so that flowers are not attacked by fungi. Time required for pressing varies with type of flowers and water content of tissue however, it should be completed within 4 weeks. This drying time could be reduced if flowers folded in the sheets are put in oven at an appropriate temperature.

E.g.: Candytuft, Chrysanthemum, Pansy, Rose, Daisy, Phlox, Statice, Zinnia, Ferns, Silver oak, Thuja, Cockscomb etc.
Embedded drying

In this method after collecting the flowers are placed in desiccants like sand, silica gel, boric acid, borax, saw dust, alum powder, aluminium sulphate etc. In embedded drying moisture presented in the flowers can be absorbed by desiccant materials completely. Silica gel is the best desiccant for getting good quality of dry flowers.

Properties of desiccants

- Materials which are having capacity in removing of moisture from plant parts and without reacting with water vapours released during drying.
- The ideal size of desiccants is 0.02-0.2mm or 20-200 mesh.
- To keep original shape it should be heavy and not sticky.
- Less cost with easy availability.

Various steps involved in embedded drying

- The containers used for embedding are usually metal containers, preferably galvanized iron and the size of the container depends upon the size of material to be embedded.
- Desiccant is first poured into the container as one inch thick layer.
- The materials to be dried are arranged vertically on the surface.
- Pour desiccant slowly and gently so that the gaps between floral parts are properly filled up and the original shape of the material should not disturb.
- About a half inch of desiccant layer is maintained above the plant material.
- Keep the containers which filled with embedded flowers in either sun or hot air oven or microwave oven etc.
- Drying time ranging from 2 minutes to 4 weeks depended upon the mode of drying and material using for drying.
- Tacking out of the material gently from desiccant after completely dried.
- After removing the plant materials from the desiccant brushing off the remain desiccant with the help of paint brushes.
- Spraying of flower preservatives after cleaning increase life of product and protect them.

Sun drying

In this method flowers or foliage bunches are hanging upside down with the help of ropes or bamboo splits without any chemicals, but the main problem is prolonged exposure of the atmosphere results into pest and microbial attack. Either sun drying can be done by keeping plant material is embedded in desiccant in a container and exposed to sun by keeping the container everyday results rapid
dehydration. The flowers would dry in 3-4 days. Marigold, Pansies, Pompon chrysanthemum and small zinnias can be used for this type of drying.

**Microwave oven drying**

This method is quickest method of drying. The principle involved in this method is liberating moisture against the water molecules from organic substances by using electronically produced microwaves. Drying in the microwave takes 5-10 minutes, but it requires ‘setting time’ i.e. containers which containing flowers taken from microwave oven should be kept for a particular period of time at room temperature so that the moisture evaporates from the material and keep plant material dried fully it depend upon species to species. Flowers which having many petals like Marigold, Rose, Carnation, Zinnia, Chrysanthemum, Lotus etc. suitable for this method of drying.

**Hot air oven drying**

In this method plant material should be kept under controlled temperature of 40-50°C is used for drying flowers in an embedded conditions otherwise shrinkage is observed. Higher temperature accelerates degradation of pigments which present in plants. The time required depends upon the density of the flowers. The flowers that can be dried using this method are Cornflowers, Zinnia, Helipterum, Chrysanthemum, Gerbera, Paper flower, China aster, Marigold etc.

**Glycerine preservation**

This method keeps material flexible. A mixture of 1:2 ratio glycerine and warm water ideal for dehydration. Strip off the lower leaves from the stem and keep in glycerine mixture up to 5cm depth, it require 6-7 days for drying depending upon the weather conditions and plant material using for drying. Glycerine replaces the natural moisture present in the material. Eucalyptus, Magnolia, Maple leaves, Hydrangea, Gypsophylla etc is suitable for drying in this method.

**Water drying**

The stem of the flower is placed in a couple of inches of water, then the water is allowed to evaporate and be taken up by the cut flowers. Water is taken up by the cut flowers to keep the petals intact. The container and flowers should be kept in a dry, warm and dark location for 7-10 days to dry naturally.

E.g.: Hydrangeas, Yarrow, Bells-of-Ireland and Celosia.

**Freeze drying**

This method is costlier but the quality of the dried flower is very high and fetches good price. It is known as lyophilization because it relies on the principle of sublimation, whereby ice held under conditions of partial vacuum (less than 4.58 torr) and low temperature (less than 0°C) will evaporate on heating without going through a liquid phase. The absence of liquid water during the dehydration process means that undesirable chemical reactions will not occur. Hence, colour and even fragrance are retained together with original texture and structure. This process takes up to 4 weeks for drying E.g.: Carnations, Snapdragons, Rose, Gypsophila, etc.
Polyset polymer

It is a polyset polymer preservation method which is applied to the flower 45 minutes before drying. It is a chemical pre-treatment application which is used before air drying to improve the quality of the dried flowers. This method lessens drying time and minimizes shattering and wrinkling of petals which may occur during air drying.

Packing, handling and storing of dry flowers

Packaging for delicate dried plant materials should be done properly and manually during transportation and distribution by creating awareness of the product characteristics. It is always advisable to purchase a superior grade or standard cartons or boxes for packaging. Dried plant material should be protected from moisture throughout the marketing channel by placing a small quantity of silica gel at the bottom to absorb moisture. Dry material should be protected from direct sunlight or high light intensity especially from incandescent lamps, atmospheric humidity, wind and dust. Drying method is the most important consideration when storing dried plant material. Flowers hanging in bunches to air dry can simply be left hanging, so long as they are hanging out of direct sunlight. Dried flowers that have been preserved in silica gel should be stored in air-tight containers for protection against humidity and to retain floral shape and colour. Materials that have been air dried or dried in borax mixtures may be wrapped in newspaper or tissue and stored in large, long cardboard boxes for protection against invading insects, dust and strong light. However, one should make it sure that plant material is completely dry before storing, as remaining moisture content more than 11.50 per cent will cause the contents of the entire box to rot. Pressed flowers should be preserved in blotting sheets under slight pressure. Dried plant material may last for several months without deteriorating when stored properly in a clean and dry place.

Different methods of drying

<table>
<thead>
<tr>
<th>Vertical drying</th>
<th>Herbarium press</th>
<th>Press dried materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embedding in silica</td>
<td>Sun drying</td>
<td>Water drying</td>
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</table>
Dry flower arrangement

Dry flower arrangement is same as that for fresh flower arrangements in standard patterns of western, eastern and contemporary styles. Mostly flowers like static, straw flower, paper flower, nigella, briza, promos, larkspur, everlasting, roses, lavender, achillea etc. are used in dried flower arrangements.

Potpourri

Potpourri is a mixture of dried, sweet-scented plant parts including flowers, leaves, seeds, stems and roots. Aromatic oils found within the plant is the basis for a potpourri. Decorative wooden bowl or small bags made from sheer fabric are used for placing of potpourri. A potpourri can be made from two types - dry and moist. Dry method, is common, quicker and easier, but the potpourri does not last as long. "Fixative" is required for both methods to absorb the aromatic oils and releasing them slowly. Rose petals, Gomphrena, marigold petals, lotus pods suited for making potpourris. Herbs such as Artemesia, Thyme, Sage, Rosemary, Basil, Achillea (Yarrow), Lavender, Scented Geranium, Mint, Marjoram, Verbena, Anise and Fennel can be used for scent. The herbs and fruits should be thoroughly dried to prevent mildew.

Candle

It can be made by just adding dried flowers to the outside of plain candles or simply place crushed dried flowers on wax paper and then pour a little melted wax over the flowers, then roll the candle in the flowers.

Pankhuri

Dried rose petals are also known as pankhuri are used in preparing cold drinks and cooking which increases its flavour and also used in preparing floral cards as well as in potpourri.

Press dried flower products

Greeting cards, bookmarks, wall hangings, table tops, dining table mats, sceneries, collage, paper weights, it can be prepare by using press dried flowers and leaves are finally pasted with fevicol in an artistic manner. To add more value to these products petal embedded handmade paper can be used as base material.
Wreath

It is a band of flowers, foliage, twigs, roots, leaves, pods, and fruits etc are intertwined into a ring, usually placed on a grave as a memorial or worn on the head as a crown or a mark of honour.

Floral Jewellery

It includes crown, corsage and buttonhole/ boutonniere etc can be prepared by using dried flowers and foliage.

Dry Flower Products

Dry flower arrangement Potpourri Dry flower candle Pankhuri Dry flower wreath

Buttonhole Corsage Greetingcard Earings Locket

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• Images Source: Google
ORIGIN, AREA, PRODUCTION, VARIETIES, PACTAGE OF PRACTICES FOR BRINJAL

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Syn: Egg Plant, (Solanum melongena L.)
Chromosome No. 2n=24,
Family- Solanaceae, Origin- India
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Department of Agronomy, Institute of Agricultural Science, BHU, Varanasi-221005

Brinjal is one of the most common tropical vegetables grown in India. It is known by different names like aubergine(French), begun (Bengali), ringna (Gujarathi), baingan (Hindi) baarane (Kannada), waangum (Kashmiri), vange (Marathi), baigan (Oriya), Vashuthana (Malayalam), Kathiri (Tamil), venkaya (Telugu) and Peethabhala (Sanskrit). A large number of cultivars differing in size, shape and colour of fruits are grown in India. Immature fruits are used in curries and a variety of dishes are prepared out of brinjal. Fruits are moderate sources of vitamins and minerals like phosphorous, calcium and iron and nutritive value varies from variety to variety.

Uses

Brinjal is also valued for its medicinal properties and has got decholestrolizing property primarily due to presence of poly-unsaturated fatty acids (linoleic and lenolenic) present in flesh and seeds of fruit in higher amount (65.1%). Presence of magnesium and potassium salt in fruits also impart de-cholestrolizing action. In native medicines, role of brinjal in treatment of liver diseases, cough due to allergy, rheumatism, colilithiasis, leucorrhea and intestinal worms has been mentioned.

Growth habit- Based on growth habit brinjal can be classified as below:

- **Solanum melongena var. esculentum**: fruit is long, round and oval.
- **Solanum melongena var. serpentine** known as snake brinjal. Fruit is extraordinarily long. Leaves are prickly.
- **Solanum melongena var. depressum**: plant is extensively short and dwarf.

Description of popular varieties and hybrids - In brinjal a large variation in plant types, fruit colour, shape and size are available. Two types namely round and long are cultivated throughout India.

Long varieties

ArkaUnnathi–

High yielding bacterial wilt resistant variety derived from cross between ArkaKusumakar X IIHR-3. Fruits green long with fleshy green calyx. Yield: 34-36 t/ha. in 90-110 days.
**ArkaHarshitha**
High yielding bacterial wilt resistant variety derived from cross between ArkaKusumakar X IIHR-3. Fruits green long with fleshy green calyx. Yields 36-38 t/ha in 120 days.

**ArkaAvinash**
High yielding bacterial wilt resistant variety derived from cross between ArkaKusumakar X IIHR-3. Fruits green long with fleshy green calyx. Yields 40-42 t/ha in 95-115 days.

**PBHL-52-Hyb**

**KashiPrakash**
Plant of this variety are semi upright, Stem and leaves are green. Fruits are attractive with light green spots, calyx spiny, average weight 190g. The picking starts in 80-82 after transplanting and gives of yield of 650-700 q/ha.

**Pusa Purple Long**
It is a selection from a local a variety ‘Batia’ grown in Punjab, Delhi and western UP. It is early maturing cultivar becoming ready for picking in 100 to 110 days. Fruits are glossy, light purple in colour, 25-30 cm long, smooth and tender. The average yield varies from 250-275 quintals/ha. It is moderately.

**Pusa Purple Cluster**
It is a very early maturing cultivar becoming ready for picking in 75 days after transplanting. Fruits are small, dark purple in colour and borne in clusters. On an average, each fruit weight about 21g with bearing of 50 fruits per plant. This cultivar is resistant to bacterial wilt and little leaf disease.

**PusaKranti**
This cultivar is dwarf and spreading habit. Fruits are oblong with attractive purple colour. This cultivar is good for both spring and autumn planting under north Indian conditions. The average yield varies from 35 to 40 t/ha.

**Krishanagar Green Long**
It is a very popular variety in south India. Fruits are long, green and fleshy with scanty seeds. The average yield varies from 25-30 t/ha.

ArkaSheel- The fruits are medium long, with deep shining purple colour. The duration of this is 150 to 160 days. The yield varies from 35-40 t/ha.

**Arka Anand**
It is a high yielding F₁ hybrid with resistance to Bacterial wilt. Suitable for Kharif and Rabi both in grown. Average fruit weight is 50-55 gm. Yield 60-65 t/ha in 140-150 days.
Round varieties-

KashiSandesh- This is a hybrid having semi-upright height 71cm plant habit with green stems, purplish green leaves and purple, size medium, shape round, fruit length 12.5cm, diameter 10cm and weight 225g. The picking starts in 76 days after transplanting. Give an average yield of 780q/ha.

Pant Rituraj- Semi erect plant. Fruits are round, dark purple in colour. Resistant to bacterial wilt and yields is 40 t/ha.

Pusa purple round- Fruits are round, dark purple in colour. It is highly resistant to little leaf virus disease. Average yield varies from 25 to30 t/ha.

Manjri-It is a selection from a local material recommended by the department of Agriculture, Maharashtra state. The fruits are medium sized, round and dark purple colour. Average yield 27.5-30 t/ha.

Punjab Bahar- The fruits are round with deep shining colour. The average fruit weight 20-30 t/ha.

Hybrids-

Pusaanmol- It is a hybrid cultivar evolved from a cross between Pusa Purple Long and Hyderpur at IARI. It produces early and increased yield of about 80% over Pusa Purple Long.

Pusa Hybrid-5- Plant vigorous, fruits long, glossy, attractive, dark purple in colour. Fruit weight about 100g. Average yield is about 52 t/ha.

Pusa Hybrid-6- Plants semi erect, vigorous, fruits long, glossy, attractive, purple colour.

Azad Hybrid- It is cross between Azad B1 and Kalyanpur-3. Plants semi erect, branched early fruiting and round, about 45 t/ha. Less prone to shoot and fruit borer infestation.

Climate

Brinjal is warm season day neutral plant and is susceptible to severe frost. A long and warm growing season with a temperature range of 21-27°C is ideal for its production. Low temperature during the cool season cause abnormal development of the ovary (Splitting) in flower buds which then differentiate and develop into deformed fruits during that season. Crop is adversely affected by chilling temperature of winter in North India. Generally late cultivars can withstand low temperature than early ones. Plants grown luxuriantly and yield heavily during rainy season under warm humid climatic condition of Kerala.

Soil

The brinjal can be grown practically on all soils from light sandy to heavy clay loam soils. Brinjal is a hardy crop and is cultivated under a wide range of soils. Since a long duration crop with high yield, well-drained and fertile soil is preferred for the crop. Crops grown in sandy soils yield early and those grown in clayey soils yield more. Ideal pH for cultivation of crop is 5.5-6.6
Season

Brinjal can grow under a wide range of climatic conditions. In hills, brinjal is sown during March and transplanted during April. In plains there are three seasons for growing brinjal.

Autumn-winter crop

Crop is sown in June and transplanted in July

Spring-summer crop: Crop is sown in early November and transplanted in January-February. Due to low temperature, seedlings take 6 to 8 weeks for attaining normal size for transplanting and nursery beds are to be protected from frost.

Rainy season crop

Seeds are sown in March-April and transplanted during April-May. Being a low priced vegetable, rainy season crop is the most economical in many parts.

Nursery

Raised beds should be prepared (7.5×1.2×10-15cm) and seeds are sown in rows of 7.5 to 10cm apart. The beds are prepared well and leveled onecentimetre thick layer of farm yard manure is to applied and mixed properly. The seeds should be covered properly by a mixture of FYM and soil. As soon as the sowing is completed the bed should be covered with a thin layer of dry grass and kept moist till the seeds germinate. To avoid fungal diseases, the seeds should be treated with captan or thiram at the rate of 2g/kg of seed. For safe guarding, the seedlings should also be sprayed withmancozeb at a concentration of 2g/litre. About 250-375 g seed is sufficient to cover one hectare of land with 30,000-45,000 seedlings. The seedlings are ready for transplanting in about 4-5 weeks.

Preparation of land

Soil is prepared to fine tilth by giving 4-5 ploughings. Well rotten organic manure (25t/ha) is incorporated into the soil well before the final preparation. It may be grown on raised beds/ ridges during rainy season. In undulating land, in order to avoid soil erosion, small pits are dug at the point of planting and seedlings are planted.

Spacing and transplanting

Spacing depends on variety, season and fertility of soil. For long duration spreading varieties, a spacing of 75-90cm x 60-75 cm and for bushy and non-spreading varieties a distance of 45-60cm on either side are given. For early and less spreading varieties, paired row planting is advantages due to, easiness in harvesting and other cultural operations. Stocky, healthy seedlings which are free of disease and shoot and fruit borer infestation and have attained a height of 10-12cm with 3-4 leaves are to be selected and transplanted. A light irrigation should be given immediately after transplanting.

Manures and fertilizer

Brinjal is a long duration crop with high yield potential. Flower and fruit production will be adversely affected when crop is grown under low fertility conditions. Depending on available, 25 tonnes of FYM/ha may be incorporated in soil at the time
of final ploughing. Application of wet cow dung as a band, 10 -12 cm away from the plant, followed by earthing up at fortnightly interval during rainy season is a common practice for high productivity in Kerala. Fertilizer requirement for targeted production in co-2 under Tamil Nadu condition is estimated and 7.6 kg N, 1.4 kg P, and 17.3 kg K/ha are required to produce one tonnes of fruits.

<table>
<thead>
<tr>
<th>State</th>
<th>NPK (kg)</th>
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<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>100-60-60</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>100-60-25</td>
</tr>
<tr>
<td>Orissa</td>
<td>125-80-110</td>
</tr>
<tr>
<td>Punjab</td>
<td>125-60-30</td>
</tr>
<tr>
<td>Karnataka</td>
<td>125-10-50</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>100-50-50</td>
</tr>
<tr>
<td>Uttar Pradesh</td>
<td>100-50-50</td>
</tr>
<tr>
<td>West Bengal</td>
<td>120-50-50</td>
</tr>
</tbody>
</table>

**Micronutrients**

The deficiency of micronutrients in brinjal has not been noticed in field. But some workers have studied the effect of their application. The application of minor elements had no effect on vegetative growth of the plant. However, Cu increased the number of flowers and fruits, Zn improved the weight of fruits and Mn showed similar but less pronounced effect on flowering and fruiting.

**Irrigation**

Though brinjal cannot tolerate water logging, timely irrigation is essential especially for fruit set and development. In plains, irrigation is required at every third or 4th day during summer while in winter it should be at 10-15 days interval. During winter, care should be taken to keep soil moist to avoid crop loss due to frost injury. Being a row planted crop, drip irrigation is advantageous and water used in drip irrigation is only 24.47 cm compared to 69.18 cm under furrow method.

Brinjal is mainly grown as a rainfed crop in high rainfall states like Kerala by transplanting seedlings just before onset of South West monsoon. Here also transplanted seedlings should be given one or two life irrigations for initial establishment.

**Weed control**

It is essential to keep weeds under control from the initial growth itself. Shallow inter cultivation is given to remove the weeds. Three to four hoeings are normally followed for effective control of weeds, proper aeration and good growth of the plants. This facilitates better aeration to root system and gives support to plants. Application of fluchloralin @ 1.5 kg a.i./ha as a pre-emergent weedicide, applied one week after transplanting seedlings, followed by one hand weeding at 30 days after planting.
controls a broad spectrum of weeds. Use of black polythene mulches is also efficient for suppression of weeds and for better growth of plants.

**Mulching**

The most beneficial effect of mulching is that it conserves soil moisture and controls weeds. Mulching in brinjal crop with black polyethylene film reduces weed growth, accelerates crop growth, induces early bearing and increases yield.

**Use of growth regulators and chemicals**

Application of 2,4-D (2ppm) at flowering induces parthenocarpy, increases fruit set, advances fruit maturation and significantly increases total yield. Spraying of 4 CPA (Para-chlorophenol acetox acetic acid (20ppm) and N-metatolymphalamic acid (0.5%) promotes fruit set in brinjal. NAA (60ppm) alone or in combination with BA(30ppm) applied on open flowers improved fruit set and ascorbic acid, GA3, IAA and thiourea advances the flowering by 4-5 days. Spray of mixtalol (long chain C24-C34 aliphatic alcohols) at 4 ppm, 4-6 weeks after transplanting, is also effective and gave additional yield of 7.1% in F1 hybrid ArkaNavneet.

**Physiological disorder/constraints**

**Calyx withering**

This disorder occurs between mid-February and mid-April. The affected fruits become reddish brown in colour and lacking in normal luster and thus marketability of fruits is hampered. The affected fruits have much higher calcium and nitrate content than healthy ones.

**Harvesting**

Brinjal fruits are harvested at immature stage after attaining full size, but before loosing its glossy appearance. Dullness of fruit indicates over maturity. Usually fruits are harvested along with its stalk with a slight twist by hand. In some varieties, a sharp knife is also used for harvesting fruits along with fleshy calyx and a portion of fruit stalk. The harvested fruits are graded and packed in baskets or in loose gunny bags. Care should be taken to remove the fruits affected by Phomopsis blight.

**Yield**

Early short duration varieties: 20-30 t/ha

Long duration varieties: 35-40 t/ha

F1 hybrids; 55-80 t/ha

**Storage**

Fruits can be stored for 7-10 days in a fairly good condition at 7.2-7.2-10°C with 85-90% RH. Keeping quality of fruits varies with variety. It is better to store at 20°C than at 6°C and in perforated polythene bags than under open condition.
Diseases-

Damping off

This is major nursery disease. Affected seedlings topple over and die in patches. For reducing disease inducing sow seeds as loose/thin as possible on raised beds. Adequate drainage aredrenching nursery bed with Bavitin (0.1%) control disease effectively.

Phomopsis blight

This is a major disease particularly when crop is raised for seed production. Soft and water soaked brown lesions of fruits which turn black and mummified in appearance are the common symptoms. Leaves and stem may also develop dark brown sports. Seed treatment with Bavistin (1 g a.i./kg) and seedling dip in Bavistin (0.05%) for 30 minutes before transplanting, followed by two sprays of Bavistin are recommended for control of disease.

Little leaf

Diseased plants produce small sized leaves and result in bushy and stunted growth and will not produce fruits.

Bacterial wilt (Ralstoniasolanacearum)

Disease results in sudden wilting and drying up of plants. Plants are more affected during flowering and early fruiting stages. Grow resistant varieties like Swetha, Haritha, ArkaNidhi, ArkaNeelkant, Pant Samrat, UtkalTarini, UtkalMadhuri and F1 hybrid Neelima in wilt prone areas.

Mosaic

Uproot and destroy mosaic and little leaf affected plants as soon as symptoms are noticed. Avoiding ratooning and raising seedlings in seed beds treated with Phorate (1.25 kg a.i./ha), treating seedlings with systemic insecticides for eight hours followed by application of Phorate (1.25 kg a.i./ha) at 21 DAT control both little leaf and mosaic.

Pests

Fruit and shoot borer (Leucinodesorbonalis)

The larvae bore into tender parts causing drooping of young shoots and rotting of fruits. Effect plant parts should be removed along with larvae and destroyed crushing or by immersing in insecticide solution.

Jassids (Empoasca spp.)

Adults and nymphs suck sap by feeding from under surface of leave resulting in typical yellowing and drying up of leaves. Varieties Punjab Barsati and PusaKranti have tolerance to jassid attack.

Mites

Red spider mites and other mites seen on under surface of leaf suck sap and cause characteristic yellowing. Spray of neem oil garlic solution in initial stage of attack is effective for control of mites. Under severe infestation spray Kelthane (0.03%) or metasystox (0.03%).
ASHWAGANDHA AND ITS MEDICINAL PROPERTIES

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ABSTRACT

Withania somnifera is one of the indispensable medicinal herb used from the time of Ayurveda, an ancient period of Indian medicine. Broad usage of ashwagandha is viewed in the treatment of diabetes, stress, bites of snakes, memory enhancing and in the nervous breakdown. The biologically active constituents are alkaloids and steroidal lactones. Studies on ashwagandha point out that it possesses anti-inflammatory, antioxidant, antitumor properties. Countless alternative effects like sexual behavior, antibacterial, immunoresponses, and cardiovascular protection have also been considerably studied. These results uplifts this herb studies more enormously in the medicinal field of success.

Keywords: Ashwagandha, ayurveda, diabetics, withanolids, anaferine.

INTRODUCTION: Withania somnifera, known commonly as ashwagandha, Indian ginseng, poison gooseberry, or winter cherry, is a plant in the Solanaceae or nightshade family. This species is a short, tender perennial shrub growing 35–75 cm (14–30 in) tall. Tomentose branches extend radially from a central stem. Leaves are dull green, elliptic, usually up to 10–12 cm (4 to 5 in) long. The flowers are small, green and bell-shaped. The ripe fruit is orange-red. In the traditional ayurvedic writings and in the modern medical literature Withania somnifera (Ashwagandha) is a familiar medicinal plant. The species name somnifera means "sleep-inducing" in Latin. The origin of Ashwagandha is from Sanskrit language, where ashwa means horse and gandha means smell (roots smelling like horse like odour).

The roots of aswagandha distinguishes it from other medicinal plants. Today the world is looking at aswagandha because of its various beneficial properties. The roots of ashwagandha are used for the treatment for arthritis, diabetes, constipation, nervous breakdown, insomnia, fevers, skin conditions, stress, snake bites, gastrointestinal issues, and memory loss.

Biochemical Constituents of Withania somnifera:

- The main constituents are alkaloids and steroidal lactones. Alkaloids includes tropine and cuscohygrine. Leaves contain steroidal lactones, withanolides, firstly withaferin A, which was the first to be isolated from the plant.
• Tropine is a derivative of tropane containing a hydroxyl group at the third carbon.
• Tropane is a nitrogenous bicyclic compound. It is mainly known for a group of alkaloids derived from it.
• Cuscohygrine is a pyrrolidine alkaloid found in cocoa. It can also be extracted from plants of the family solanaceae, cuscohygrine usually occurs along with other, more potent alkaloids such as atropine.
• The chemical composition includes alkaloids (isopelletierine, anaferine, cuscohygrine, anhygrine etc.,) steroidal lactones contains (withanolides, withaferins) saponins, iron, resins.

Benefits of *Withania somnifera*:
- Ashwagandha is perfect for those battling stress, as it inhibits high levels of cortisol, the ‘stress hormone’. It also relieve physical and mental stress and help in overcoming depression that is the reason it was used in tranquilizers and antidepressant in drugs.
- The results, published in the Indian Journal of Psychological Medicine shows that ashwagandha helps in promoting relaxation as it is a natural adaptogen.
- In several studies, ashwagandha has been shown to lower blood sugar levels.
- Ashwagandha helps in increasing testosterone levels and significantly boosts the sperm quality and fertility in men.
- Ashwagandha also slows the growth of cancerous tumors, hence it has the potential to be a serious anti-cancer agent.
- For painful joints, swollen and for inflamed parts ashwagandha is a herb of choice (arthritis).
- It lowers the cholesterol level and also stabilizes the blood sugar. Also found to increase haemoglobin content in blood and hair melanin.
- Ashwagandha is effective for insomnia but does not act as a sedative. It calms the nervous system which in turn makes the body to settle and sleep.

Side effects of *Withania somnifera*:
- Pregnant women should not consume ashwagandha in any form which may lead to early birth or abortion.
- Large doses of ashwagandha causes vomiting, diarrhea and stomach upset.
- Ashwagandha may lead to allergies, bleeding, drowsiness, dry mouth, erectile dysfunction, liver damage, fever.
- Ashwagandha may worsen hyperthyroidism, lower blood sugar way too much, aggravate autoimmune diseases.
REFERENCES


ROLE OF DIFFERENT SOURCES OF NUTRIENTS
THEIR AVAILABILITY, FUNCTIONS AND EFFECTS ON
GROWTH AND FLOWERING OF ORNAMENTAL
CROPS: AN OVERVIEW

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3. Department of Horticulture, JV College Baraut, Baghpat, UP, India 250611

INTRODUCTION:

Floriculture has become an important commercial activity in agriculture sector in the post globalization era. Floriculture activity has marked as a viable and profitable trade area with a potential to activate self-employment among low and middle income farmers, and earn the very essential foreign exchange in the developing countries such as India. The world floriculture production is growing at a rate of 10 per cent per year. Almost 45 to 50 countries are active in the production of floriculture on a large scale. In terms of production value, the Thailand, Netherlands, USA, UK and China are in the top. The economic slowdown has affected the floriculture industry internationally with demand for floriculture products were declined in major countries, such as Europe, The USA and Japan. Depression in pricing has been observed across the product segments. The floriculture sector in India is facing several challenges at the production level mostly related to availability of basic inputs, proper irrigation and skilled manpower. At the marketing stage also Indian traders are facing major challenges related to product diversification and product differentiation. With increasing involvement of super markets in flower business, managing transport is also becoming a critical factor for the Indian flower traders (Harisha, 2017). It has been documented that proper nutrients, cultural practices and control of diseases and insects play an important roles in crop production. Each type of plant is unique and has an optimum nutrient range as well as a minimum requirement level. Below this minimum level, plants start to show nutrient deficiency symptoms. Excessive nutrient uptake can also cause poor growth because of toxicity. Therefore, the proper amount of application and the placement of nutrients is important. Soil and plant tissue tests have been developed to assess the nutrient content of both the soil and plants. By analyzing this information, plant scientists can determine the nutrient need of a given plant in a given soil.

In addition to the levels of plant-available nutrients in soils, the soil pH plays an important role in nutrient availability and elemental toxicity. This chapter describes the flower production in India, essential nutrients for plants, the chemical forms in which they are available to plants, their function in plants, symptoms of their deficiencies, and recommended nutrient levels in plant tissues of selected crops. The visual quality of ornamental plants is necessarily linked to an adequate balance of nutrients. Plant height, shape and coloration are qualitative aspects of ornamental
species, directly influenced by mineral nutrition, among other environmental aspects. The nutritional requirements of ornamental species are not yet well established, often resulting in inefficient use of chemical and organic fertilizers, without respecting the needs of each species as well as the proper time for application. This leads to the low quality of the final product, as well as high production costs, which justifies the importance of a nutritional knowledge of the species. In addition to plant nutrients, some elements not considered essential, such as silicon, may provide improvements in the quality of certain species, including ornamental plants (Neto et al., 2015).

Floriculture:

Floriculture is a discipline of Horticulture and it includes cultivation of flowers and ornamental plants for selling or for use as input materials in cosmetic industry as well as in the pharmaceutical sector. The present day floral industry is one of the most dynamic and fast growing industry, which has achieved significant rate of growth during the past few years and has extended worldwide with the major paradigm shift of production centers from developed to developing countries. India is also interested to emerge as an important production base for floriculture output. Irregular climatic conditions, genetic variety, versatile human resources etc put India a unique scope for enormous employment of existing resources and exploration of avenues yet untouched. The production and export of floricultural products have received a considerable interest in recent decades from the researchers, policy makers, agricultural and horticultural experts. It is often argued that horticulture and allied activities have to be given importance in view of the field’s potential in employment, export and income generation. On this background, horticulture has been provided additional interest in recent years. The plan outlays have been stepped up in successive plans for development of horticulture as well as floriculture. However, in India, some states are not in this process. This may be due to lack of infrastructural facilities, guidance to farmers by the department of horticulture as well as unsuitable weather conditions. Further, after attaining self-sufficiency in food grain production, the policy focus is being directed more towards remunerative crops and export potential crops. An important emerging activity in horticultural sector is floriculture. This co-sector has been encouraged, because of its demand both in domestic as well as world markets. The increases in per capita income and urbanization have led to a greater preference and increased demand for flowers and ornamental plants. At present, flowers are being extensively used in various nations. The testimony of this is mushrooming growth of florist centers in urban areas. Still, this sector has a few bottlenecks. These have to be tackled and consequently the activity should become more remunerative to the agricultural farmers. (Harisha, 2017).
The data given in Figure-1 clearly indicates that among the various horticultural crops, vegetable ranked first in production point of view followed by fruits, plantation crops, spices and minimum production in floricultural crops. The table-1 also indicates that in the year 2012-13, the flower and aromatic share was 1% which was increased 1.1% in the year 2014-15, 2015-16 and 2016-17 respectively. Similarly, the data presented in Fig. 2 clearly demonstrates that Tamil Nadu has the maximum share in flower
production i.e. 19% of overall flower production in India, followed by Karnataka (13%), West Bengal (12%), Madhya Pradesh (10%) and minimum share 4% was in Assam.

Table 1. Percentage Share and production of various Horticultural crops

<table>
<thead>
<tr>
<th>Crops</th>
<th>2012-13 %</th>
<th>2013-14 %</th>
<th>2014-15 %</th>
<th>2015-16 %</th>
<th>2016-17 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits</td>
<td>30.2</td>
<td>32.1</td>
<td>30.8</td>
<td>31.5</td>
<td>31.5</td>
</tr>
<tr>
<td>Vegetables</td>
<td>60.3</td>
<td>58.7</td>
<td>60.3</td>
<td>59.1</td>
<td>59.3</td>
</tr>
<tr>
<td>Flowers &amp; Aromatics</td>
<td>1.0</td>
<td>1.0</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Plantation Crops</td>
<td>6.3</td>
<td>5.9</td>
<td>5.5</td>
<td>5.8</td>
<td>5.7</td>
</tr>
<tr>
<td>Spices</td>
<td>2.1</td>
<td>2.1</td>
<td>2.2</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Total Horticulture</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Source: Horticultural Statistics at a Glance 2017

Table 2. Production and share of flowers in different states in India 2016-17

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>State</th>
<th>Production (in ‘000 MT)</th>
<th>% Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TAMIL NADU</td>
<td>416.63</td>
<td>18.55</td>
</tr>
<tr>
<td>2</td>
<td>KARNATAKA</td>
<td>280.92</td>
<td>12.51</td>
</tr>
<tr>
<td>3</td>
<td>WEST BENGAL</td>
<td>272.76</td>
<td>12.14</td>
</tr>
<tr>
<td>4</td>
<td>MADHYA PRADESH</td>
<td>216.00</td>
<td>9.62</td>
</tr>
<tr>
<td>5</td>
<td>GUJARAT</td>
<td>186.00</td>
<td>8.28</td>
</tr>
<tr>
<td>6</td>
<td>ANDHRA PRADESH</td>
<td>140.34</td>
<td>6.25</td>
</tr>
<tr>
<td>7</td>
<td>UTTAR PRADESH</td>
<td>118.29</td>
<td>5.27</td>
</tr>
<tr>
<td>8</td>
<td>MAHARASHTRA</td>
<td>106.77</td>
<td>4.75</td>
</tr>
<tr>
<td>9</td>
<td>CHHATISGARH</td>
<td>105.11</td>
<td>4.68</td>
</tr>
<tr>
<td>10</td>
<td>ASSAM</td>
<td>91.47</td>
<td>4.07</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td>312.11</td>
<td>13.89</td>
</tr>
<tr>
<td>All India Total</td>
<td></td>
<td>2246.40</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Source: Horticulture Statistics Division, Department of Agri. & Cooperation.

The data presented in table 2 clearly demonstrates that Tamil Nadu had the maximum production (416.63 thousand MT) with 18.55% share in flower, followed by Karnataka (12.51%) with 280.92 thousand MT production, West Bengal (12.14%) with 272.76 thousand MT production, Madhya Pradesh (9.2%) with 216 thousand MT production and minimum share was 4.07% with 312.11 thousand MT production in Assam. State wise total productivity of loose flowers is presented in Table-3.
Table 3. State wise productivity of loose flowers of India (Total) in (MT/ha)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>STATES/UTs</th>
<th>2014-15</th>
<th>2015-16</th>
<th>2016-17 (Provisional)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SIKKIM</td>
<td>68.18</td>
<td>68.18</td>
<td>68.18</td>
</tr>
<tr>
<td>2</td>
<td>HIMACHAL PRADESH</td>
<td>33.92</td>
<td>32.55</td>
<td>32.55</td>
</tr>
<tr>
<td>3</td>
<td>NAGALAND</td>
<td>0.00</td>
<td>12.72</td>
<td>12.72</td>
</tr>
<tr>
<td>4</td>
<td>TAMIL NADU</td>
<td>6.24</td>
<td>13.81</td>
<td>12.67</td>
</tr>
<tr>
<td>5</td>
<td>BIHAR</td>
<td>9.59</td>
<td>12.01</td>
<td>12.01</td>
</tr>
<tr>
<td>6</td>
<td>MADHYA PRADESH</td>
<td>11.72</td>
<td>11.73</td>
<td>11.73</td>
</tr>
<tr>
<td>7</td>
<td>HARYANA</td>
<td>10.35</td>
<td>10.48</td>
<td>10.40</td>
</tr>
<tr>
<td>8</td>
<td>GUJARAT</td>
<td>9.45</td>
<td>9.45</td>
<td>9.45</td>
</tr>
<tr>
<td>9</td>
<td>ANDHRA PRADESH</td>
<td>6.77</td>
<td>8.07</td>
<td>8.46</td>
</tr>
<tr>
<td>10</td>
<td>KARNATAKA</td>
<td>7.12</td>
<td>7.28</td>
<td>6.73</td>
</tr>
<tr>
<td>11</td>
<td>ASSAM</td>
<td>6.46</td>
<td>6.67</td>
<td>6.67</td>
</tr>
<tr>
<td>12</td>
<td>PUNJAB</td>
<td>7.75</td>
<td>6.23</td>
<td>6.25</td>
</tr>
<tr>
<td>13</td>
<td>MAHARASHTRA</td>
<td>5.31</td>
<td>5.97</td>
<td>5.85</td>
</tr>
<tr>
<td>14</td>
<td>JHARKHAND</td>
<td>13.77</td>
<td>4.85</td>
<td>4.85</td>
</tr>
<tr>
<td>15</td>
<td>TELANGANA</td>
<td>2.92</td>
<td>3.77</td>
<td>3.81</td>
</tr>
<tr>
<td>16</td>
<td>CHHATTISGARH</td>
<td>4.56</td>
<td>3.78</td>
<td>3.78</td>
</tr>
<tr>
<td>17</td>
<td>ODISHA</td>
<td>3.45</td>
<td>3.78</td>
<td>3.78</td>
</tr>
<tr>
<td>18</td>
<td>WEST BENGAL</td>
<td>2.69</td>
<td>2.72</td>
<td>2.73</td>
</tr>
<tr>
<td>19</td>
<td>MIZORAM</td>
<td>916.88</td>
<td>4.32</td>
<td>2.39</td>
</tr>
<tr>
<td>20</td>
<td>UTTAR PRADESH</td>
<td>1.99</td>
<td>1.99</td>
<td>2.16</td>
</tr>
<tr>
<td>21</td>
<td>RAJASTHAN</td>
<td>1.07</td>
<td>1.76</td>
<td>1.76</td>
</tr>
<tr>
<td>22</td>
<td>UTTARAKHAND</td>
<td>1.28</td>
<td>1.14</td>
<td>1.31</td>
</tr>
<tr>
<td>23</td>
<td>JAMMU &amp; KASHMIR</td>
<td>0.75</td>
<td>0.60</td>
<td>0.57</td>
</tr>
<tr>
<td>24</td>
<td>ARUNACHAL PRADESH</td>
<td>0.42</td>
<td>0.47</td>
<td>0.47</td>
</tr>
<tr>
<td>25</td>
<td>MANIPUR</td>
<td>0.37</td>
<td>0.39</td>
<td>0.42</td>
</tr>
<tr>
<td>26</td>
<td>KERALA</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>27</td>
<td>MEGHALAYA</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>OTHERS</td>
<td></td>
<td>4.63</td>
<td>4.03</td>
<td>0.12</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>6.67</td>
<td>5.97</td>
<td>5.34</td>
</tr>
</tbody>
</table>

Source: Horticultural Statistics at a Glance 2017
Role of nutrients management in ornamental plants.

Nutrient management plays an important role in production and productivity in ornamental plants. A number of reasons have been observed behind the low productivity in ornamental plants. Among the various reasons behind low productivity, poor soil and nutrient management is a major cause. Therefore, nutrient management has prime importance for successful cultivation. Among the nutrients, plants require 16 essential elements. Among these Carbon, hydrogen, and oxygen are derived from the atmosphere, soil and water. The remaining 13 essential elements (nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, zinc, manganese, copper, boron, molybdenum, and chlorine) are supplied either from soil minerals and soil organic matter or by organic or inorganic fertilizers. For plants to utilize these nutrients efficiently, light, heat, and water must be adequately supplied. The use of organic manures and bio fertilizers along with balanced use of chemical fertilizers is known to improve the physico-chemical and biological properties of soil, besides improving the efficiency of applied fertilizers (Sharma et al., 2016). Agrochemical is evolved by the contraction and combination of words agricultural and chemical, and is a generic term used for the various chemical products typically used in agriculture. Agrochemicals essentially help in intensifying crop production and to reduce the effects of pests and parasites on farm animals. Agrochemical basically refers to the broad range of pesticides and fertilizers. A fertilizer is any material, organic or inorganic, natural or synthetic, that supplies plants with the necessary nutrients for plant growth and optimum yield. Organic fertilizers are made from materials derived from living things. Animal manures, compost, etc. are organic fertilizers. Chemical fertilizers are manufactured from nonliving materials. Rock phosphate for example, is a common source of phosphorus in chemical fertilizers (Gupta and Hussain, 2014).

To increasing the production and get more income by flower production in the country, There is an urgent need of scientific approach to promote the relevant management practices, improvement of flower germplasm, balanced nutrient management, modern production technology, quality planting material, precision farming etc., for conservation and commercialization of the floriculture industry and diversification from the traditional field crops due to higher returns per unit area. The overall strategy for increasing crop yields and sustaining them at high level must include integrated approach to the management of nutrients (Wani et al., 2017). Although many factors have contributed to the nutrient load in surface and groundwater, fertilizer use has been one of the significant influences (Pettygrove et al. 1998). Factors militating against sufficient crop production can be social, political, scientific and technological including the use of fertilizer. Besides, insufficient utilization of nutrients from fertilizers, fertilizer rates and types and appropriate application methods also contribute to the persistent low yield and economic low returns out of farmers fields. To reverse the declining yield trends, intensification through the use of inorganic fertilizers and other land augmenting technologies is very essential.

Now a day’s, agriculture is getting more and more dependent upon the supply of synthetic inputs such as chemical fertilizers, pesticides etc. which are inevitable to
meet food demand for growing population in the world. However, excessive, imprudent and imbalanced use of inputs may throw devastating impacts on the water, air and soil environments. Probably the soil environment is the most vulnerable to the direct effects of these practices in modern agriculture. They could destroy the fertility of the soil in a long run which compels the scientific community to look for the alternatives like organic farming and integrated use of organic and inorganic fertilizers. Inorganic fertilizer, generally refer to chemically synthesized plant nutrient compounds which are usually applied to the soil to supplement fertility. Inorganic or mineral fertilizers are mined out of mineral deposits with little processing such as lime, potash or phosphate rock or industrially manufactured through chemical processes such as Urea. The demand and use of fertilizer has a close interaction on the supply factors. Inadequate supply of fertilizer has led farmers to rely heavily on organic waste as an alternative source of plant nutrients (Nenna, 2014). Nutrient has multifaceted potential for the improvement of plant performance and resource efficiency while also enabling the protection of the environment and resource quality. Lower inputs of chemical fertilizer and therefore lower human and environmental costs (such as intensity of land use, N use, reactive N losses and GHG emissions) were achieved under advanced nutrient practices without any negative effect on crop yields.

Table 4 Essential plant nutrients for flowering plants

<table>
<thead>
<tr>
<th>Nutrients Supplied by Air and Water</th>
<th>Nutrients Supplied by the Soil System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Mineral</td>
<td>Primary or Macronutrients</td>
</tr>
<tr>
<td>Carbon - C</td>
<td>Nitrogen – N</td>
</tr>
<tr>
<td>Hydrogen - H</td>
<td>Phosphorus – P</td>
</tr>
<tr>
<td>Oxygen - O</td>
<td>Potassium – K</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: book of fertilizers and their use. Agricultural Extension Service, the University of Tennessee
**Table 5. Functions in plants and available forms of nutrients** (Uchida, R. 2000)

<table>
<thead>
<tr>
<th>Nutrient Element</th>
<th>Functions in Plants</th>
<th>Plant Available From Soil Solution Complex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>Promotes rapid growth, chlorophyll formation and protein synthesis.</td>
<td>Anion and Cation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO3⁻, NH4⁺</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Stimulates early root growth. Hastens maturity. Stimulates blooming and aids seed formation.</td>
<td>Anion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H2PO₄⁻, HPO₄⁻</td>
</tr>
<tr>
<td>Potassium</td>
<td>Increases resistance to drought and disease. Increases stalk and straw strength.</td>
<td>Cation</td>
</tr>
<tr>
<td></td>
<td>Increases quality of grain and seed.</td>
<td>K⁺</td>
</tr>
<tr>
<td>Calcium</td>
<td>Improves root formation, stiffness of straw and vigor. Increases resistance to seedling diseases.</td>
<td>Cation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ca⁺⁺</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Aids chlorophyll formation and phosphorus metabolism. Helps regulate uptake of other nutrients.</td>
<td>Cation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mg⁺⁺</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Amino acids, vitamins. Imparts dark green color. Stimulates seed production.</td>
<td>Anion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SO₄²⁻</td>
</tr>
<tr>
<td>Boron</td>
<td>Aids carbohydrate transport and cell division.</td>
<td>Anion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H₃BO₃⁻, H₂BO₃⁻, HBO₃⁻, BO₃⁻, B₄O₇⁻</td>
</tr>
<tr>
<td>Copper</td>
<td>Enzymes, light reactions.</td>
<td>Cation*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cu⁺⁺</td>
</tr>
<tr>
<td>Iron</td>
<td>Chlorophyll formation.</td>
<td>Cation*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fe⁺⁺, Fe⁺⁺⁺</td>
</tr>
<tr>
<td>Manganese</td>
<td>Oxidation-reduction reactions. Hastens germination and maturation.</td>
<td>Cation*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mn⁺⁺</td>
</tr>
<tr>
<td>Element</td>
<td>Description</td>
<td>Cation*</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Zinc</td>
<td>Auxins, enzymes.</td>
<td>Cation*</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Aids nitrogen fixation and nitrate assimilation.</td>
<td>Anion</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Essential for nitrogen fixation.</td>
<td>Cation</td>
</tr>
<tr>
<td>Nickel</td>
<td>Grain filling, seed viability</td>
<td>Cation</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Water use.</td>
<td>Anion</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Component of most plant compounds.</td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Component of most plant compounds.</td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>Component of most plant compounds.</td>
<td></td>
</tr>
</tbody>
</table>

Source: book of fertilizers and their use. Agricultural Extension Service, the University of Tennessee

* Also available to plants in chelate form (a nutrient form having the essential nutrient linked to an organic compound so that it stays available for plant use within certain ranges of soil pH).

The data embodied in Table 4 that plants obtained the nutrients from air, water and soil system. CHO is non mineral nutrients and plants received these nutrients from soil and water. Besides these, NPK is primary/macronutrients and play an important role in growth and development of plants. Ca, Mg and S is a secondary plant nutrients and Zn, Cl, B, Mo, Cu, Fe, Mn, Co and Ni is micronutrients and also very important for plants. The data presented in Table 5 reported the function of nutrients in plants and their available form. N, P, K, Cl, Mg and molybdenum (Mo) is mobile nutrients. Because these nutrients are mobile, visual deficiencies will first occur in the older or lower leaves and effects can be either localized or generalized. In contrast, immobile nutrients [B, calcium (Ca), Cu, Fe, Mn, Ni, S and Zn] cannot move from one plant part to another and deficiency symptoms will initially occur in the younger or upper leaves and be localized. Zn is a partial exception to this as it is only somewhat immobile in the plant, causing Zn deficiency symptoms to initially appear on middle leaves and then affect both older and younger leaves as the deficiency develops. The functions of nutrients and their availability are presented in Table-5

**Sources of nutrients in flowering crops:**

**Organic manures**

Organic manures are valuable by-products of farming and allied industries, derived from plant and animal sources. These manures have the advantage of supplying secondary and micro nutrient along with NPK, which is important for sustained production
Farm Yard Manure (FYM)
FYM is a decomposed mixture of dung and urine of farm animals along with the litter (bedding material) and left-over material from roughages or fodder fed to the cattle. On an average, it contains 0.5% N, 0.2% P2O5 and 0.5% K2O

Enriched organic manure
The enriched farmyard manure is prepared by using 10 kg of rock phosphate and 10 kg of each biofer- tilizers viz., Azospirillum, Azotobacter and Phosphobacteria is thoroughly mixed with 1000 kg of decom- posed and powdered farmyard manure on dry weight basis and made into a heap like structure. The heap is kept for 60 days for composting under the shade with 60% moisture. For enriched poultry manure compost, 20 kg of rock phosphate and 10 kg of each biofertilizers viz., Azospirillum, Azotobacter and Phosphobacteria are thoroughly mixed with 1000 kg of poultry manure on dry weight basis and made into a heap like structure. The heap is kept for 60 days for composting under the shade with 60% moisture (Sims et al., 1992)

Vermicompost
Compost made from the biological activity of earthworms. It contains 1.9% N, 2.0% P and 0.8% K, 100 mg/Kg Cu and 500 mg/kg Mn. Earthworms effectively harness the beneficial soil micro flora, destroy soil pathogens and convert organic wastes into valuable products known as cast which contains biofertilizers, vitamins, enzymes, antibiotics, growth hormones and proteinaceous worm biomass. Hence, earthworms are called as 'artificial fertilizer factories'. The exotic species used for making vermicompost are Eisenia foetida, Eudrillus euginiae and Perionyx excavatus, while indeginous species include Lampito mauriti, and Perionyx sansbaricus.

Poultry manure
It is rich organic manure, since liquid and solid excreta are excreted together resulting in no urine loss.

Green Manuring
Green manure crops are grown usually for restoring or enhancing soil organic matter content, properties of soil and nitrogen content in the soil and their use in cropping system is called green manuring. Legumes are generally used as green manure crops due to their ability to fix atmospheric nitrogen in the root nodules through symbiotic association with a bacterium

According to the Chandra (2005), there are different green leaf manure crops that can be cultivated and they are:

Cowpea
Cowpea is one of the important leguminous green leaf manure crops. It has been observed that cowpea is easily decomposable and very well suited for green manure purpose. June-July months are best suited for sowing of this manure. Even though, it is being cultivated in summer months (March to April). Use of effective Rhizobium bacteria increases the fixation of nitrogen up to 40 kg/ha.
**Dhaincha (Sesbania aculeata)**

Dhaincha is suitable for loamy and clayey soils. It is fairly resistant to drought as well as stagnation of water. It grows well even in alkaline soils and corrects alkalinity if grown repeatedly for 4-5 years. The roots have plenty of nodules. It yields about 10-15 tonnes of green manure per ha and requires a seed rate of 30-40 kg/ha. Use of effective Rhizobium strain with seeds fixes the Nitrogen 1 kg/day.

**Sesbania speciosa**

It is a valuable green manure for wetlands and can be grown in a wide range of soils. Seed production is prolific however, its pods are frequently attacked by insects. This green manure can be raised on the field borders. Sesbania seedling (21days) can be planted in a single line at 5-10 cm apart in the borders of the fields. In about 90 days it produces about 2-4 tonnes of green manure per ha. It does not affect the rice yield by shading or root effect. If second rice crop is planted immediately after the first crop, the manure can be incorporated into the field. About 300-400g of seeds are sufficient to raise nursery for one ha area. To control insects *Verticillium lacanii* (Liquid) fungi is useful.

**Sunnhemp (Crotalaria juncea)**

It is a quick growing green manure crop and gets ready for incorporation in about 45 days after sowing. It does not withstand heavy irrigation leading to flooding. The crop is at times subject to complete damage by leaf eating caterpillars. The crop can produce about 8-12 tonnes of green biomass per ha. To prepare this manure, 30 kg seed per hectare is requirement.

**Sesbania rostrata**

One of the important features of this green manure is to produces nodules in the stem in addition to root nodules. The stem nodulation is an adaptation for waterlogged situation since flooding limits growth of green manures and may reduce root nodulation. Under normal condition, both root and stem nodules are effective in N fixation. It has higher N content of 3.56% on dry weight basis. Biomass production is higher during summer (April – June) than in winter (Dec. – Jan.) season. This green manure can also be produced by raising seedlings (30 days old) and planted in the paddy field along the bunds or as intercrop with rice. Use of *Rhizobium* bacteria increase the nitrogen fixation (60-100 kg/ha/year).

**Wild Indigo (Tephrosia purpurea)**

This is a slow growing green manure crop and cattle do not prefer to graze it. The green manure is suitable for light textured soils, particularly in single crop wetlands. It establishes itself as a self-sown crop and the seeds remain viable till the harvest of rice. On an average about 3-4 tonnes of green manure is obtained in one ha. The seed rate is 30 kg/ha. The seeds have a waxy impermeable seed coat and hence scarification is required to induce germination. Soaking seeds in boiling water for 2-3 minutes is also equally effective in promoting germination.
**Indigo (Indigofera tinctoria)**

It resembles wild indigo and is a long duration crop with more leafy growth. It comes up well in clayey soils with one or two irrigations.

**Pillipesara (Phaseolus trilobus)**

This is a dual purpose crop yielding good fodder for the cattle and green manure. Pillipesara comes up well in hot season with sufficient soil moisture. Loamy or clayey soils are best suited. After taking one or two cuttings for fodder or light grazing by animals, the crop can be incorporated into the soil. About 5-8 tonnes of manure can be obtained from one ha.

**Glyricidia (Glyricidia maculeata)**

This is a shrubby plant that comes up well in moist situations. Under favourable conditions, it grows well like a tree. It can be easily grown in waste lands, farm road sides, field bunds, etc. The crop can be established by stem cuttings or seedlings. It is planted on the field borders. It can be pruned for its tender loppings and compound leaves for green leaf manuring at the time of puddling rice. On an average, a well-established plant yields 12-15 kg green matter. About 400 plants on the peripheral bunds yields 5-6 tonnes green manure/ha.

**Karanj (Pongamia glabra)**

It is a leguminous tree grown in wastelands. On an aaverage, a tree can yield 100-120 kg of green matter. The leaves contain about 3.7% N (on dry weight basis).

**Calatropis (Calotropis gigantica)**

On roadsides and fallow lands, the plant grows wild under different soil and climatic conditions. The leaves are more succulent and a plant can produce about 4-5 kg of green matter. Besides, it also helps in controlling soil born pests like termite

**Oil cakes**

Many kinds of oilcakes can be used in crops as a source of nutrients. Nutrients present in oil cakes, after mineralization, are made available to crops 7 to 10 days after application. Before application to the flowering crop, oilcakes should be well-powdered to facilitate their application and decomposition by soil microorganisms. Depending on crop, oilcakes are applied broadcast, drilled or placed near the root zone. The oil cakes are of two types. Edible oil cakes which can be safely fed to livestock; e.g.: Groundnut cake, Coconut cake, Niger cake, Rape seed cake, Sesame cake etc. Non edible oil cakes which are not fit for feeding livestock; e.g.: Castor cake, Neem cake, Mahua cake, Safflower cake etc

**Biogas slurry**

Biogas (Gobar gas) plant produces methane and biogas slurry, which could be used as valuable manure in bulbous flower crops. Biogas slurry is quite rich in nitrogen than the original ingredients due to addition of living and dead micro-organisms. Biogas slurry also contains phosphates, potash, sulphur and a number of micro-nutrients like...
zinc and iron. Biogas slurry is extremely cheap and is made by locally available material. It can be directly used in rice after mixing with irrigation water.

**Urine**

Animal urine is a very good source of nitrogen, because 60% of the nitrogen excreted is found in urine and only 40% in manure. As few as two cattle can save the cash equivalent of purchasing about 100kg of urea per year. Urine can be applied directly as liquid fertiliser.

**Liquid manures**

These can be made using fresh plant material (plant tea), compost (compost tea) or fresh animal manure (manure tea). Manure tea and plant tea are both rapid sources of nitrogen, while compost tea is a more nutritionally balanced liquid fertiliser.

**Plant tea**

Fresh and green material is soaked in water for several days or weeks to undergo fermentation. Nutrient- or nitrogen-rich material should be used.

**Ashes**

The ashes of burnt organic material are often also used as organic fertiliser. Ash provides a rapid supply of phosphorous; however burning organic material also includes a loss of other nutrients and thus has severe long-term consequences.

**Biofertilizers scenario**

The biofertilizers market is projected to grow at a CAGR of 14.08% from 2016, to reach USD 2,305.5 million by 2022 (Biofertilizers Market Analysis, Grand View Research, San Francisco, USA). The market is driven by factors such as: (i) increase in demand for fertilizers due to the rise in global food production and (ii) development of new biofertilizer manufacturing technologies. The high growth potential in emerging markets and untapped regions provide new growth opportunities for the players in the biofertilizers market.

On the other hand, some factors restraining the biofertilizers market are lack of awareness and low adoption of biofertilizers coupled with poor infrastructure. Although biofertilizers were first commercialized in North America and Europe, there is increasing preference towards their use in parts of Asia Pacific and South America. North America was the largest market for biofertilizers, followed by Europe. Together these markets accounted for over 50% of the global revenue. Asia Pacific is the third largest market for biofertilizers, with increased demand from regional markets such as India, China and Taiwan. Asia Pacific is expected to witness double-digit growth over the period 2013 to 2020 due to the increased consumer preference towards organic food and growing agricultural activities. However, contrary to other regions, the key application of biofertilizers in Asia Pacific is soil treatment but not seed treatment.

In India, during the 2008-09, the production of bio-fertilizers was 25065.035 ton which had been increased upto 20040.36 and 37997.61ton in 2009-10 and 2010-11 and again reached 80696.46 ton in 2014-15 (NCOF, 2014 and 2015). It is estimated that the present requirement of biofertilizers is around 5,50,000 metric tonnes and there
is an ample potential to increase it to 50,000-60,000 tons by 2020 (Pindi and Satyanarayana, 2012); however, the total production of biofertilizers in our country is much less than requirement which points out the inevitability of increase in biofertilizer production. Biofertilizers can be grouped in to five categories (Barman et al., 2017).

Nitrogen (N2) fixing Biofertilizers: It can be sub group in three category
Free-living - Example, *Azotobacter, Clostridium, Anabaena*, Nostoc
Symbiotic - Example, *Rhizobium, Frankia, Anabaena azollae*
Associative Symbiotic - Example, *Azospirillum*

P-solubilizing biofertilizers
Bacteria - Example, *Bacillus megaterium* var. *phosphaticum, Bacillus circulans, Pseudomonas striata*  
Fungi - Example, *Penicillium sp., Aspergillus awamori*

P-mobilizing biofertilizers
Orchid mycorrhiza – Example, *Rhizoctonia solani*

Biofertilizers for micro nutrients
Silicate and zinc solubilizers - Example, *Bacillus sp.*

Plant growth promoting *Rhizobacteria*

Pseudomonas - Example, *Pseudomonas fluorescens*

**Application of bio-fertilizers**

Seed treatment was the largest application of biofertilizers and accounted for over 70% of the market in 2012. Treating seeds with biofertilizers helps them sustain bacteria and virus attacks and also helps increasing the yield. In addition, biofertilizers help in harnessing atmospheric nitrogen and making it available to the plant. Seed treated with biofertilizers are capable of increasing phosphorous content of soil by solubilizing it and improving availability. Soil treatment is the other primary application of biofertilizers and it involves the spraying of biofertilizers over the agricultural land. It increases the fertility of the soil and improves the yields of the planted crop.

**Bio-fertilizers**

It is well known fact that some biofertilizers fixed the atmospheric N and can be increased by organisms such as *Rhizobium, Azotobacter*, blue green algae, *Azolla/Anabaena* (Gaur and Singh, 1995). The commonly used organic fertilizers/biofertilizers are as follows
Azotobacters and Azospirillum

These are free-living bacteria that fix atmospheric nitrogen in cereal crops without any symbiosis and they do not need a specific host plant. Azotobacters are abundant in well-drained and neutral soil. They can fix 15-20 kg/ha N per year. Azotobacter sp. can also produce antifungal compounds to fight against many plant pathogens.

Rhizobia

Rhizobia are symbiotic bacteria that fix atmospheric N2 gas in plant root nodules and have a mutually helpful relationship with their host plants. The plant roots supply essential minerals and newly synthesized substances to the bacteria. Rhizobium inoculation is a well-known agronomic practice to ensure adequate N supply for legumes in place of N fertilizer.

Plant growth promoting rhizo-bacteria (PGPR)

PGPR represent a wide variety of soil bacteria which, when grown in association with a host plant, result in stimulation of host growth. PGPR modes include fixing N2, increasing the availability of nutrients in the rhizosphere, positively influencing root growth and morphology and promoting other beneficial plant–microbe symbioses. Some researchers have indicated that PGPR will often have multiple modes of action. Ratti et al., (2001) found that a combination of the arbuscular mycorrhizal fungi Glomus aggregatum, the PGPR Bacillus polymyxa and Azospirillum brasilense maximized biomass and P content of the aromatic grass palmarosa (Cymbopogon martinii) when grown with an insoluble inorganic phosphate.

Phosphate-solubilizing bacteria (PSB)

Under acidic or calcareous soil conditions, large amounts of phosphorus are fixed in the soil but are unavailable to the plants. Phosphobacterins, mainly bacteria and fungi, can make insoluble phosphorus available to the plant. The solubilization effect of phosphobacterins is generally due to the production of organic acids that lower the soil pH and bring about the dissolution of bound forms of phosphate. It is reported that PSB culture increased yield up to 200-500 kg/ha and thus 30 to 50 kg of superphosphate can be saved.

Vesicular arbuscular mycorrhiza (VAM)

Mycorrhizae are mutually beneficial (symbiotic) relationships between fungi and plant roots. VAM fungi infect and spread inside the root. They possess special structures known as vesicles and arbuscules. The plant roots transmit substances (some supplied by exudation) to the fungi, and the fungi aid in transmitting nutrients and water to the plant roots. Some VAM fungi form a kind of sheath around the root, sometimes giving it a hairy, cottony appearance. Because they provide a protective cover, mycorrhizae increase seedling tolerance to drought, to high temperatures, to infection by disease fungi and even to extreme soil acidity.

Inorganic fertilizer scenario

According to the Food and Agriculture report world demand for total fertilizer nutrients is estimated to grow at 1.8% per annum from 2014 to 2018. The demand for
nitrogenous, phosphatic and potash is forecasted to grow annually by 1.4%, 2.2%, and 2.6%, respectively, during the period. Over the next five years, the global capacity of fertilizer products, intermediates and raw materials will increase further. The global demand for nitrogenous fertilizers is expected to grow around 5.6% to 119.4 MT in four years through 2018, according to the Food and Agriculture Organization of the United Nations. Asian nations, led by China and India, are expected to account for 58% of this increase.

India is the 2nd largest consumer of fertilizers in the world, after China and USA. India also ranks second in the production of nitrogenous fertilizers and third in phosphatic fertilizers whereas, the requirement of potash is met through imports since there are limited reserves of potash in the country. It accounts for 12.2% of the world's production of nitrogenous (N) and phosphatic (P) nutrients and 12.6% of the world's consumption of NPK. However, India annual consumption of chemical fertilizers in nutrient terms (NPK), has increased from 0.7 lakh MT in 1951-52 to 277.39 lakh MT 2011-12 and it had been reached up to 413.24 lakh MT during the year 2016-17. Urea dominates the total fertilizer production in the country. While India is the world's second largest consumer of urea and the Government of India is working towards increasing the production of urea so as to end imports by 2022 and achieve self-sufficiency in urea production. The production of urea in the year 2015-16 was 244.8 LMT which was decreased to 241.9 LMT during the year 2016-2017. The maximum urea imported by the India was 87.49 LMT during 2014-15 and it was decreasing in 2015-16 and 2016-17 respectively. The total DAP production was 36.5 LMT during 2012-13 and it was decreased in 2013-14. The the total production of DAP in 2015-16 was 37.9 LMT and it was again increased upto 43.3 LMT during the year 2016-17. Kumar and Chaudhary, (2018) reported that during the year 2012-13, the total DAP imported from the other countries was 57.02 LMT which was decreased during the year 2013-14 and the total quantity was 32.61 LMT. The maximum DAP (60.80 LMT) was imported during the year 2016-17 and it was again decreased during the year 2016-17. Among the total fertilizers, MOP is totally imported from the other countries. Maximum MOP (41.97 LMT) was imported during the year 2014-15 and the minimum MOP imported during the year 2012-13. In the year 2015-16 lesser MOP was imported as compared to the 2014-15 but the MOP quantity again increased during the year 2016-17 and its reached upto 37.36 LMT. Out of the total fertilizer production, India produces only 10%-12% of DAP but due to recent fall of raw material prices in the international markets, phosphates have become cheaper and its economical to produce the fertilizer rather than importing the end product. Hence, the government is encouraging sprucing up the production of DAP, which is the second most widely used fertilizer after urea. Production of Complex Fertilizers includes the various grades of NPK Fertilizers (Nitrogenous- Phosphorus- Potassic). The Government is encouraging SSP production as SSP is also considered as a substitute to diammium phosphate (DAP), which is largely import based and costlier vis-a-vis to SSP.

Types of fertilizers
A fertilizer is a chemical product either mined or manufactured material containing one or more essential plant nutrients that are immediately or potentially available in
sufficiently good amounts. Chemicals fertilizers are classified on the basis of quantum required by the soil as primary, secondary and micronutrients. Primary nutrients are further categorized on the type of nutrients they are supplied to the soil which are as nitrogenous, phosphatic and potassic fertilizers. Secondary nutrients include calcium, magnesium and sulphur while micronutrients, include iron, zinc, copper, boron and chlorine. India is dependent on imports for raw materials for production of nitrogenous & phosphatic fertilizers. Product wise Chemical Fertilizers are classified into Urea, Diammonium Phosphate (DAP), Single Super Phosphate (SSP), Muriate of Potash (MOP) and other Complex fertilizers like Calcium Ammonium Nitrate (CAN) and various grades of NPK Fertilizers (Fertilizers having different grades of Nitrogen (N), Phosphorus (P), and Potassium (K)). In India the most widely used fertilizers in the Nitrogenous category are Urea, DAP and MOP for Phosphorus and Potassium respectively.

**Application of inorganic fertilizers in ornamental plants:**

For healthy growth and optimal yield of ornamental plants, nutrients must be available to plants in correct quantity, proportion and in a usable form at the right time. To fulfill these requirements, chemical fertilizers and/or organic manures are needed. Fertilization has been reported to have an influence on the phyto-nutritional quality of crops. Inorganic fertilizer is said to reduce the antioxidant levels, while organic fertilizer has been proven to enhance antioxidant content in plants. Applying fertilizers, particularly in the inorganic form, in excess of plant requirements can increase the chances of fertilizer loss and environmental pollution. Organic manures, apart from improving physical and biological properties of soil, help in improving the efficiency of chemical fertilizers. In the past, agricultural production was focused on maximizing the quantity of crop produced for commercial markets. Hence, compound fertilizer has been used as a common agricultural practice. However, recently health conscious consumers are interested in optimizing the nutritional composition with minimal chemical residues on foods produced through environmentally friendly agricultural practices. Substituting chemicals with organic fertilizers is one of the common principles in this production system. Inorganic fertilizers have had significant effects on World crop production and are essential components of today’s agriculture. Estimates show that agricultural production is raised by 50% as a result of chemical fertilizers and 60% of the population owes its nutritional survival to nitrogen (N) fertilizers. However, of the total applied N, less than 50% is recovered in the soil–plant system, while the remainder is lost to the environment (Ibrahim *et al*., 2013).

Inorganic fertilizers can be applied by hand or with application equipment. When hand applied, it is essential to distribute the fertilizers uniformly and at the recommended rates to avoid over- or under-fertilization. Application equipment needs proper adjustment to ensure uniform spreading. Broadcast fertilizer should be incorporated after application to enhance effectiveness or to avoid evaporation losses of N. With banding or spot application, take care that no fertilizer is placed too close to either the seed or the germinating plant, to avoid damage to the seedling or roots. Inorganic fertilizers need to be applied to crop at least two times within a growing season (split application), either basally at planting or top-dressed during vegetative
growth. The amount of inorganic fertilizer used in most small farms falls far below standard extension recommendations, due to poor purchasing power, risk aversion due to poor and unreliable rainfall and lack of significant returns. When available, fertilizer use is less labour intensive, thus allowing extra time for other tasks (or for earning income elsewhere (Gupta and Hussain, 2014).

Today fertilizer has become essential to modern agriculture to feed the growing population. Use of fertilizers, especially the chemical fertilizers has brought in blessings on humanity, which helped contain hunger and death in different corners of the world. Though chemical fertilizers increase crop production, their overuse has hardened the soil, decreased fertility, strengthened pesticides, polluted air and water, and released greenhouse gases, thereby bringing hazards to human health and environment as well. It has already been proved how chemical fertilizers pose serious challenges to the balanced and sustainable growth. Accordingly, scientists and researchers are seen arguing in favor of organic fertilizers as the best solution to avoid soil pollution and many other threats to environment and life caused by overuse of chemical fertilizers. Since salt content is one of the most critical characteristics of chemical fertilizers, they are expected to be harmful to agriculture in the long run as salts are harmful for plants as well as soil. Continuous use of these chemical fertilizers depletes essential soil nutrients and minerals that are naturally found in fertile soil. When we use chemical fertilizers, they do not help replenish soil nutrients and its fertility contrary to the popular belief but, replenish only nitrogen, potassium and phosphorous. And we know phosphorous does not dissolve in water and its overuse may cause hardening of soil. Alkaline fertilizers like sodium-nitrate develop alkalinity in soil reducing its fertility and making it barren. So to say, soil fertility and vegetation depend much on the balanced supply of essential nutrients and minerals. As such, overuse of specific nutrients may cause imbalance in the supply of soil nutrients further resulting in soil degradation and the loss of equilibrium of a stable soil. Though chemical fertilizers will help plants grow faster; plants will not be healthy and strong as plants grown in that manner do not have enough time to mature to develop a good root growth, strong stems, or nutritious fruits and vegetables. Even they will be less likely to survive because they will be more susceptible to pests and diseases as they lack good immune system and enough resistance against these forces. Besides this, chemical fertilizers can cause root burn or fertilizer burn, as chemical fertilizers do not allow enough water intake for the plants. As already said, chemical fertilizers are high in nitrogen salts, and when the nitrogen is absorbed by soil too quickly, it will dehydrate and dry up the plant. But organic fertilizers are not like them; they are slowly released which will allow time for microbial activity to break down the organic materials in the fertilizers. When we talk of microbial activity, we need to remember that natural microbes which include beneficial insects, fungus, and bacteria found in the soil, are very much helpful for healthy soil and plant growth. Needless to say, use of chemical fertilizers will kill these soil friendly microorganisms. In their larger threat to environment, animals and human health; chemical fertilizers will ultimately end up leaking into the adjacent water bodies; ponds, streams, ground water etc. and contaminate water supply as a result of which humans as well as animals may suffer numerous short term and long term hazardous chemical effects on their health and
body. On contrary, organic fertilizers are not so detrimental to environment. Now-a-days, organic fertilizer containing macro- and micro-nutrients are even obtained from mangrove floral resources, as these are rich in minerals and also iodine. In India, awareness is growing up gradually to grow marine floral based organic fertilizer (Zeman et al., 2014).

**Merits and demerits of inorganic fertilizers:**

a) **Merits of organic fertilizers:** the nutrients in chemical fertilizers are already in inorganic form and so can be immediately used by the plants. It is important to understand that there is no fundamental difference in nutritional quality between organic and inorganic fertilizers. Chemical fertilizers are made with synthetic ingredients designed to stimulate plant growth. Commercial chemical fertilizers have the advantage of predictability and reliability. Formulations are blended with accuracy and you can buy different blends for different types of plants. Commercial chemical fertilizers contain a balanced distribution of the three main essential nutrients needed for optimum plant growth: nitrogen, phosphorous and potassium. Many formulas also contain iron, sulfur and cooper. The amounts of the three main ingredients are listed in that order, by percentage, on commercial fertilizer labels as the N-P-K ratio. Percentages of trace minerals are not always listed. Commercial formulated fertilizers allow you to know exactly which nutrients you're giving your plants, rather than guessing at the composition of organic formulas. (www.homeguides.sfgate.com).

b) **Demerits of chemical fertilizers:** Although inorganic fertilizers are immediately available to plants, they have three major disadvantages. They are subject to leaching, which occurs when the fertilizers are washed by rain or irrigation water down below the level of the plant roots. Nitrogen is particularly susceptible to leaching. As well, a heavy application of chemical fertilizers can "burn" seedlings and young plants. This is actually a process of drying out, or desiccation, due to the presence of chemical salts within the commercial fertilizers. A third problem associated with the use of chemical fertilizers is that overly heavy applications can build up toxic concentrations of salts in the soil and create chemical imbalances (Gupta and Hussain, 2014). Commercial chemical fertilizers are more expensive than natural fertilizers. They may contain ingredients that may be toxic to the skin or respiratory system. You also need to mix and measure them accurately. If you use too much, you can kill your plants. Chemical fertilizers can build up in the soil, causing long-term imbalances in soil pH and fertility (www.homeguides.sfgate.com).

**Application of organic nutrient in ornamental plants:**

Organic nutrients applied in agriculture may originate from very different sources. They can be produced on-farm, as farmyard manure, slurries, poultry manures, or can originate off-farm (mostly from food industry residues). These materials are composed of valuable nutrient (fertilizing value) and organic matter (source of organic carbon) which can benefit the majority of crops, including horticultural ones. Their use has an important impact on all components of soil fertility (chemical, physical and biological) and on the environment (in terms of risk of both water and air pollution).
Indeed, the increased nitrogen application rates that have been registered in horticultural productions have increased the level of NO\textsubscript{3}- leaching and soil N\textsubscript{2}O release in the atmosphere and it is considered that agriculture contributes up to 90% of the total N\textsubscript{2}O anthropogenic greenhouse gas (GHG) emissions. Solid and liquid organic fertilizers are generally slow-release fertilizers and rely on biological activity for mineralization into forms that can be absorbed by the plants. They are used mainly as base dressing but the top dressing is also possible (less for leafy vegetables). For top dressing concerns are raised for the vegetables hygiene and food safety. Besides the influence of soil microorganisms, the process of mineralization depends on several environmental conditions (e.g. soil temperature and humidity) and agricultural practices (e.g. tillage stimulates mineralization). Therefore, only a portion of the applied nitrogen may be available to the crop in the season of the application. To compensate for this, the producer could consider applying liquid mineral fertilizers, particularly for short-season crops. Indeed, the lack of temporal synchrony between the mineralization of N from organic matter and its uptake by the crop is a major challenge for fertility management with organic fertilizers. As both chemical and organic fertilizers have their own advantages and disadvantages, the establishment of a complex nutrient management system is preferred for horticultural crops, although cropping systems without chemical fertilizers are also a normal practice (i.e. organic farming) (Hajdu et al., 2016).

Horticultural production firms have a diverse set of options when considering nutrient sources for crop production. A producer’s decision begins with a fundamental choice between organic, inorganic or a combination organic and inorganic nutrient management program. Increasing consumer interest in sustainable and organic crop production has resulted in greater demand for organic nutrient sources that are approved by the Organic Materials Review Institute (OMRI). The number of fertilizer products containing organic nutrient sources is increasing. Simultaneously, producer knowledge about how to manage nutrition when these nutrient sources are used is limited. Previous research has compared plant growth from inorganic and organic nutrient sources; and plant growth results varied depending on many factors (Nelson, 2013).

**Advantage of organic nutrient**

The use of organic nutrient (manure and other organic sources) could open an array of opportunities/benefits related to the agronomic, economic and social domains as:

**(a) Agronomic benefits:**

- Enhancing soil biological activity by favoring the root colonization by mycorrhizal fungi or by rhizosphere bacteria: these microorganisms can improve N, P and K supply (and of microelements) by mobilization of low-soluble nutrient,
- Improving the soil physical properties, thus ameliorating soil structure and water holding capacity,
Supplying nutrients in a balanced way, which increases plant growth and prolongs the plant health status by suppressing certain soil borne diseases and parasites,

The new organic sourced and processed fertilizers (often marketable products) make it possible to be applied according to the nutrient demand of the plant and soil status. This opportunity is mainly relevant to regions with a high soil P content, where P has become the limiting factor of fertilization.

Environmental benefits due to keeping/enhancing microbial diversity, reducing soil acidification or alkalization and by reduction of GHG emissions or decomposition of toxic substances.

(b) Economic benefits:

- Reduced needs in chemical fertilizers, soil management practices,
- Reduced costs of externalities (i.e. those linked to the whole production and utilization chains),

(c) Social benefits:

- Enhanced recycling of organic materials, with benefit for the environment and for the development of new industries/production processes,
- Facilitating the contact between local farms for exchange of organic sources which should allow to choose a product that is the most efficient for a particular crop.

Disadvantage of organic nutrient

Some disadvantage that can limit the wide use of new organic nutrient can be pointed out:

- Lack of proper common legislation that define their characteristics, quality standards, marketing requirements and safety use,
- Legislation constrains at different levels (national, regional) in the use of locally available products (particularly of animal origin) that need to undergo a slight transformation process. There is not always a very clear legislation about the use of these products,
- Limited knowledge on sustainability of the products in terms of energy consumption, overall crop applicability,
- Lack of knowledge on the availability and on the characteristics (e.g. quality according to the source linked with quality assurance and certification) of the new organic nutrients,
- Lack of knowledge at farmers level about the effectiveness of the new organic nutrients, which reduces their potential application,
- Lack of monitoring the manure stocks and trade (exchanges). The monitoring/registration system is different in the EU regions, there are sources of organic fertilizers which are not monitored (e.g. chicken manure in
Hungary). There is also a differentiated monitoring by central authorities (e.g. registration only in the nitrate vulnerable zones) and statistical offices (national registration).

- Some particularities for new organic nutrients are:
  - They are comparatively low in nutrient content, so a larger volume is needed to provide enough nutrients for crop growth,
  - The nutrient release rate is rather slow to meet crop requirements in a short time, therefore nutrient deficiency may occur for some specific crop types,
  - The major plant nutrients may not exist in organic fertilizer in sufficient quantity to sustain maximum crop growth. For example manure can be processed in order to have a better nutrient ratio or a combination of products can used,
  - For some organic products as the compost and digestate the nutrients are highly variable, compared with chemical fertilizers the composition is input dependent,

In cases when the organic sourced fertilizers has to transported to large distances (the optimum is below 5-7 km) and there are large amounts used/hectare, the total cost (transportation and fertilizer cost) can be higher compared to the chemical nutrient (Hajdu et al., 2016).

**Application of both (organic and inorganic) nutrient in ornamental plants:** The application of organic wastes combined with or without mineral fertilizer to soil is considered as a good management practices in any agricultural production system because it improves, plant quality and soil fertility (Mahmoud et al., 2009). Many studies have been conducted comparing organic to industry-standard inorganic fertilizer regimens. Some studies support grower experiences indicating that with proper management, organic fertilizers can be used to produce high quality crops during greenhouse production. However, there are also many studies reporting reduced plant quality with organic fertilizer use (Peet et al., 2004). A reduction in plant quality when using organic nutrient sources may be due to multiple factors. Among these factors is the differing rate of nutrient mineralization from different organic sources. This difference contributes to the unpredictability of organic fertilizer performance. A study has explored nutrient release from three soluble organic fertilizers in an incubation study and greenhouse bioassay with turf in which he found that nitrification was rapid, with > 90% of mineral nitrogen in nitrate form after only 1-week of incubation at 25°C. Dry organic fertilizers such as fish waste, guano, and feather meal all have nitrogen content >10% dry weight and relatively rapid nitrogen mineralization in agricultural soils; studies show that 60 to 80% of the N is available within 4 to 8 weeks (Hartz and Johnstone, 2006). Described the same variability in nitrogen mineralization from liquid-based organic fertilizers and reported different mineralization rates at different substrate temperatures when using the same organic nutrient source. With the observed variability in organic nutrient mineralization rates, and conflicting evidence on the efficacy of organic fertilizers when compared to inorganic nutrient sources, the need for further investigation of organic fertilizers in horticultural production systems is evident (Gaskell, 2006).
Integrated nutrient management in flowering crops:

Sustainable agriculture has become a burning issue due to “energy crisis” and “environmental protection”. One aspect of sustainable agriculture is Integrated Nutrient Management (INM). Many regions in India like Kashmir, Himachal and other hilly regions have huge potential for quality flower production. Since floriculture is energy and cost intensive type of farming, the input cost of fertilizers is very high, which can be avoided by going for alternative methods like INM. There is scant information available concerning the use of organic fertilizer as the sole source of nutrients in flower production, especially in the cultivation of flowers has made its applicability more difficult. INM is a practice that is being rapidly adopted by growers, combines the use of adjusted nutrient rates, more efficient fertilizer sources, organic matter and soil inoculation. INM holds great promise in exhibiting the growing nutrient demands of intensive farming like Floriculture and maintaining productivity at its optimum with holistic improvement in the quality of resource base, which is very much important in case of cut and bulbous flowers. Investigations by many researchers have revealed the beneficial influence of INM, on vegetative (plant height, leaf area, leaf number), floral (first bud appearance, floral diameter, weight of flower) and yield attributes (seed weight, seed production) of many flower crops, reduced the cost of fertilizer inputs and increased the B/C ratio, despite maintaining a good soil physico-chemical environment. It can be concluded that by reducing the levels of chemical fertilizer and optimizing the dose of different organic fertilizer can improve yield and quality in ornamental crops without adversely affecting the edaphic and environmental features (Wani et al., 2017).

Integrated nutrient management (INM) programme is a critical component of the type of integrated farming systems (Edwards et al., 1990). The program involves maximize biological inputs to crop production and minimize the use of inorganic amendments so as to create a much more sustainable pattern of crop production, not only ecologically but also environmentally (National Research Council, 1991). Integrated Nutrient Management in floricultural crops is very important to address the issues like poor quality of cut flowers and planting material, inappropriate planting methods and fertilization practices which result in low yield and production. One of the factors affecting the productivity of most of the floricultural crops is improper use of nutrients. To improve the productivity, adequate amount of fertilizers in balanced proportion should be used which has been given less attention by the flower growers or floriculturists. Kumar and Chaudhary (2018) revealed that INM increases crop growth and yield of floricultural crops as compared with conventional methods. Proper nutrient supply practices increases nutrients use efficiency and improving soil health and sustainability. Strong and convincing evidence indicates that INM practice could be an innovative and environment friendly practice for sustainable growth and yield of floricultural crops.

Advantage of integrated nutrient management

- Enhances the availability of applied as well as native soil nutrients.
- Synchronizes the nutrient demand of the crop with nutrient supply from native and applied sources.
• Provides balanced nutrition to crops and minimizes the antagonistic effects resulting from hidden deficiencies and nutrient imbalance.
• Improves and sustains the physical, chemical and biological functioning of soil.
• Minimizes the deterioration of soil, water and ecosystem by promoting carbon sequestration, reducing nutrient losses to ground and surface water bodies and to atmosphere.

Disadvantage of integrated nutrient management

• Organic sources used in INM are comparatively low in nutrient content, so larger volume is needed to provide enough nutrients for crop growth.
• The nutrient composition of compost and FYM is highly variable; the cost is high as compared to chemical fertilizers.

References:

• Hajdu, Z., Malusa, E., coopman, F. and Neve, S. (2016). Opportunities and bottlenecks in the utilisation of new kinds of organic fertilizers,1-8


Nelson, G.S. (2013). Organic and inorganic fertilization with and without microbial inoculants in peat-based substrate and hydroponic crop production, 1-10


Advances in Horticultural Crops


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INTRODUCTION

Protoplast is the living content of a cell that is surrounded by a plasma membrane. It includes the entire cell without its inherent cellulosic cell wall. Protoplasts are important sources of improvement and are unique for studying the structure and function of cell organelles, cytoplasmic membrane transport in plants, genetic manipulations and cell wall formation. Protoplast fusion is one of the important means to overcome barriers that exist between plant species or genera or in other words, it is used to overcome barriers that arise due to various inter-generic or inter-specific crosses. Protoplast fusion enables to transfer desirable qualities like resistance to pathogens or stress factors, even between the genotypes that cannot be hybridized in a traditional way. Fusion of protoplasts is relatively a new versatile technique to induce or promote genetic recombination in a variety of prokaryotic and eukaryotic cells. The high regeneration ability of protoplasts is a pre-requisite for protoplast utilization in crop improvement programmes. For obtaining a high regeneration frequency, it is necessary to optimize the conditions of protoplast isolation, culture density, composition of culture media and growth regulator concentrations, dark and light periods in the initial culture phase and the developing phase of calli capable of transfer to an induction medium. The mechanical isolation of protoplasts was first time carried out by Klercker (1892) from the tissue of Stratiotes aloides L. In 1960, large number of protoplasts were obtained from the root tips of tomato Solanum lycopersicon Mill. by applying enzymes with cellulase and pectinase activity. In 1978, protoplast fusion between Solanum tuberosum L. and Solanum lycopersicum L. resulted in hybrid cells which were regenerated fully into complete plants which else was not possible by sexual hybridization. Some of the important functions of protoplast are as under:

1. The protoplast in culture can be regenerated into a whole plant.
2. Hybrids can be developed from protoplast fusion.
3. It is easy to perform single cell cloning with protoplasts.
4. Genetic transformations can be achieved through genetic engineering of protoplast DNA.
5. Protoplasts are excellent materials for ultra-structural studies.
6. Isolation of cell organelles and chromosomes is easy from protoplasts.
7. Protoplasts are useful for membrane studies (transport and uptake processes).
8. Isolation of mutants from protoplast cultures is easy.
Isolation of Protoplasts

For protoplastic fusion to be carried out, it is important that the cell wall of plants or microorganisms is degraded. There are two important methods of separation of protoplasts:

a) Mechanical method

b) Enzymatic method.

A. Mechanical method:

This method of isolation is crude and tedious and results in the separation of a very small number of protoplasts. The technique involves the following stages:

Epidermis → a plasmolysed cell → dissection of a cell → protoplast released

A small piece of epidermis from a plant is selected and the cells are subjected to plasmolysis which results in shrinking of protoplasts away from the cell walls. For plasmolysis, the source tissue is placed in a hypertonic solution (about 13%) of mannitol (Katarzyna, 2014) which provides stable osmotic environment and prevents the unusual expansion and bursting of protoplast even after loss of cell wall. The plasmolysed tissue is then dissected to release the protoplasts. This method of isolation is no more in use because of certain limitations viz., yield of protoplasts and their viability is low, restricted to certain tissues with vacuolated cells, laborious and tedious method. However, it eliminates the unknown influence of enzymes on protoplasts (Grzebelus et al. 2012a).

Enzymatic method: In order to overcome the limitations of above method, use of enzymes for protoplast isolations has become the matter of choice because protoplasts are gained at a high quantity, cells are not damaged and the osmotic conditions may be influenced. This method causes minimal or no damage to the protoplasts. The mesophyll tissue, being more responsive, of fully expanded leaves of young plants or newly developed shoots are most frequently used for isolation. It can be completed by two approaches:

a) In case of two step or sequential method, the tissue is first treated with pectinase (macerozyme) to separate cells by degrading middle lamella. These free cells are then exposed to cellulose to release protoplasts. The leaf segments in an enzyme mixture A (0.5 % macerozyme + 0.3% potassium dextran sulphate in 13% mannitol at pH 5.8) are vacuum infiltrated for 5 minutes and then transferred to water bath at 25°C and subjected to slow shaking. After 15 minutes, the enzyme mixture is replaced by the fresh enzyme mixture A. Now the leaf segments are incubated for another hour and the mixture is filtered using nylon mesh, centrifuged at a speed of 100 g for 1 minute and then washed three times with 13% mannitol. The pure sample of isolated protoplasts so obtained is then incubated with enzyme mixture B (2 % cellulose in 13% solution of mannitol at pH of 5.4) for about 90 minutes at 30°C. Following incubation the mixture is centrifuged at a speed of 100 g for 1 minute, after which the protoplast form a pellet. Now the protoplasts are cleaned by one step method.
b) One step or simultaneous/direct method involves the simultaneous use of both the enzymes that is, macerozyme and cellulose and is preferred method for protoplast isolation. In this method, the cells are exposed to the enzymes for a shorter time than at two-step isolation. The leaf segments are incubated overnight (15-18h) with enzyme mixture (0.5% macerozyme + 2% cellulose in 13% sorbitol or mannitol at pH 5.4) at 25°C and teased gently to liberate the protoplasts. The mixture is then filtered through fine wire gauge to remove leaf debris, transferred to screw-capped tubes and centrifuged at a speed of 100 g for 1 min, after which the protoplasts form a pellet. The supernatant is discarded and the process is repeated three times. Now the protoplasts are washed three times with 15% sorbitol which is later replaced by 20% sucrose solution and centrifuged at a speed of 200g for 1 min. The cleaned protoplast will now float and can be pipetted out and bulked. The yield of protoplasts is higher because both the palisade and spongy parenchyma cells of mesophyll tissue of leaves are used.

Factors to be considered for isolation of protoplasts:
A number of factors influence protoplast release like thickening of cell walls, temperature, duration of enzyme incubation, pH of the enzyme solution, gentle agitation, and nature of the osmoticum and the individual steps during the isolation of protoplasts. (Sinha et al., 2003). Some the important ones are described as under:

Nature of plant material
Any plant tissue or organ viz., leaves, shoot apices, roots, coleoptiles, hypocotyls, petioles, embryos, pollen grains, calli or cell suspensions can be used for isolation of protoplasts. Among these, the mesophyll tissue of fully expanded leaves of young plants or new shoots are more frequently used. For example, in case of genus Brassica, leaf mesophyll is the most reliable source enabling the isolation of a high number of relatively uniform cells. Both field grown and protected plant material can be taken for isolation of protoplasts. The physiological condition of the plant influences the success of the isolation of protoplasts, therefore the plants grown under controlled conditions (light, temperature) are considered as the reliable source. In order to ensure high yields of viable protoplasts, growing conditions of shoot cultures must be optimum. Lighting conditions and the growth medium are especially important (Grzebelus et al. 2012a).

Table 1. Sources of protoplasts from different vegetable species

<table>
<thead>
<tr>
<th>Species</th>
<th>Source of protoplasts</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brassica carinata</td>
<td>Mesophyll leaf cells</td>
<td>Beránek et al., 2007, Klíma et al., 2009</td>
</tr>
<tr>
<td>B. rapa</td>
<td>Hypocotyl</td>
<td>Chikkala et al., 2009</td>
</tr>
<tr>
<td>Brassica napus</td>
<td>Leaves</td>
<td>Klíma et al., 2009 and Watanabe et al., 2002</td>
</tr>
<tr>
<td>Brassica oleracea var. botrytis</td>
<td>Leaves</td>
<td>Kielkowska and Adamus 2012</td>
</tr>
<tr>
<td>Plant</td>
<td>Tissue</td>
<td>Authors</td>
</tr>
<tr>
<td>---------------</td>
<td>----------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td><em>Brassica sp.</em></td>
<td>Hypocotyls</td>
<td>Cardoza and Stewart, 2004</td>
</tr>
<tr>
<td><em>Broccoli</em></td>
<td>Younger leaves</td>
<td>Kennedy et al., 2005, Kirti et al., 2001</td>
</tr>
<tr>
<td><em>Vicia faba</em></td>
<td>Root nodules</td>
<td>Peiter et al., 2003</td>
</tr>
<tr>
<td><em>Cucumis metuliferus</em>, <em>C. melo</em> and <em>Solanum tuberosum</em> (<em>S. pinnatisectum</em>, <em>S. bulbocastanum</em>)</td>
<td>Callus</td>
<td>Navratilova et al., 2006</td>
</tr>
<tr>
<td><em>Brassica oleracea</em> ssp. alba and rubra, <em>B. oleracea</em> var. sabauda</td>
<td>Hypocotyls, leaves</td>
<td>Agnieszka Kielkowska &amp; Adela Adamus, 2012</td>
</tr>
<tr>
<td><em>Beta vulgaris</em></td>
<td></td>
<td>Grzebelus et al., 2012b</td>
</tr>
<tr>
<td><em>Dacus carota</em></td>
<td>Shoots</td>
<td>Katarzyna (2014), Grzebelus et al., 2012a</td>
</tr>
</tbody>
</table>

**Enzymes**

The enzymes that can digest the cell wall are required for protoplast isolation. As plant cell wall is mainly composed of cellulose, hemicelluloses and pectin which can be respectively degraded by the enzyme cellulases, hemicellulases and pectinases. Cellulase and hemicellulase decompose the cell wall and releases protoplasts. Pectinases dissolve the middle lamella thus separates the individual cells. Density and viability of isolated protoplasts depend on the concentration of used enzymes, the period of enzymatic action and pH of the enzymatic solution. A slight change in pH is detrimental and may reduce the viability of protoplasts, thus the stability of the protoplasts can be increased by addition of certain inorganic solutes like (Ca$^{2+}$) or organic buffers (morpholino ethane sulphonic acid) that minimizes the changes during incubation. There are various enzymes that are used for protoplast isolation and are commercially available. These enzymes are used at a pH of 4.5 to 6.0 and temperature of 25-30°C with a wide variation in incubation period that may range from half an hour to 20 hours (Agnieszka et al., 2014). However, the exact concentrations and time of treatment vary with the genotype. The digestion environment may contain many toxic compounds, such as enzyme impurities and components released after tissue wounding. Thus, digestion time is a critical factor for good protoplast viability. Salts, growth regulators, and buffers in the isolation medium are also important for long-term viability of protoplasts. The purification of protoplasts and
perfect removal of the residues of cell walls, damaged protoplasts and isolation enzymes are the condition of further cultivation of protoplasts and are done by repeated centrifugation (Veera et al., 2009).

Some of the commercially available enzymes for protoplast isolation:

<table>
<thead>
<tr>
<th>Enzyme A. Cellulases</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulase YC</td>
<td><em>Trichoderma virde</em></td>
</tr>
<tr>
<td>Cellulysin</td>
<td><em>Trichoderma virde</em></td>
</tr>
<tr>
<td>Driselase</td>
<td><em>Irpex lactus</em></td>
</tr>
<tr>
<td>Cellulaseonozuka R-10</td>
<td><em>Trichoderma virde</em></td>
</tr>
</tbody>
</table>

**Hemocellulase**

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemicellulase</td>
<td><em>Aspergillus niger</em></td>
</tr>
<tr>
<td>Helicase</td>
<td><em>Helix pomatia</em></td>
</tr>
<tr>
<td>Rhozyme HP 150</td>
<td><em>Aspergillus niger</em></td>
</tr>
<tr>
<td>Hemicellulase H 2125</td>
<td><em>Rhizopus sp</em></td>
</tr>
</tbody>
</table>

**Pectinases**

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macerase</td>
<td><em>Rhizopus arrhizus</em></td>
</tr>
<tr>
<td>Pectolyase</td>
<td><em>Aspergillus japonicas</em></td>
</tr>
<tr>
<td>Macerozyme R 10</td>
<td><em>Rhizopus arrhizus</em></td>
</tr>
<tr>
<td>Zymolyase</td>
<td><em>Arthrobacter luteus</em></td>
</tr>
</tbody>
</table>

**C. Osmotic conditions**

The osmotic pressure of isolated protoplasts is adjusted by adding mannitol, sorbitol, glucose or sucrose into the enzymatic mixture, washing solution and culture medium for better stability of protoplasts. Osmotic potential between 470 and 700 mOsm is considered as optimum. A higher value of the osmotic potential prevents the bursting of protoplasts, but it can lead to the inhibition of their division.

**Purification of protoplasts**

Purification of protoplasts is necessary to remove undigested cells, tissues, broken protoplasts and cell clumps. The isolated protoplasts are present in the media with cell debris and can be removed by sedimentation, floatation, filtration or by washing. A nylon sieve of (50–100 μm) is used to remove larger parts of undigested tissue and cell clusters. Damaged cells and isolation enzymes can be removed by repeated centrifugation (3–10 min, 75–100 × g). The crude preparations are further purified by density-gradient centrifugation using percoll (Pharmacia). Protoplasts are re-suspended in an isotonic solution of 60% (w/v) percoll, 1.2 M sorbitol and pH 6.0 of density 1.156 g ml⁻¹. This is similarly buffered with isotonic percoll diluted to lower densities to form discontinuous gradients and further centrifuged at 400g for 15 minutes using a swing out rotor. Percoll is removed from the purified protoplast preparation by diluting five to ten folds with SM buffer and centrifuging (400g for 1 min) in an angle head rotor.
Determination of plating density and viability of protoplasts

It is essential to ensure that isolated protoplasts are healthy and viable so that they are capable of undergoing sustained cell divisions and regeneration. For successful cultivation of protoplasts, their high viability and sufficient density are important. The plating density of the protoplast can be determined by using Fuchs-Rosenthal haemocytometer which facilitates adjusting the density of protoplasts to an appropriate level. The protoplasts fail to divide if their plating density ranges about 10 times to the said optimum value. Generally, the optimum plating density is in the range $5 \times 10^4$ to $1 \times 10^6$ protoplasts ml$^{-1}$. Cells stimulate mitotic division of adjacent cells by releasing growth factors, including amino acids, into the surrounding medium, a process commonly known as medium conditioning or nurse culture.

The viability of protoplasts in a given sample is most frequently determined by using several dyes including Flourescein diacetate (FDA) staining and Calcofluor white (CFW). These dyes accumulate inside the viable protoplasts and can be determined by fluorescence microscopy. Use of Evans blue is another device for testing the viability of protoplasts. Impermeability of the cell to this dye presumably indicates viability of protoplasts. Cyclosis or protoplasmic streaming can also be helpful in testing the viability of protoplasts.

**Effect of enzyme treatment duration on viability of protoplasts of B. oleracea var. botrytis cv. Siria and B. napus (OP-1)**

<table>
<thead>
<tr>
<th>Duration of enzyme treatment</th>
<th>No. of protoplasts (MFA)</th>
<th>No. of viable protoplasts</th>
<th>Viable protoplasts (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10–12 h</td>
<td>14.1</td>
<td>6.9</td>
<td>48.9</td>
</tr>
<tr>
<td>16–18 h</td>
<td>13.4</td>
<td>4.0</td>
<td>29.9</td>
</tr>
</tbody>
</table>

*Narpal et al., 2006*

**Regeneration in a mesophyll protoplast culture of B. oleracea var. botrytis cv. Siria and B. napus breeding line OP-1**

<table>
<thead>
<tr>
<th>Species</th>
<th>Culture density</th>
<th>Plating efficiency (%)</th>
<th>Callus formation frequency (%)</th>
<th>Percentage of regeneration (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>B. oleracea</em></td>
<td>$11.2 \times 10^4$/ml</td>
<td>$80.87 \pm 4.96$</td>
<td>$47.99 \pm 7.80$</td>
<td>$69.05 \pm 7.45$</td>
</tr>
<tr>
<td><em>B. napus</em></td>
<td>$9.8 \times 10^4$/ml ±</td>
<td>$47.94 \pm 7.43$</td>
<td>$39.96 \pm 5.31$</td>
<td>$2.72 \pm 2.98$</td>
</tr>
</tbody>
</table>

*Narpal et al., 2006*
In vitro responses of protoplasts isolated from various Australian sourced cauliflower cultivars (Chikkala *et al.*, 2009)

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Protoplast yield (x10^6 p/g fwt)</th>
<th>Viability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thalassa</td>
<td>2.6</td>
<td>96.0</td>
</tr>
<tr>
<td>White Star</td>
<td>2.2</td>
<td>97.0</td>
</tr>
<tr>
<td>Brittany</td>
<td>2.1</td>
<td>96.7</td>
</tr>
<tr>
<td>Quick Heart</td>
<td>2.0</td>
<td>96.0</td>
</tr>
<tr>
<td>All Year Hybrid</td>
<td>2.6</td>
<td>96.2</td>
</tr>
<tr>
<td>Phenomenal Early</td>
<td>2.7</td>
<td>96.7</td>
</tr>
<tr>
<td>Early Glory</td>
<td>2.5</td>
<td>97.5</td>
</tr>
</tbody>
</table>

# p/g fwt: protoplast per gram of fresh fruit weight of leaf tissue

Protoplast yield and viability of leaf-derived protoplasts from different species of *Daucus* genus

<table>
<thead>
<tr>
<th>Accession</th>
<th>Protoplast yield (x10^6/g FW) Mean ± SE</th>
<th>n</th>
<th>Protoplast viability (%) Mean ± SE</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>D. carota subsp. Sativus</em></td>
<td>4.5 ± 1.2 a 2</td>
<td></td>
<td>66.6 ± 2.6 bc 4</td>
<td></td>
</tr>
<tr>
<td><em>D. carota subsp. Azoricus</em></td>
<td>2.9 ± 1.2 ab2 2</td>
<td></td>
<td>92.6 ± 3.2 a 2</td>
<td></td>
</tr>
<tr>
<td><em>D. carota subsp. Drepanensis</em></td>
<td>4.5 ± 0.6 a 3</td>
<td></td>
<td>73.9 ± 6.6 ab 6</td>
<td></td>
</tr>
<tr>
<td><em>D. carota subsp. maritimus</em></td>
<td>4.0 ± 0.4 a 4</td>
<td></td>
<td>475.8 ± 9.6 ab 5</td>
<td></td>
</tr>
<tr>
<td><em>D. aureus</em></td>
<td>2.6 ± 0.7 ab3 3</td>
<td></td>
<td>63.0 ± 0.3 bc 3</td>
<td></td>
</tr>
<tr>
<td><em>D. montevidensis</em></td>
<td>1.4 ± 0.4 b 5</td>
<td></td>
<td>48.9 ± 1.6 c 4</td>
<td></td>
</tr>
<tr>
<td><em>D. pusillus</em></td>
<td>1.7 ± 0.3 b 5</td>
<td></td>
<td>72.2 ± 5.7 ab 6</td>
<td></td>
</tr>
<tr>
<td>Mean/total</td>
<td>2.8 ± 0.3 24</td>
<td></td>
<td>69.7 ± 2.9 30</td>
<td></td>
</tr>
</tbody>
</table>

Katarzyna *et al.*, 2014
FW : fresh weight, n : number of independent protoplast isolations. Means within columns with the same letters were not significantly different at $P \leq 0.05$

**Effect of accession and different conditions during protoplast culture on regeneration capacity from 2-month-old protoplast-derived tissue within the *Daucus* genus**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Accession</th>
<th>Normal plants (mean ± SE)</th>
<th>Abnormal plants (mean ± SE)</th>
<th>Clumps of non regenerating callus (mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>D. carota subsp. Sativus</em></td>
<td>20.5 ± 4.4 b</td>
<td>12.2 ± 2.5 b</td>
<td>45.4 ± 16.3 a</td>
</tr>
<tr>
<td></td>
<td><em>D. carota subsp. Azoricus</em></td>
<td>9.2 ± 3.7 b</td>
<td>1.3 ± 0.6 b</td>
<td>9.7 ± 5.8 b</td>
</tr>
<tr>
<td></td>
<td><em>D. carota subsp. Drepanensis</em></td>
<td>18.3 ± 4.2 b</td>
<td>30.7 ± 9 a</td>
<td>10.1 ± 3.1 b</td>
</tr>
<tr>
<td></td>
<td><em>D. carota subsp. Maritimus</em></td>
<td>8.3 ± 2.4 b</td>
<td>0.5 ± 0.4 b</td>
<td>7.3 ± 2.8 b</td>
</tr>
<tr>
<td></td>
<td><em>D. aureus</em></td>
<td>73.2 ± 33.7 a</td>
<td>6.5 ± 1.9 b</td>
<td>17.6 ± 7.7 b</td>
</tr>
<tr>
<td></td>
<td><em>D. montevidensis</em></td>
<td>0.0 ± 0.0 b</td>
<td>0.0 ± 0.0 b</td>
<td>0.0 ± 0.0 b</td>
</tr>
<tr>
<td></td>
<td><em>D. pusillus</em></td>
<td>0.0 ± 0.0 b</td>
<td>0.0 ± 0.0 b</td>
<td>0.0 ± 0.0 b</td>
</tr>
<tr>
<td><strong>Culture technique</strong></td>
<td>ETAF</td>
<td>20.2 ± 8.3</td>
<td>2.0 ± 0.5 b</td>
<td>21.3 ± 5.3 a</td>
</tr>
<tr>
<td><strong>ETAF</strong></td>
<td>TAL</td>
<td>11.7 ± 1.7</td>
<td>11.7 ± 3.0 a</td>
<td>3.5 ± 0.9 b</td>
</tr>
</tbody>
</table>

Katarzyna et al., 2014

# TAL: thin alginate layer; ETAF: extra thin alginate film

**Cultivation of protoplasts**

Isolated protoplasts require osmotic protection until their new primary walls can counteract the turgor pressure exerted by the cytoplasm. Media added with osmotix, usually a non metabolisable sugar alcohol, such as mannitol, or sorbitol can be added to maintain the osmotic potential of the culture media. Protoplasts from different species and from different tissues of the same species may vary in their nutritional requirements. Liquid, semi-liquid or solid media are used for cultivation of protoplasts but mostly liquid medium is preferred because it avoid build up of toxic exudates around cells. In liquid culture, the medium can be refreshed periodically, thus reducing the concentration of toxic exudates. The protoplasts can be suspended in a liquid medium in Erlenmeyers flask without shaking and can be cultured in small quantities in hanging drops (or in micro drop arrays) or in micro chambers. There are three important ways of culturing in liquid media:
a) drop cultures, cultivation in small drops 40–100 μl placed on the inside of the lid of Petri dish,
b) microchamber cultures, similar to drop cultures, drops of 30 μl containing 1 to several protoplasts,
c) microdroplet cultures, the drops are minimized and each can contain only one protoplast,
d) protoplast suspension is in a thin layer at the bottom of Petri dish.

The plating of protoplasts involves protoplast culture in 1.6 percent of difco agarified medium (37°C) and then pouring off into small petri plates containing agar medium. The agar medium provides good support and thus can be easily handled. Most commonly MS media supplemented with auxin and cytokinin is used, although exceptions exist where only auxin is required, as in carrot and *A. thaliana* (Dovzhenko et al., 2003). Sucrose and glucose are the regular choices of carbon sources in most media.

**Effect of different media on shoot regeneration from protoplast derived calli in *Brassica oleracea var. botrytis*cv. Siria**

<table>
<thead>
<tr>
<th>Medium **</th>
<th>No. of cultured calli</th>
<th>No. of survived calli</th>
<th>No. of calli with shoots</th>
<th>Regeneration (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>327</td>
<td>327</td>
<td>225</td>
<td>68.80</td>
</tr>
<tr>
<td>E1</td>
<td>280</td>
<td>280</td>
<td>177</td>
<td>63.20</td>
</tr>
<tr>
<td>E2</td>
<td>202</td>
<td>193</td>
<td>59</td>
<td>30.56</td>
</tr>
<tr>
<td>E3</td>
<td>107</td>
<td>99</td>
<td>14</td>
<td>14.14</td>
</tr>
</tbody>
</table>

*Narpal et al., 2006*

**E – 2% sucrose, 1 mg/l NAA, 0.02 mg/l GA3, 1 mg/l iP; E1 – 2% sucrose, 0.25 mg/l NAA, 0.02 mg/l GA3, 1 mg/l iP, 100 ml/l coconut milk, 4 g agarose; E2 – 2% sucrose, 3.0 mg/l BAP, 0.1 mg/l GA3, 4 g agarose; E3 – 1 mg/l NAA, 0.02 GA3, 1 mg/l BAP**

**Regeneration from protoplasts**

Regeneration of cell wall from cultured protoplasts is completed within few hours and may take several days to complete the process under suitable conditions. Freshly formed cell wall is composed of loosely arranged micro fibrils which later on organize to form a typical cell wall. Majority of the cell organelles aggregate around the nucleus and represent the first visible signal of the protoplast growth. Loss of spherical shape of cell wall indicates that cell wall has started regenerating. Protoplasts that cannot regenerate their own cell wall are not capable of normal mitosis. The ability of protoplasts to divide may range between 0% and 80%. It was found in hypocotyl protoplasts of *Brassica napus* that after 6 days of cultivation only 20% of cells divided. Tylicki et al. (2002, 2003) used an immune detection approach to monitor changes in
the tubulin cytoskeleton during protoplast culture and plant regeneration in *Solanum lycopersicoides*. Asamoto *et al.* (2003) observed unusual elongated fibres in protoplasts from leaves of *Betula platyphylla* and embryogenic cells of *Larix leptolepis*, with calcium and magnesium ions, respectively, having most significant effects on such structures in protoplasts of these genera. The fibres fluoresced with Calcoflour White and Aniline Blue, indicating the presence of cell wall components, including callose (beta-1,3-Glucan). Hasegawa *et al.* (2002) reported an efficient method for plant regeneration from protoplasts of 6-year-old callus of garlic. Majewska-Sawka and Munster (2003) suggested that the recalcitrance to regeneration of mesophyll cells of sugar beet may be related to newly synthesised cell wall components containing large quantities of pectins, arabino galactan proteins, and callose.

**Protoplast Fusion**

It is a novel technique to make crosses between different species or genera to transfer both nuclear and cytoplasmic hereditary information from both the parents which could not be achieved in sexual process, thus leads to the formation of mixture of genetic information. This technique of hybrid production through the fusion of protoplast from different genetic backgrounds is known as somatic hybridization or para sexual hybridization or protoplast fusion and is an important means to transfer genes encoding male sterility which otherwise was not possible by conventional methods. It has a greater scope of introducing genetic variability to achieve resistance to diseases and pests, tolerance to a biotic stresses and improving growth and quality of the product. Qian *et al.* (2003) generated somatic hybrids between *Brassica napus* and *B. rapa* and reported that the source of parental material influenced the characteristics of the resultant somatic hybrid plants while as Ishikawa *et al.* (2003) fused leaf protoplasts of *Moricandia arvensis* (2n=28) with hypocotyl protoplasts of *B. oleracea* (2n=18) to generate novel hybrids (2n=46). Chloroplast and mitochondrial DNAs were from *M. arvensis*, with leaf anatomy having a characteristic C3–C4 intermediate trait typical of *M. arvensis*. Such somatic hybrids will be useful bridging material to introduce the C3–C4 trait into Brassicas. Protoplast fusion has also been widely used in *Solanum* species, particularly potato (*Solanum tuberosum*) to widen the gene pool and to increase the genetic diversity (Orczyk *et al.*, 2003). Isolated protoplasts are surrounded by flexible plasma membrane with its outer surface negatively charged. The lack of cell wall allows the plasma membrane of two or more protoplasts to come in close contact. Protoplast fusion can be broadly classified into two categories:

1. **Spontaneous fusion**: Spontaneous fusion is an uncontrolled fusion of two or more protoplasts. Protoplast during isolation often fuse spontaneously and this phenomenon is called spontaneous fusion. During the enzymatic degradation of cell walls, some of the adjacent protoplasts may fuse together to form homokaryons or heterokaryons. This type of fusion, more common in protoplasts of actively dividing cells or due to expansion and coalescence of plasmodesmatal connections between the cells, is strictly intra specific and has no significance. However it may be important to study the nature and function
of plasmodesmata, physiology and control of mitosis in multinucleated cells, nuclear fusion and chromosome doubling.

2. **Induced fusion:** Fusion of freely isolated protoplasts from different sources with the help of fusion inducing chemicals agents is known as induced fusion. Here the membrane is destabilized temporarily during the formation of pores and cytoplasmic connections among neighbouring protoplasts. Fusion agents are important because isolated protoplasts do not fuse with each other because the surface of isolated protoplast carries negative charges (-10mV to -30mV) around the outside of the plasma membrane and thus there is a strong tendency in the protoplast to repel each other due to their same charges. This type of fusion can be done physically by bringing protoplasts into intimate contact with micromanipulators, micropipettes or by electro fusion but chemo fusion using a suitable fusogen like phosphor ethyl glycol is most frequently used for fusion of isolated protoplasts.

   a) **Chemofusion:**
   A number of chemicals, known as fusogens, can be used for fusion of isolated protoplasts. The mechanism involved is reduction of negative charge on the surface of protoplasts which allows the cytoplasmic membranes to come closer to each other and result in fusion. These agents include sodium nitrate, polyethylene glycol, Calcium ions (Ca$^{2+}$). Chemical fusogens cause the isolated protoplast to adhere each other and leads to tight agglutination followed by fusion of protoplast. A relatively high concentration of fusogen (NaNO$_3$, CaNO$_3$, polyvinyl alcohol, polyethylene glycol) in combination with high pH (9.0–10.5) and Ca$^{2+}$ ions is used. These factors disrupt the integrity of the cytoplasmic membrane because they change its surface charge. PEG (Phospho ethylene glycol) is the most effective fusogen. PEG (1,800–6,000 mol wt) induces protoplast aggregation and subsequent fusion. Isolated protoplasts of two donors are mixed and treated with PEG of different molecular mass (1,800–6,000) at concentrations of 15–45% for 15–30 minutes. PEG increases the frequency of forming heterokaryons (over 10% of affected protoplasts) and makes the heterokaryons viable. For effective fusion, 10–15% DMSO (Dimethyl sulphoxide) or Concanavalin-A or sea water in combination with PEG may be added. PEG polymer acts as a bridge connecting protoplasts whereas Ca$^{2+}$ ions link the negatively charged PEG and membrane surfaces. This type of fusion is non-specific, inexpensive and results in massive fusion product but it can be cytotoxic.

**Electrofusion**
It involves application of alternating short duration direct impulses or electric stimulation to fuse the protoplasts. It involves two main processes. The protoplasts are subjected to a high-frequency AC field (>100 kHz) which draws the protoplasts towards regions of higher field strength, that is toward the electrodes. This phenomenon is called as di-electrophoresis and requires a medium of low conductivity. Thus, compared with the medium, the protoplasts are highly conductive electrical path and the poles of the protoplasts also become local regions of high field strength. Consequently, the protoplasts are attracted to each other as well as to the electrodes and become aligned in 'pearl chains' along the lines of force of the AC field. Once cell
contact has been established, the second step involves super imposition of DC pulse of sufficient magnitude (about 1kV/cm) to produce reversible breakdown of the cell membrane. This procedure causes the fusion of neighbouring protoplasts within the pearl chains. Cell lysis rather than fusion results if the DC pulse is too long or too large. Electrofusion is easy to control, have fusion frequency up to 100%, gives high reproducibility and is less cytotoxic but the equipment used are expensive.

1. The fusion process between any two protoplasts of different species in any mixed population can be followed under microscope, this would be of particular interest when producing hybrid cells

2. Fusion process is synchronous and extends over a short duration so the hybrids don’t lose their viability.

Merits of Electrically Induced Protoplast Fusion

3. Viability can also be affected by fusogenic compounds, which are thus able to interact with total membrane surface in an uncontrolled manner. In this method there is no use of such fusogenic compounds.

4. Yield of somatic hybrids is very high.

5. During the fusion, loss of intercellular substances is generally very low.

**Mechanism of fusion:**

There are three main principles governing fusion of protoplasts

1) Agglutination

2) Membrane fusion

3) Rounding off of the fused protoplasts

During agglutination, the plasma membrane of the protoplasts come in close contact with each other followed by membrane fusion at localized places which creates cytoplasmic channel. The fused protoplasts begin to become round due to expansion of cytoplasmic bridges thus forming spherical hetero or homokaryons. Fusion between the isolated protoplasts of same species gives homokaryons, whereas fusion between isolated protoplasts of different species form heterokaryons.

**Selection of somatic hybrids**

The protoplast suspension recovered after the treatment with fusion inducing agents consists of following cell types:

1) Unfused protoplasts of the two species.

2) Homokaryons (Two or more protoplasts of same species)

3) Heterokaryons (hybrid protoplasts)

**About** 20 -25 % of protoplasts are actually involved in the fusion and 0.5 to 10 % is contributed by heterokaryons and contains the mixture of above three and becomes necessary to select the hybrid cell i.e heterokaryons. The commonly used techniques are based on morphological, cytological and biochemical methods. Biochemical
method is used to label the protoplasts of two parents by different fluorescent agents. The selected one may be based on the phenomenon of auxin autotrophy. The parental protoplasts require auxins for their proliferation whereas hybrid callus tissue does not require an auxin (auxin autotropic), thus allowing to select somatic hybrids by growing them in auxin free culture. Auxin autotrophy of hybrid is expressed only as a result of genetic combination of two parental protoplasts. The selection of auxotropic mutants is possible only if the hybrid cells can grow on a minimal medium.

In a majority of cases, the somatic hybrid is morphologically similar to both parents, such features are included in vegetative or floral morphology. Morphological features are usually intermediate between the two parents and can be easily identified. These include leaf shape, size, root morphology, flower shape or its structure etc. The somatic hybrids like Pomato which is fused products of potato and tomato show abnormal morphology and can be easily identified. Besides a number of enzymes are there that posses unique isozymes that can be used for identification of somatic hybrids, eg amylases, esterases, aspartases, iso peroxidases etc. These isozymes are often variable within the same plant thus it is necessary to use the same isozyme from each plant for a specific tissue and with same age. In crosses between carrot and tobacco green protoplasts of tobacco and red anthocyanin of carrot were used as markers for identification.

Genetic analysis can be undertaken only if the hybrid plants are fertile. Many hybrid plants of distant related species are sterile. Modern molecular technologies of RFLP (restriction fragment length polymorphism) and RAPD (random amplified polymorphic DNA) can be used for the comparison of genotypes, while flow cytometry supplies a quick analysis of nuclear DNA to establish ploidy.

**Recent examples of the transfer of useful agronomic traits by protoplast fusion:**

<table>
<thead>
<tr>
<th>Parental combination</th>
<th>Trait transferred</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B. napus (+) B. rapa</strong></td>
<td>Increased biomass and yield</td>
<td>Qian et al. (2003)</td>
</tr>
<tr>
<td><strong>B. napus (+) Orychophragmusviolaceus</strong></td>
<td>Improved fatty acid composition in seeds</td>
<td>Hu et al. (2002b)</td>
</tr>
<tr>
<td><strong>B. napus (+) Sinapisarvensis</strong></td>
<td>Enhanced resistance to Blackleg (<em>Leptosphaeriamaculans</em>)</td>
<td>Hu et al. (2002a)</td>
</tr>
<tr>
<td><strong>B. oleracea (+) Moricandiaarvensis</strong></td>
<td>Introduction of the C3–C4 intermediate trait</td>
<td>Ishikawa et al. (2003)</td>
</tr>
<tr>
<td><strong>Raphanussativus (+) Diplotaxistenuifolia</strong></td>
<td>Introduction of the C3–C4 intermediate trait</td>
<td>Bang et al. (2003)</td>
</tr>
<tr>
<td><strong>S. melongena (+) S. aethiopicum</strong></td>
<td>Resistance to bacterial wilt (<em>Ralstoniasolanacearum</em>)</td>
<td>Collonnier et al. (2001)</td>
</tr>
<tr>
<td><strong>S. melongena (+) S.</strong></td>
<td>Resistance to bacterial and fungal disease</td>
<td>Collonnier et al.</td>
</tr>
<tr>
<td><strong>sisymbrifolium</strong></td>
<td><strong>wilts</strong></td>
<td><strong>(2003)</strong></td>
</tr>
<tr>
<td>------------------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
</tbody>
</table>

| **S. tuberosum (+) S. etuberosum** | Resistance to potato virus Y | Gavrilenko et al. (2003) |
| **S. tuberosum (+) S. nigrum** | Resistance to potato blight (Phytophthora infestans) | Szczerekabowa et al. (2003) |
| **S. tuberosum (+) S. stenotomum** | Resistance to bacterial wilt (R. solanacearum) | Focket et al. (2001) |

**Verification and characterization of somatic hybrids**

After selecting the desired hybrids/cybrids following protoplast fusion, it is required to carry out one or more tests to compare the parent protoplast lines with the putative hybrids. Some of the techniques that are used:

**Morphology:** Somatic hybrids in most of the cases show characters intermediate between the two parents such as, shape of leaves, pigmentation of corolla, plant height, root morphology and other vegetative and floral characters. The method is not much accurate as tissue culture conditions may also alter some morphological characters or the hybrid may show entirely new traits not shown by any of the parents.

**Isozyme analysis:** Multiple molecular forms of same enzyme which catalyses similar or identical reactions are known as isozymes. Electrophoresis is performed to study banding pattern as a check for hybridity. If the two parents exhibit different band patterns for a specific isozyme the putative hybrid can be easily verified. The isozymes commonly used for hybrid identification include, acid phosphatase, esterase, peroxidase.

**Cytological analysis:** Chromosome counting of the hybrid is an easier and reliable method to ensure hybridity as it also provides the information of ploidy level. Cytologically the chromosome count of the hybrid should be sum of number of chromosomes from both the parents. Besides number of chromosomes, the size and structure of chromosomes can also be monitored. However, the approach is not applicable to all species, particularly where fusion involves closely related species or where the chromosomes are very small. Moreover, sometimes the somaclonal variations may also give rise to different chromosome number.

**Molecular analysis:** Specific restriction pattern of nuclear, mitochondrial and chloroplast DNA characterizes the plastomes of hybrids and cybrids. Molecular markers such as RFLP, RAPD, ISSR can be employed to detect variation and similarity in banding pattern of fused protoplasts to verify hybrid and cybrid
Practical Applications of Somatic Hybridization and Cybridization

1. Means of Genetic Recombination in Asexual or Sterile Plants:

Somatic cell fusion is the only approach through which two different parental genomes can be recombined among plants that cannot reproduce sexually. Similarly, protoplasts of sexually sterile plants can be fused to produce fertile diploids and polyploids. Protoplasts isolated from dihaploid potato clones have been fused with isolated protoplasts of *Solanum brevidens* to produce hybrids of practical breeding value.

2. Overcoming Barriers of Sexual Incompatibility:

In plant breeding programmes, sexual crossing at interspecific and intergeneric levels often fails to produce hybrids due to incompatibility barriers, which can be overcome by somatic cell fusion. Somatic hybridisation of dihaploid and tetraploid potato protoplast with isolated protoplasts of *Solanum brevidens, S. phureja* and *S. penellii* resulted in the synthesis of fertile, partially amphidiploid plants possessing important agricultural traits, e.g. resistance to potato leaf virus V and Erwinia soft rot. Similarly, somatic hybrids between *Brassica napus* and *B. nigra* have been produced which is resistant to *Phoma Lingam*.

3. Cytoplasm Transfer:

In genus Brassica, two desirable traits coded by cytoplasmic genes have been genetically manipulated through interspecific cybridisation between different species of Brassica. These traits include cytoplasmic male sterility (cms) and resistance herbicide. Similarly, cytoplasmic genes coding for Atrazine and cms have been transferred into cabbage, rice and potato.

**Conclusion**

Protoplast technology has various applications other than regeneration of complete plants and production of hybrids of sexually incompitable species. These techniques have been instrumental in generating basic scientific information on cell biology, plant incompatibility, membrane functions, cell organelle studies and cell wall regeneration, ultrastructure and molecular architecture of plant cells. These techniques are now being used for transfer of cytoplasmic male sterility. Protoplast can take up macromolecules (nucleic acids and proteins), viruses, cell components like chromosomes and chloroplasts by phagocytosis.

**Literature Cited:**


Gavrilenko, T., Thieme, R., Heimbach, U. and Thieme, T. 2003. Fertile somatic hybrids of *Solanumtuberosum* (+) dihaploid*Solanumtuberosum* and their backcrossing progenies: relationships of genome dosage with tuber development and resistance to potato virus Y. *Euphytica*. **131**:323 – 32


MUSHROOM CULTIVATION: MONEY SPINNER FOR FARMERS

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Department of Business Management, CCS Haryana Agricultural University, Hisar-125004

ABSTRACT

Food and Agricultural Organization (FAO) of United Nations has recognized mushroom as food item contributing to the protein nutrition of developing countries like India, where there is a heavy dependence on cereal diet. It contains about 90% moisture and is a low caloric food. The significant feature of mushroom is that this nutritious and tasteful food is cultivated entirely from waste products and converts a wide spectrum of agricultural and industrial wastes into a substrate on which the growth of mushroom is supported. There are various types of edible mushroom available world widely but in India, generally four types of mushroom are cultivated - White Button Mushroom, Portobello Mushroom, Dhingri (Oyster) Mushroom and Paddy Straw Mushroom, among all above white button mushroom are grown all over the world and account for 35-45 % of the total mushroom production. India has tremendous potential for the growth of mushroom production with production capacity between 2000-3000 tonnes/annum. In India, 50% of mushroom production comes from marginal farmer and small manufacturing units and the remaining mushroom produced by industrial institutions. Farmers are generating additional income by cultivating mushroom, the raw material are locally available and mushrooms houses are built of kaccha bricks, preparing shelves out of sarkandas. Assistance to mushroom farmers is provided by Department of Agriculture under National Horticulture Mission for spawn units, compost preparation and training. Due to lack of information regarding mushroom cultivation more farm advisory service should be provided to the mushroom growers for dissemination of technical know-how at their door step. The economies of scale in mushroom cultivation should be followed.

Keywords: Compost, Mushroom production, Spawn production, Straw, White button

INTRODUCTION

The first mushroom ―Auricularia auricula‖ was cultivated about 600 A.D. later, around 800-900 A.D. “Flammulina velutipes” cultivated in China. Edible, medicinal, and wild mushroom are the three major components of the global mushroom industry. World production of cultivated mushrooms has increased more than 30-fold since 1978. China is the major producer of cultivated, edible mushrooms. Lentinus edodes is now the world is leading cultivated edible mushroom with about 22% of the world supply. Lentinula and four other genera (Pleurotus, Auricularia, Agaricus, and Flammulina) account for 85% of the world’s total supply of edible mushrooms. In India mushroom farming is commercialised recently under controlled conditions. Himachal Pradesh, Punjab, Haryana, Uttar Pradesh, Maharashtra, Tamil Nadu, Karnataka and Andhra Pradesh are the major mushroom producing states.
Status of mushroom cultivation in India

In the last two decades, the global mushroom industry has expanded very rapidly by the addition of newer types of mushrooms for commercial cultivation. However, mushroom as a vegetable is yet to find regular place among the Indian consumers. India has witnessed an indifferent response in its growth despite of abundance of agro wastes, favourable agro-climate, rich fungal biodiversity, and a relatively low-cost labour. At present, the total mushroom production in India is approximately 0.13 million tons. From 2010-2017, India has registered an average growth rate of 4.3% per annum in mushroom industry. Out of the total mushroom produced, white button mushroom contribute to 73% followed by oyster mushroom (16%), paddy straw mushroom (7%) and milky mushroom (3%). Per capita consumption of mushrooms in India is inadequate as compared to other vegetables and data indicates it is less than 100 grams per year. Indian mushroom industry generated revenue of Rs. 7282.26 lacs by exporting 1054 quintals of white button mushroom in canned and frozen form in the year 2016-2017. The spawn demand in India is estimated about 8000-10000 tons per annum as considering production statistics. The contribution of public sector organizations in spawn supply was limited to 10% only whereas majority of this commercial spawn to the growers is being supplied by the private units.

Importance of mushroom in human nutrition

Mushrooms have been recognized by Food and Agriculture Organization (FAO) of United Nations as food item contributing to the protein nutrition of the developing countries like India, where there is a heavy dependence on cereal diets. It is a low caloric food (about 30 calories/100 g fresh weight) and it contains about 90 per cent moisture, 20-35 per cent protein (dry weight basis) which is higher than the vegetables and fruits. Mushrooms are rich in lysine and tryptophan as well as good source of vitamins of B-complex group, vitamin C (4 to 8 mg/100 g) and have no starch. Indeed, total carbohydrate content is 4 to 5 per cent, which consists mainly of chitin, hemicellulose, glycogen, and very little fresh sugars (0.5%) are present. It has low fat content (0.3%) and high PUFA linoleic acid (70%). In place of cholesterol, Ergosterol is present which can be converted in to vitamin D by the human body. Furthermore, folic acid and vitamin B12 are present in mushroom which are normally absent in vegetables. The significant feature of mushroom is that it is cultivated entirely from waste products and converts a wide spectrum of agricultural and industrial wastes into a substrate on which the growth of mushroom is supported. Mushroom is known as 'ecological miracle' because after the harvesting, the solid residue left is the form of organic compost that further enrich the soil.

Types of mushroom: There are four type of mushroom cultivated in India. They are:

1. White button mushroom: It is the most popular mushroom grown and consumed all over the world. With advancement of technology in India, the production of mushroom is not limited to the winter season, but , now produced throughout the year in small, medium and large farms. The average yield of white button mushroom is 3-4 kg per tray.
2. Portobello Mushroom: For growing Portobello mushrooms indoors, there is need of a growing tray. The tray should be about 8 inches deep to hold compost, peat moss, and the spores. Partially decomposed compost is best for it. The temperature should be between 65 and 70 degrees F.

3. Dhingri (Oyster) Mushroom: The mushroom is easy to grow with good flavour and texture. In countries like South-East Asia, it is more popular where cultivation of button mushroom is not possible under their natural climatic condition. It is known to be highly nutritious and recommended for controlling obesity. It has low fat content that makes it an ideal diet for blood pressure patients. About one kg mushroom can be obtained from 5-6 kg wet straw.

4. Paddy Straw Mushroom: It is also known as Chinese mushroom. It is usually grown on raised beds, which are laid in open, exposed or shady places over which temporary sheds are built to protect the beds from direct sunlight and rain. The production of mushroom is more steady and reliable under indoor raised beds in a well-ventilated room. The total yield of the mushroom is about 2-2.5 kg per bed.

White button mushroom

India is tremendously focused on white button mushroom production, which is a highly sophisticated and capital-intensive activity. According to the recent production data (official data of ICAR-DMR, Solan), button mushroom share in India is maximum amounting to 73% followed by oyster mushroom which contributes about 16%. There are two types of mushroom growers in India, seasonal growers who are growing button mushrooms during the winter seasons in north-western part and those who are growing white button mushroom round the year. The total production of white button mushroom from both seasonal and high tech cultivation units in India is estimated 94676 metric tonnes. Out of this, approximately 8500 metric tons of button mushrooms was produced from the seasonal growing units located in Haryana and Punjab, which accounted for 9% of total button mushroom production. By effectively utilizing the seasonal variations, the farmers of Punjab and Haryana region uses less input for mushroom cultivation. Many growers started adopting the cultivation of white button mushroom for livelihood and income generation. There are various advantages like nearness to market, availability of raw materials at cheaper price, availability of good quality of spawn helps in the mushroom production from this region. Previously, white button mushroom production was confined to temperate hilly regions of India. However, with the development of short method of composting and optimization of fruiting conditions using the chilling system, there has been a remarkable change in its production scenario and spread to all the corners of the country. At present, highest production of button mushroom is registered from the Punjab followed by Haryana and Maharashtra and contributing 43% of the total white button mushroom production in India.

Production technology of white button mushroom

Agro-climatic Requirements

In India, button mushrooms are grown seasonally and under controlled environment. It requires 20-28°C for vegetative growth (spawn run) and 12-18°C for
reproductive growth and relative humidity of 80-90% along with adequate ventilation. Seasonally, it is grown during the winter months in the north-west plains of India and for 8-10 months in a year on the hills. However, it is now possible to cultivate this mushroom anywhere in India due to adoption of the modern technology.

Average 3-4 crops of white button mushrooms in a year can be taken by the growers depending upon the cultivated varieties. Incidence of pests or pathogens and non-availability of pure quality of spawn are the major factors affecting the yield of the crop in terms of both the quality and quantity.

**Varieties / Strains**

Ooty 1 and Ooty (BM) 2 (released in 2002) are the two strains of button mushrooms released for commercial cultivation by the scientists of Horticulture Research Station of the Tamil Nadu Agricultural University at Vijayanagaram, Ooty. The strains, which are mostly cultivated in India, are S-11, TM-79 and Horst H3.

**Cultivation Technology**

The entire process of mushroom production can be divided into the following steps:

1. Spawn production
2. Compost preparation
3. Spawning
4. Spawn running
5. Casing
6. Fruiting
7. Pest and disease
8. Harvesting

**1. Spawn Production**

Spawn is produced from fruiting culture / stocks of selected strains of mushrooms under sterile conditions. Stock culture may be produced in the lab or obtained from other reputed sources. The spawn should be of good quality in terms of size, flavour and texture apart from the high yield potential and longer shelf life.

**2. Compost Preparation**

The substrate on which button mushroom is grown, mainly prepared from a mixture of plant wastes (cereal straw/ sugarcane bagasse etc.), supplements (rice bran/ wheat bran) ,salts (urea , superphosphate / gypsum etc), and water. To produce 1 kg of mushroom 220 g. of dry substrate materials is required. It is recommended that each ton of compost should contain 6.6 kg nitrogen, 2.0 kg phosphate and 5.0 kg of potassium (N:P:K- 33: 10:25) which would get converted into 1.98% N, 0.62% P and 1.5% K on a dry weight basis. The ratio of C: N in a good substrate should be 25-30: 1 at the time of staking and 16-17: 1 in the case of final compost.
(A) Short Method of composting

During the first phase of compost preparation, paddy straw is placed in layers and sufficient water is added to the stack along with fertilizers, wheat bran, molasses etc. It is mixed thoroughly with the straw and made into a stack (almost 5 feet high, 5 feet wide and of any length can be made with the help of wooden boards). The stack is turned and again watered on the second day. On the fourth day, the stack is again turned for the second time by adding gypsum and water. The third and final turning is given on the twelveth day when the colour of the compost changes into dark brown and it starts emitting a strong smell of ammonia. The second phase is the pasteurization phase. The compost prepared as a result of microbe mediated fermentation process needs to be pasteurized in order to kill undesirable microbes and to convert ammonia into microbial protein. The complete process is carried out inside a steaming room where the temperature of air is maintained 60°C for 4 hours. The finally obtained compost should be granular with 70% moisture content and pH 7.5. It should have a dark brown colour, sweet unobnoxious smell and free from ammonia, insects and nematodes. After the process is completed, the substrate should be cooled down to 25°C.

(B) Long Method of composting

The long method of composting is usually practiced in areas where facilities for steam pasteurization are not available. In this method, the first turning is given about six days after preparation of the substrate for composting. The second turning is given on the tenth day followed by third one on the thirteenth day when gypsum is added. The fourth, fifth and sixth turnings are given on the sixteenth, nineteenth and twenty-second day. On the twenty-fifth day the seventh turning is given by adding 10% BHC (125 g.) and the eighth turning is given on the twenty-eighth day after which it is checked whether there is any smell of ammonia present in the compost. The compost is ready for spawning only when it does not have any smell of ammonia, otherwise a few more turnings are required at an interval of three days till there is no smell of ammonia.

3. Spawning

The process of mixing spawn with compost is called spawning. The different methods followed for spawning are given below:

(i) **Spot Spawning:** Lumps of spawn are planted in 5 cm deep holes made in the compost at a distance of 20-25 cm. The holes are later covered with compost.

(ii) **Surface Spawning:** The spawn is evenly spread on the top layer of the compost and then mixed to a depth of 3-5 cm. The

(iii) **Layer Spawning:** About 3-4 layers of spawn mixed with compost top portion are covered with a thin layer of compost are prepared which is again covered with a thin layer of compost like in surface spawning.

The spawn is mixed through the whole mass of compost at the rate of 7.5 ml./kg compost or 500 to 750 g/ 100 kg compost (0.5 to 0.75%).
4. **Spawn Running**

After the completion of spawning process the compost is filled in polythene bags (90x90 cm, 150 gauge thick having a capacity of 20-25 kg per bag)/trays (mostly wooden trays 1x1/2 m. accommodating 20-30 kg compost) / shelves which are either covered with a newspaper sheet or polythene. The fungal bodies grow out from the spawn and take about two weeks (12-14 days) to colonise. The temperature maintained in cropping room is 23 ± 2°C. Higher temperature is detrimental for growth of the spawn and temperature below that specified for the purpose would result in slower spawn run. The relative humidity should be around 90% and a higher CO₂ concentration than normal would be beneficial.

5. **Casing**

The compost beds after complete spawn run should be covered with a layer of soil (casing) about 3-4 cm thick to induce fruiting. The casing material should be having high porosity, water holding capacity and the pH range between 7-7.5. Peat moss is considered to be the best casing material which is not available in India, as such the mixtures like garden loam soil and sand (4:1), decomposed cow dung and loam soil (1:1) and spent compost (2-3 years old), sand and lime are commonly used. The casing before application should be either pasteurized (at 66-70°C for 7-8 hours), treated with formaldehyde (2%), formaldehyde (2%) and bavistin (75 ppm.) or steam sterilized. The treatment needs to be done at least 15 days before the material is used for casing. After casing is done the temperature of the room is again maintained at 23-28°C and relative humidity of 85-90% for another 8-10 days. Low CO₂ concentration is favourable for reproductive growth at this stage.

6. **Fruiting**

Under favourable environmental conditions viz. temperature (initially 23 ± 2°C for about a week and then 16 ± 2°C), moisture (2-3 light sprays per day for moistening the casing layer), humidity (above 85%), proper ventilation and CO₂ concentration (0.08-0.15 %) the fruit body initials which appear in the form of pin heads start growing and gradually develop into button stage.

7. **Pest & Diseases**

The insect pests mostly observed are nematodes, mites and springtails. The crop is suspect to several diseases like Dry Bubble (brown spot), Wet Bubble (White Mould), Cobweb, Green Mould, False truffle (Truffle disease), Olive green mould, Brown plaster mould and Bacterial blotch. Professional help and extension advice have to sought by the entrepreneur to adopt appropriate and timely control measures against pests & diseases.

8. **Harvesting and Yield**

Harvesting is done at button stage and caps measuring 2.5 to 4 cm across and closed are ideal for the purpose. The first crop appears about three weeks after casing. Mushrooms need to be harvested by light twisting without disturbing the casing soil. Once the harvesting is complete, the gaps in the beds should be filled with fresh sterilized casing material and then watered. About 10-14 kg fresh mushrooms per 100
kg, fresh compost can be obtained in two months crop. Short method used for preparation of compost under natural conditions gives more yields (15-20 kg per 100 kg compost).

**Post harvest management**

1. **Packing and Storage**

   (A) **Short Term Storage**

   Button mushrooms are highly perishable. Harvested mushrooms are cut at the soil line and washed in a solution of 5g KMS in 10 L of water for removing the soil particles as well as to induce whiteness. After removing excess water these are packed in perforated poly bags each containing around 250-500 g. of mushrooms. They can be stored in polythene bags at 4-5°C for a short period of 3-4 days. The mushrooms are usually packed in unlabelled simple polythene or polypropylene for retail sale. In developed countries, modified atmosphere packaging (MAP) and controlled atmosphere packaging (CAP) are in trend.

   (B) **Long Term Storage**

   White button mushrooms are not generally dried by common procedures used in case of oyster, paddy and shiitake mushrooms. Canning is the most popular method for preserving the white button mushrooms and sizeable quantity of canned produce are exported to international markets. Besides that, freeze-drying, IQF and pickling are also practiced by some units.

**Sources of technology**

(i) National Centre for Mushroom, Chambaghat, Solan, Himachal Pradesh-173213

**Export avenues**

World mushroom production has gradually increased from 0.30 million tons to 3.41 million tons over a period of last 50 years from 1965 to 2015 (Singh et al., 2017). Resultantly, the world trade trend shows that the mushroom export/import has also continuously increased during the period. On the export front, till 1993, Indian contribution to the world trade was almost negligible, but it was heartening to note that for the first time, during 1994, India not only figured in the US imports, but emerged as the second largest exporter of canned mushrooms replacing Taiwan. In the year 2016-2017, the total exports of white button mushroom from India in canned and frozen form stood at 1054 quintals and generated an income of Rs. 7282.26 lakhs (DGCIS export data. 2017).

Major export destinations for Indian mushroom are European countries, USA and Hong Kong. India exports mushroom in two forms-fresh and prepared/processed. Button mushroom accounts for approximately 95 percent of total mushroom exports. Regarding the imports, mushroom spawn has registered 89.45% of growth rate in the year 2016-17 compared to the previous year. Mushroom spawn is mainly importing from the countries like Netherlands, France and Taiwan.
Marketing of mushrooms

Mushroom cultivation is a reliable and effective way for resource poor cultivators to grow nutritious food in a short space of time. It also provides an opportunity to generate a highly tradable commodity, thereby contributing to income generation. But, majority of the farmers fails to make profits out of their mushroom production activity due to the poor marketing strategy (Shirur et al., 2015). Marketing of mushrooms in India is not yet organised. It is the simple system of producers selling directly to retailer or even to consumer, which has its own limitations. The production of mushrooms, mainly seasonal, has also exacerbated its marketing problems. There have been frequent reports of gluts in north Indian States during the winter months forcing the distress sale of the mushrooms. This reinforces that effort to increase the production without solving its marketing problems, would be counter-productive. Here are some approaches for successful marketing:

- Exploring various marketing options for fresh mushrooms – depending on transport infrastructure, selling directly to local customers, local traders, markets, intermediaries, regional wholesalers, local restaurants, shops or farmer cooperatives.
- Adding value and increasing the shelf life of the mushrooms by creating processed products, including dried or pickled mushrooms, sauces, teas, extracts, etc.
- Becoming organized and teaming-up with other producers, to bulk up on volume and the variety of mushrooms, and attract traders regularly to enable reliable sales of the perishable produce.
- Identifying existing markets and trading routes, and identifying any niches to be filled (for example, organic mushrooms, fair trade or cooperative produce).

Opportunities for mushroom production in India

India is not a major producer of any of the mushroom varieties, still farmers cultivate edible and medicinal mushrooms in one or other part, due to its diverse climatic conditions. India has a good combination of both the technical and non-technical manpower needed to operate the mushroom growing activities. Mushroom cultivation is based on recycling of agricultural residues, which are available in huge quantities. Black carbon emission from biomass burning, is the second largest contributor to the current global warming. At present the areas with Rice - Wheat cropping system in India is facing tough challenge to handle the mounting crop residues. Mushroom cultivation can effectively utilize these crop residues for production and plays crucial role in management of these crop residues. The supply and demand gap in the world trade and the shrinkage of production of mushroom in western result in better market prices for Indian mushroom producers. With a domestic population of more than 1.2 billion, India itself is a large market for mushrooms. The development of rapid infrastructure facilities and well-organized distribution network provides the greater scope for marketing of perishable products in order to meet domestic consumer demands. To be successful in both domestic and export market it is essential to produce quality mushrooms and mushroom fortified value added products at competitive rates without any agro chemical residues. Efforts should also be made to
exploit the commercial utilization of mushroom substrate left after cultivation for preparation of organic manure, vermi-compost, briquettes, etc. One final reason for optimism concerning India is potential as a major mushroom producer is its geographical location, making it more convenient to export mushrooms to the Middle East, Southeast Asia and European countries.

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PACKAGING TECHNOLOGY OF HORTICULTURAL CROPS

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The increasing demand for fresh and quality packaged food, consumer convenience and manufacturers concern for longer shelf life of the food products is driving the market for Global active and smart packaging technology for food Markets. Being perishable, fruits and vegetables require to be preserved until they are sold and used by consumers. This offers challenges in food preservation. The package must not only act as an inert barrier to the external environment but also resist respiration issues.

Demands on package performance continue to increase as a result of market and social changes. Active packaging reduces the need for additional preservatives in perishable food stuffs. Thus the shelf-life is extended and the food stuffs maintain freshness longer and are mildly preserved. Research work in this area brings out newer methods and technologies for improving the active packaging. Some of the new developments:

Ethylene scavenger:

Ethylene (produced by all plants) is a plant growth hormone and has a detrimental impact even at low concentrations on the quality and shelf-life of many fruits and vegetables during storage and distribution. Ethylene induces fruit ripening and accelerates fruit softening and ageing. There are several methods used by the horticultural industry to minimize the impact of ethylene during storage and distribution.

The two major methods are:

1. Low temperatures of storage: reduces the production of ethylene by lowering respiration and metabolic rates of the produce.

2. Controlled atmospheric storage with low oxygen and high level of carbon dioxide: suppresses respiration rates and renders the produce less sensitive to the effects of ethylene. There is a need to generate varying concentrations of carbon dioxide to suit specific food requirements. Since carbon dioxide is more permeable through plastic films than is oxygen, carbon dioxide will need to be actively produced in some applications to maintain the desired atmosphere in the package.

Packaging technologies with an aim to scavenge or absorb ethylene from the surrounding environment of packaged produce have also been developed. The most widely used ethylene-scavenging packaging technology is based on a sachet that contains either potassium permanganate or activated carbon with a metal catalyst. Several ethylene-removing plastic film-based products consisting of PE impregnated with finely dispersed minerals like clays, zeolites and carbon have been developed.
Oxygen scavengers can be incorporated in the packaging system itself rather than being added as sachets or labels as seen above. The oxygen scavenger can be incorporated into crowns, cans and a variety of metal and plastic closures. A novel plastic-based ethylene-scavenging technology developed by Food Science Australaias based on irreversible and specific reaction between diene (Tetrazine) and ethylene. Tetrazine is colored while its product with ethylene is colorless. This feature can provide the indication of the residual ethylene scavenging activity. The disadvantage however is that Tetrazine is sensitive to moisture. Another alternative approach is to use of ethylene inhibitors such as 1-methylcyclopropene (1-MCP). 1-MCP binds to the ethylene receptors in plant tissue and, as a result prevents the hormonal action of ethylene. However, it requires a dedicated fumigation chamber. A chemical reagent, incorporated into the packaging film, traps the ethylene produced by ripening fruit or vegetables. The reaction is irreversible and only small quantities of the scavenger are required to remove ethylene at the concentrations at which it is produced.

**Oxygen Scavenger:**

The presence of oxygen in food packages accelerates the spoilage of many foods. Oxygen can cause off-flavour, colour change and nutrient loss, among other degradation. One of the most promising applications of oxygen scavenging systems in food packages is to control mould growth. Most moulds require oxygen to grow and in standard packages it is frequently mould growth which limits the shelf life. This also delays oxidation of and therefore rancidity development. Sachets containing oxygen absorbents, where the scavenging material is usually finely divided iron oxide.

**Antimicrobial Packaging:**

Extends shelf-life and promotes safety by reducing the rate of growth of specific microorganisms by allowing direct contact of the package with the surface of solid foods. The packaging could be self-sterilizing or sanitizing to greatly reduce the potential for recontamination of processed products and simplify the treatment of materials to eliminate product contamination. Antimicrobial systems can be constructed by using antimicrobial packaging materials, antimicrobial inserts (such as sachets) to generate antimicrobial atmosphere conditions inside packages, or antimicrobial edible food ingredients in the formulation of food. Since antimicrobial packaging systems are designed to control the growth of microorganisms in packaged foods, the systems essentially consist of packaging materials, the in-package atmosphere, target microorganisms, and antimicrobial agents. These elements are related to one another and to the final system design features. Antimicrobial packaging technologies have been developed considerably. Technologies that release volatile or gaseous microbial control agents are preferred due to the typically limited contact of the produce with the package surfaces.

**Controlled Release of Sulfur Dioxide:**

Sulfur dioxide (SO2) is an effective gaseous microbial agent, in use for over 80 years. SO2 is traditionally used as antioxidant and preservative in fruit and vegetable
products, dried fruits, snack products and wine. The main advantage of SO\textsubscript{2} is the combination of antioxidative activity with its ability to inhibit polyphenol oxidase, which is catalysing browning of food products. Furthermore, sulphur dioxide acts as food preservative preventing microbial growth. However, SO\textsubscript{2} and sulphites strongly reduce vitamin B1 uptake. Reduced uptake of this vitamin can lead to several health problems such as chronic headache and disturbance of the memory. Food is the main source for the uptake of sulphur dioxide. A special risk group is the group of asthma patients, as sulphites promote attacks of asthma. High levels of sulfur dioxide can result in undesirable bleaching of the fruit, making them unacceptable for sale. Furthermore, in 1989, a residue tolerance level of 10 ppm for sulfur dioxide was introduced by the US. Environmental Protection Agency (EPA) because it can cause adverse effect on people suffering from asthma. Several approaches to developing a plastic-based packaging film for the controlled release of sulfur dioxide have been used. Some methods that show potential are:

- Multi layer plastic film with external surface containing calcium sulfite that will release sulfur dioxide with inside layer of organic acid like citric acid. Moisture from produce gets absorbed by inner layer. This causes migration of hydrogen ion from acid compound to outer layer. Reaction of acid with calcium sulfite triggers liberation of sulfur dioxide.

- Sodium metabisulfite can be blended into the polymer having different water vapour transmission rates. A film based on this modified polymer can release sulfur dioxide in controlled manner depending upon its water transmission rate.

- A plastic film that has been incorporated by sodium chloride in the form of encapsulation can release chlorine dioxide, a general biocide in controlled rates.

- Laminating a sulfite-containing film to a film containing a food grade organic acid such as citric or succinic acid.

Three approaches are followed to finally replace SO\textsubscript{2} and sulphites in food:

a. Reduction of oxygen contact of the food products by modified atmosphere packaging or by edible coatings for fruits and vegetables

b. Use of plant metabolites as antioxidants and antimicrobial agents

c. Inhibition of polyphenol oxidase, which is responsible for enzymatic browning in fruit and vegetable products

**Modified Atmosphere Packaging (MAP):**

A technique used for prolonging the shelf-life period of fresh or minimally processed foods. In this preservation technique, the air surrounding the food in the package is changed to another composition. This way the initial fresh state of the product may be prolonged. Shelf-life is prolonged with MAP since it slows the natural deterioration of the product. MAP is used with various types of products, where the mixture of gases in the package depends on the type of product, packaging materials and storage temperature. Meat and fish need very low gas permeability films so for non-respiring
products (meat, fish, cheese etc.) high barrier films are used. Fruits and vegetables are respiring products where the interaction of the packaging material with the product is important. If the permeability (for \( \text{O}_2 \) and \( \text{CO}_2 \)) of the packaging film is adapted to the products respiration, an equilibrium modified atmosphere will establish in the package and the shelflife of the product will increase. Instead of preserving foods through the extremes of heat (sterilization) or cold (freezing), MAP utilizes "minimal processing" - preserving food with the absolute least amount of damage to quality, texture, taste and nutrition. MAP has been in existence for the last several decades. Several technologies have been developed with an aim to replace the existing headspace gas mixture with the ideal ratio of oxygen and carbon dioxide to preserve the produce until it is consumed by the user. Some of the most common MAP systems are:

- Micro perforation of PE packaging film
- Incorporation of inorganic particles along with micro perforated PE film

**Humidity and condensation control**

Water loss from fresh produce or minimally processed foods as a result of normal respiration, microbiological activity, or physical activity can occur as a result of evaporation from the product followed by permeation through the package material, when the package material does not provide an adequate water-vapor barrier. Condensation or "sweating" is a problem in many kinds of packaged foods, particularly fresh fruit and vegetables. When one part of the package becomes cooler than another, water vapor condenses as liquid droplets in the cooler areas. If the liquid water is kept away from the product, it harms package appearance and consumer appeal, both of which are important. When condensation moistens the product’s surface, soluble nutrients leak into the water, encouraging rapid growth of mold spores and leading to loss of nutrients. The use of humidity-control technology reduces condensation inside packages of respiring and other high-water-content foods and eliminates water films on the food without further drying the food. Therefore, moisture-sensitive humidity of the tray is controlled by:

- The presence of sodium chloride;
- Overwrap material claimed to be capable of controlling the relative humidity within a package that consists of a duplex of two sheets: the external sheet is a water-vapor barrier and the inner sheet is a water-vapor-permeable (but not water-permeable) film;
- A sandwich package composed of two sheets of polyvinyl alcohol (PVA) film sealed along the edge. Between the two sheets is a layer of propylene glycol humidifying agent.
- The PVA film is very permeable to water-vapor but is a barrier to the propylene glycol;
- A sheet made of aluminum metallized film with nonwoven fabric on the reverse side, to absorb meat and fish exudations.
• Multilayer package containing a layer of PVOH or cellulosic fiber like paper sandwiched between PE films. Although active packaging may provide many benefits to shelf life extension, there are several issues to consider before implementing such a packaging system. The regulatory status of the active packaging system, cost-to-benefit ratio, production capability, commercial viability, consumer acceptance, and sensory effects on the food. Generally, the shelf life has clearly been extended through implementation of active packaging. Combinations of systems along with new technologies to be further developed will continue to improve the quality and safety of food.

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MATURITY INDICES, HARVESTING AND POST HARVEST HANDLING OF FRUITS AND VEGETABLES

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I. MATURITY

It is the stage of fully development of tissue of fruit and vegetables only after which it will ripen normally. During the process of maturation the fruit receives a regular supply of food material from the plant. When mature, the abscission or corky layer which forms at the stern end stops this inflow. Afterwards, the fruit depend on its own reserves, carbohydrates are dehydrated and sugars accumulate until the sugar acid ratio form. In addition to this, typical flavour and characteristic colour also develop. It has been determined that the stage of maturity at the time of picking influence the storage life and quality of fruit, when picked immature like mango develop white patches or air pockets during ripening and lacking in normal brix acid ratio or sugar acid ratio, taste and flavour on the other hand if the fruits are harvested over mature or full ripe they are easy susceptible to microbial and physiological spoilage and their storage life is considerably reduce. Such fruits persist numerous problems during handling, storage and transportation. Therefore, it is necessary or essential to pick up the fruits or vegetables at correct stage of maturity to facilitate proper ripening, distant transportation and maximum storage life.

Horticultural maturity

It is a developmental stage of the fruit on the tree, which will result in a satisfactory product after harvest.

Physiological maturity

It refers to the stage in the development of the fruits and vegetables when maximum growth and maturation has occurred. It is usually associated with full ripening in the fruits. The Physiological mature stage is followed by senescence.

Commercial maturity

It is the state of plant organ required by a market. It commonly bears little relation to Physiological maturity and may occur at any stage during development stage.

Harvest Maturity

It may be defined in terms of Physiological maturity and horticultural maturity, it is a stage, which will allow fruits / vegetables at its peak condition when it reaches to
the consumers and develop acceptable flavour or appearance and having adequate shelf life.

**Table 1: Criteria of maturity for harvesting fruits and vegetables**

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Physical</th>
<th>Chemical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango</td>
<td>Olive green colour with clear lenticels, shoulder development size sp. gravity, days from fruit set.</td>
<td>Starch content, flesh colour</td>
</tr>
<tr>
<td>Banana</td>
<td>Skin colour, drying of leaves of the plant, brittleness of floral ends, angularity of the fruit, and days from emergence of inflorescence.</td>
<td>Pulp/peel ratio, starch content</td>
</tr>
<tr>
<td>Citrus</td>
<td>Colour break of the skin from green to orange, size</td>
<td>Sugar/acid ratio, TSS</td>
</tr>
<tr>
<td>Grapes</td>
<td>Peel colour, easy separation of berries, characteristic aroma</td>
<td>TSS 18-12 Thompson seedless, 12-14 for Bangalore Blue, 14-16 for Anab-e-shahi</td>
</tr>
<tr>
<td>Apple</td>
<td>Colour size</td>
<td>Firmness as measured by pressure tester</td>
</tr>
<tr>
<td>Papaya</td>
<td>Yellow patch or streaks.</td>
<td>Jelliness of the seed, seed colour</td>
</tr>
</tbody>
</table>

Vegetables are harvested at harvest maturity stage, which will allow it to be at its peak condition when it reaches the consumer, it should be at a maturity that allows the produce to develop an acceptable flavour or appearance, it should be at a size required by the market, and should have an adequate shelf life. taken from pollination to horticultural maturity under warm condition, skin colour, shape, size and flavour and abscission and firmness are used to assess the maturity of the produce.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Vegetables</th>
<th>Time to harvest Maturity (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ridge gourd</td>
<td>5 - 6</td>
</tr>
<tr>
<td>2.</td>
<td>Squash</td>
<td>7 - 8</td>
</tr>
<tr>
<td>3.</td>
<td>Brinjal</td>
<td>25 – 40</td>
</tr>
<tr>
<td>4.</td>
<td>Okra</td>
<td>4 - 6</td>
</tr>
<tr>
<td>5.</td>
<td>Pepper (green stage)</td>
<td>45 - 55</td>
</tr>
<tr>
<td>6.</td>
<td>Pepper (red stage)</td>
<td>60 -70</td>
</tr>
<tr>
<td>7.</td>
<td>Pumpkin (mature)</td>
<td>65 - 70</td>
</tr>
<tr>
<td>8.</td>
<td>Tomato (mature green)</td>
<td>35 - 45</td>
</tr>
<tr>
<td>9.</td>
<td>Tomato (red ripe stage)</td>
<td>45 - 60</td>
</tr>
<tr>
<td>10.</td>
<td>Peas</td>
<td>30 - 35</td>
</tr>
</tbody>
</table>
Skin colour
Loss of green colour in citrus and red colour in tomato.

Shape, size and flavour
Sweet corn is harvested at immature stage, smaller cobs marketed as baby corn. Okra and cow pea are harvested at mature stage (pre fiber stage). In chilli, bottle gourd, bitter gourd, cluster beans maturity is related to their size. Cabbage head and cauliflower curd are harvested before un pleasant flavour.

Abscission and firmness
Musk melon should be harvested at the formation of abscission layer. In cabbage and lettuce should be harvested at firmness stage.

Factors affecting maturity
1. Temperature: Higher temperature gives early maturity. e.g. Gulabi (Pink) grapes mature in 100 days in Western India but only 82 days are enough in the warmer Northern India. Lemon and guava takes less time to mature in summer than in winter. Sun-scorched portions of fruits are characterized by chlorophyll loss, yellowing, disappearance of starch and other alcohol insoluble material, increase in TSS content, decrease in acidity and softening.

2. Soil: Soil on which the fruit tree is grown affects the time of maturity. e.g. Grapes are harvested earlier on light sandy soils than on heavy clays.

3. Size of planting material: This factor in propagated fruits affects fruit maturity. e.g. In pineapple, the number of days taken from flowering to fruit maturity was more by planting large suckers and slips than by smaller ones.


5. Pruning intensity: It enhanced the maturity of Flordasun and sharbati Peaches.

6. Girdling: Process of constricting the periphery of a stem which blocks the downward translocation of CHO, hormones, etc. Beyond the constriction which rather accumulates above it. In Grape vines it hastens maturity, reduces the green berries in unevenly maturity cultivar and lowers the number of short berries. It is ineffective when done close to harvest. CPA has an additive effect with girdling

Maturity index

MATURITY INDEX

Maturity index
The factors for determining the harvesting of fruits, vegetables and plantation crops according to consumer’s purpose, type of commodity, etc and can be judged by visual means (colour, size, shape), physical means (firmness, softness), chemical analysis (sugar content, acid content), computation (heat unit and bloom to harvest period), physiological method(respiration). These are indications by which the maturity is judged. Various index are as Follows;
1. Visual indices

It is most convenient index. Certain signals on the plant or on the fruit can be used as pointers. E.g. drying of top leaves in banana, yellowing of last leaf of Peduncle in jackfruit. Flow of sap from cut fruit stalk of mango slows down if the harvest is done after maturity but in immature fruits, exudation is more and comes with force in a jet form. In papaya, the latex becomes almost watery. The flow gets reduced on maturity in Sapota. In fruits like banana and Sapota, floral ends become more brittle and shed with a gentle touch or even on their own. In Sapota, the brown scurf on the fruit skin starts propping. In mango, lenticels become more prominent and the waxy bloom gradually disappears. Grapes develop translucent bloom. Other changes like angularity in banana, development of creamy wide space between custard apple segments and the flattening of the eyes in pineapple and tubercles in litchi serve as reliable maturity indices.

2. Seed development

It can also be used as an index of fruit maturity, e.g. endocarp hardening for stone and fiber development for dessert in mango.

3. Start of bud damage

Occasionally it can be used as an index of fruit maturity in mango.

4. Calendar date

For perennial fruit crops grown in seasonal climate which are more or less uniform from year to year, calendar date for harvest is a reliable guide to commercial maturity. This approach relies on a reproducible date for the time of the flowering and a relative constant growth period from flowering through to maturity. Time of flowering is largely dependent on temperature, and the variation in number of days from flowering to harvest can be calculated for some commodities by use of the degree-concept.

5. Heat units

Harvest date of newly introduced fruits in a widely varying climate can be predicted with the help of heat unit. For each cultivar the heat requirement for fruit growth and development can be calculated in terms of degree days: Maturity at higher temperature is faster as the heat requirement is met earlier. This heat unit helps in planning, planting, harvesting and factory programmes for crops such as corn, peas and tomato for processing.

MATURITY OF FRUITS AND VEGETABLES

Banana

The fruit is harvested when the ridges on the surface of skin change from angularity to round i.e. after the attainment of 3% full stages. Dwarf banana are ready for harvest within 11-14 months after planting while tall cultivars takes about 14-16
months to harvest. Peel colour change from dark green to light green the remaining style ends were dry, and brittle and fruits were less angular in shape.

**Guava**

TSS acid ratio, specific gravity and colour are determined the maturity in guava. For e.g.

<table>
<thead>
<tr>
<th>Fruit Type</th>
<th>TSS Acid Ratio</th>
<th>Specific Gravity</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allahabad Safeda</td>
<td>35.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apple Colour Guava</td>
<td>26.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chittidar Guava</td>
<td>28.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lucknow</td>
<td>49.34</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Specific gravity - Less than 1
Colour - Light green to yellow.

**Ber**

In ber maturity is judged by colour (yellow), specific gravity (less than 1) and TSS

**Pomegranate**

Sugar percentage should be 12-16% and acid percentage 1.5—2.5%, variety Ganesh harvest when seed colour becomes pink. In this stage TSS 12.5% and sugar acid ratio 19.5%.

**Bael**

It takes one year for fruiting after flowering. It is the fruit which ripen after one year of flowering. April start harvesting and may end it start in flowering.

**Mango**

This can be judged when one or two mangoes ripen on the tree are fall on the ground of their own accord. This process of fallen is known as tapaca specific gravity 1.01—1.02 and TSS 10-14%.

**Table 3 Maturity indices of vegetable crops**

<table>
<thead>
<tr>
<th>Root, bulb and tuber crops</th>
<th>Maturity indices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radish and carrot</td>
<td>Large enough and crispy</td>
</tr>
<tr>
<td>Potato, onion and garlic</td>
<td>Tops beginning to dry and topple clown</td>
</tr>
<tr>
<td>Yams, bean and ginger</td>
<td>Large enough</td>
</tr>
<tr>
<td><strong>FRUIT VEGETABLES</strong></td>
<td></td>
</tr>
<tr>
<td>Cowpea, snap bean, sweet pea, winged bean</td>
<td>Well filled pods that snap readily</td>
</tr>
<tr>
<td>Lima bean and pigeon pea</td>
<td>Well filled pods that are beginning to lose their greenness.</td>
</tr>
</tbody>
</table>
Okra
Desirable size reached and the tips of which can be snapped readily

Snake gourd
Desirable size reached and thumbnail can still penetrate flesh readily

Egg plant, bitter gourd, slicing cucumber
Desirable size reached but still tender

Tomato
Seeds slipping when fruit is cut, or green colour turning pink

Muskmelon
Easily separated from vine with a slight twist leaving clean cavity (full slip stage).

Watermelon
Dull hollow sound when thumped

FLOWER VEGETABLES

Cauliflower
Curd compact

Broccoli
Bud cluster compact

II. HARVESTING

The goals of harvesting are to gather a commodity from the field at the proper level of maturity with a minimum of damage and loss, as rapidly as possible and at a minimum cost. This is achieved through hand-harvesting in most fruit, vegetable and flower crops.

1. Hand Harvesting

Hand harvesting has a number of advantages over machine harvest. People can accurately determine product quality, allowing accurate selection of mature product. This is particularly important for crops that have a wide range of maturity and need to be harvested several times during the season. Properly trained workers can pick and handle the product with a minimum of damage. Many fresh-market products have a short shelf life if they are bruised or damaged during harvest and handling. The rate of harvest can easily be increased by hiring more workers. Hand- harvesting also requires a minimum of capital investment. The main problem with hand harvesting is labor management. Labor supply is a problem for growers who cannot offer a long employment season. Labor strikes during the harvest period can be costly. In spite of these problems, quality is so important to marketing fresh- market commodities successfully that hand harvesting remains the dominant method of harvest of most fruits and vegetables and for all cut flowers.

Effective use of hand labor requires careful management. New employees must be trained to harvest the product at the required quality and at an acceptable rate of productivity. Employees must know what level of performance and must be encouraged and trained to reach that level.
2. Mechanical Harvesting

Mechanical harvest is currently used for fresh-market crops that are roots, tubers, or rhizomes and for nut crops. Vegetables that are grown below ground (radishes, potatoes, garlic, carrots, beets and others) are always harvested only once and the soil can be used to cushion the product from machine caused mechanical injury. Tree nuts and peanuts are protected by a shell and easily withstand mechanical handling. A number of products destined for processing such as tomatoes, wine grapes, beans, peas, prunes, peaches, and some leafy green vegetables are machine harvested because harvest damage does not significantly affect the quality of processed product. This is often because the product is processed quickly after harvest. These crops have also been amenable to new production techniques and breeding that allow the crop to be better suited to mechanical harvest.

The main advantage of mechanical harvest equipment is that machines can often harvest at high rates. Tree nut harvesters, for eg. attaching a shaking mechanism to the tree and remove most of the nuts in few seconds. The nuts are either caught on a fabric-covered frame or picked up from the ground by other machines. This allows an orchard to be harvested very quickly compared to handshaking with poles. Machine harvest also reduces management problems associated with workers. The commodity must be grown to accept mechanical harvest.

Demerits of Mechanical Harvesting

Machines are rarely capable of selective harvest. Mechanical harvesting will not be feasible until the crop or production techniques can be modified to allow one time harvest. Harvesting machines often causes excessive product perennial crops eg. Bark damage from a tree shaker. The harvesting machines are quite expensive.

III. POST HARVEST HANDLING

Being living organs, fruits and vegetables continue to respire even after harvesting when they have a limited source of food reserves. In addition to degradation of respiratory substrates, a number of changes in taste, colour, flavour, texture and appearance take place in the harvested commodities which make them unacceptable for consumption by the consumers if these are not handled properly. Post harvest technology starts immediately after the harvest of fruits and vegetables. The whole process of processing the commodities is categorized as Handling of fresh produce. Post harvest Technology of fresh fruits and vegetables combines the biological and environmental factors in the process of value addition of a commodity.

1. Precooling

Precooling (prompt cooling after harvest) is important for most of the fruits and vegetables because they may deteriorate as much in 1 hr at 32°C. In addition to removal of field heat from commodities, precooling also reduces bruise damage from vibration during transit. Cooling requirement for a crop vary with the air temperature during harvesting, stage of maturity and nature of crop. There are many methods of precooling viz, cold air (room cooling, forced air cooling), cold water (hydrocooling),
direct contact with ice (contact icing), evaporation of water from the produce (evaporative cooling, vacuum cooling) and combination of vacuum and hydrocooling (hydrovac cooling). Some chemicals (nutrients/growth regulators/ fungicides) can also be mixed with the water used in hydrocooling to prolong the shelf life by improving nutrient status of crop and preventing the spread of post harvest diseases.

2. Washing, Cleaning and Trimming

Before fresh fruits and vegetables are marketed various amounts of cleaning are necessary which typically involves the removal of soil dust, adhering debris, insects and spray residues. Chlorine in fresh water is often used as disinfectant to wash the commodity. Some fungicides like Diphenylamine (0.1 - 0.25%) or ethoxyquin (0.2 - 0.5%) may be used as post harvest dip to control the disorders. Eg. Apple superficial scald. For cleaning of some fruit type vegetables (melons, brinjals, tomatoes, cucumber) they should be wiped with damp cloth. Many vegetable need trimming, cutting and removal of unsightly leaves or other vegetative parts.

3. Sorting, Grading and Sizing

Sorting is done by hand to remove the fruits which are unsuitable to market or storage due to damage by insects, diseases or mechanical injuries. The remainder crop product is separated into two or more grades on the basis of the surface colour, shape or visible defects. For eg, in an apple packing house in India 3 grades viz. Extra Fancy, Fancy and standard may be packed for marketing. The fourth “cull” grade is meant for processing. After sorting and grading, sizing is done either by hand or machine. Machine sizers work on two basic principles: weight and diameter. Sizing on the basis of fruit shape and size are most effective for spherical (Oranges, tomato, certain apple cultivars) and elongated (Delicious apples and European pears or of non-uniform shape) commodities, respectively.

4. Curing

Curing is an effective operation to reduce the water loss during storage from hardy vegetables viz, onion, garlic, sweet potato and other tropical root vegetables. The curing methods employed for root crops are entirely different than that from the bulbous crops (onions and garlic). The curing of root and tuber crops develops periderms over cut, broken or skinned surfaces wound restoration. It helps in the healing of harvest injuries, reduces loss of water and prevents the infection by decay pathogens.

Onions and garlic are cured to dry the necks and outer scales. For the curing of onion and garlic, the bulbs are left in the field after harvesting under shade for a few days until the green tops, outer skins and roots are fully dried.

5. Waxing

Quality retention is a major consideration in modern fresh fruit marketing system. Waxes are esters of higher fatty acid with monohydric alcohols and hydrocarbons and some free fatty acids. But coating applied to the surface of fruit is
commonly called waxes whether or not any component is actually a wax. Waxing generally reduces the respiration and transpiration rates, but other chemicals such as fungicides, growth regulators, preservative can also be incorporated specially for reducing microbial spoilage, sprout inhibition etc. However, it should be remembered that waxing does not improve the quality of any inferior horticulture product but it can be a beneficial adjunct to good handling.

The advantages of wax application are:

- Improved appearances of fruit.
- Reduced moisture losses and retards wilting and shrivelling during storage of fruits.
- Less spoilage specially due to chilling injury and browning.
- Creates diffusion barrier as a result of which it reduces the availability of O2 to the tissues thereby reducing respiration rate. - Protects fruits from microbiological infection.
- Considered a cost effective substitute in the reduction of spoilage when refrigerated storage is unaffordable.
- Wax coating are used as carriers for sprout inhibitors, growth regulators and preservatives.

The principal disadvantage of wax coating is the development of off-flavour if not applied properly. Adverse flavour changes have been attributed to inhibition of O2 and CO2 exchange thus, resulting in anaerobic respiration and elevated ethanol and acetaldehyde contents. Paraffin wax, Carnauba wax, Bee wax, Shellac, Wood resins and Polyethylene waxes used commercially.

6. Packaging

Proper or scientific packaging of fresh fruits and vegetables reduces the wastage of commodities by protecting them from mechanical damage, pilferage, dirt, moisture loss and other undesirable physiological changes and pathological deterioration during the course of storage, transportation and subsequent marketing. For providing, uniform quality to packed produce, the commodity should be carefully supervised and sorted prior to packaging. Packaging cannot improve the quality but it certainly helps in maintaining it as it protects produce against the hazards of journey. Striking developments have been in the field of packaging of horticultural produce and the gunny bags, grasses and stem leaves used so far for packaging are now being replaced by a variety of containers such as wooden boxes, baskets woven from bamboo or twigs, sack/jute bags and corrugated fibre board (CFB) boxes.

7. Storage

A number of storage techniques (ground storage, ambient storage, refrigerated storage, air cooled storage, zero energy storage, modified atmospheric storage, hypobaric storage and controlled atmosphere storage) are being used for fruits and
vegetables depending upon the nature of the commodity and the storage period intended.

Reference-

- www.postharvest.ucdavis.edu
- www.postharvest.ifsa.ufl.edu
NUTRITIONAL VALUE OF FRUIT CROPS

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ABSTRACT

Nutraceuticals is the any substance that is food or part of food that provide medicinal or health benefits, including prevention and treatment of disease, which are present in plant in the form of antioxidant and phytochemical. Fruits are a good source of fiber, selected minerals, vitamins and antioxidants without which human body cannot maintain proper health and develop resistance to disease. Nutraceuticals also act as natural pigments which are abundantly present in plants acting as disease preventing and curative agent. Various phytochemical such as Flavanols, Flavonoids, Isoflavones, and antioxidant such as Beta-Carotene, Lycopene, Gluthione etc, are present in different colour group of fruit. These chemical compound functions as fighting against heart disease and cancer, and also act as an anti-inflammatory agent. Chemical compound containing more amount of vitamin C and E, for role in reducing the risk of cancer, also lowering cholesterol and blood pressure and also fights against many chronic diseases.

Nutraceuticals role in disease preventing and human nutrition, it has a great demand in future because, human body are less responsive to chemical and pharmaceutical and drugs. So, for current and future development of nutraceuticals, needs to established safety studies including all the terminology related to human health, nutrition and disease. The present chapter gives a brief idea about nutraceuticals and provides a gist on the presence of nutraceuticals from various fruits and some of their health protecting roles.

INTRODUCTION:

We need a wide range of nutrients for growth, developments and to lead an active and healthy life. The nutrients consist of carbohydrates, proteins, fats, vitamins and minerals. Fruits are the nutritive part of human diet being rich in vitamins and minerals. As such they come under the category of “protective foods”. The constituents obtained by the human body from fruits include water, carbohydrates, fats, proteins, fiber, minerals, organic acids, pigments, vitamins and antioxidants, among others. Fruits are a good source of fiber, selected minerals, vitamins and antioxidants without which human body cannot maintain proper health and develop resistance to disease. They also contain pectin, cellulose which stimulate intestinal activities and energy giving substances like oil, fats and proteins. They are relatively low in calories and fat (avocado and olives being the exceptions), they have no cholesterol, they are rich in carbohydrates and fiber, they contain vitamin C and carotene, and some are a good source of vitamin B6. Fruits are relatively low in sodium and high in potassium. Ascorbic acid in fruits enhances the bioavailability of iron in the diet. They play an important role in prevention or control of human diseases like obesity, cancer, diabetes, heart disease,
hypertension, anemia, scurvy, peptic ulcers, diarrhea, etc. Thus many fruits confirm to the saying “An apple a days keeps doctor away”.

Most fruits are available almost year-round in a wide variety and they not only taste good, but they also have favorable attributes of texture, color, flavor and ease of use. They can be fresh, cooked, hot or cold, canned, pickled, frozen or dried.

**DAILY REQUIREMENT OF NUTRIENTS:**

For a balanced nutrition, about 23 nutrients are required to be supplied through our diet. These include carbohydrates, proteins, fats, vitamins and minerals. The Indian council of medical research (ICMR) has recommended a balanced diet to contain 120 gm fruits and 300 gm of vegetables. The recommended daily allowances (RDA) nutrients for an Indian man and woman, doing moderate work, as prescribed by (ICMR) New Delhi are given in Table 1.

Table 1. Recommended Daily Allowances (RDA) of Nutrients for an Indian Man and Woman

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Nutrients</th>
<th>Average Man*</th>
<th>Average Woman*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Energy (kcal)</td>
<td>2875</td>
<td>2225</td>
</tr>
<tr>
<td>2</td>
<td>Proteins (g)</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>Fat (g)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>Calcium (mg)</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>5</td>
<td>Iron (mg)</td>
<td>28</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>Vitamin A (IU)</td>
<td>2400</td>
<td>2400</td>
</tr>
<tr>
<td>7</td>
<td>Vitamin B₁ (mg)</td>
<td>1.4</td>
<td>1.1</td>
</tr>
<tr>
<td>8</td>
<td>Vitamin B₂ (mg)</td>
<td>1.6</td>
<td>1.3</td>
</tr>
<tr>
<td>9</td>
<td>Niacin (mg)</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td>10</td>
<td>Pyridoxine (mg)</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>11</td>
<td>Folic acid (ug)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>12</td>
<td>Vitamin B₁₂ (ug)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>13</td>
<td>Vitamin C (mg)</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>

Note: * weighing 60kg, doing moderate work. ** weighing 50kg, doing moderate work.

(Source: Gopalan et al. 2004)

**NUTRITIONAL VALUES OF FRUIT CROPS:**

A. As a source of vitamin- Vitamin carry out many vital functions of body and are involved in the utilizations of major nutrients like carbohydrates, proteins and fats. These are required in small quantity non-ethesial are essential for well-being of the body. Vitamin are classified as water soluble and fat soluble. Water soluble vitamin are ascorbic acid or vitamin C and vitamin B complex. These are not stored in the body and
they are required daily in diet. Whereas fat soluble vitamin are vitamin A, D, E, and K. They are accumulated in the body and are not required daily in our diet but their excessive intake may be toxic.

1) Vitamin A (carotene) - It is fat soluble and essential for growth and reproduction. Deficiency cause cessation of growth, night blindness, drying of tear glands, roughness and emtion of skin in children, formation of stones in kidney and bladder and pimppling. This vitamin is present in fruits in the Form Of Pro-Vitamin A Or Carotene Which Is Converted To Vitamin A In Our Body. It Is Found In Mango, Papaya, Jackfruits, Dates, Banana, etc.

2) Vitamin B1 (Thiamin) - It is essential for the maintenance of good appetite and normal digestion. This vitamin is necessary for growth, fertility, lactation and normal functions of nervous tissue. Deficiency causes beriberi disease, loss of appetite, loss in weight fall in body temperature, sore throat, etc. It is found in Cashew Nut, Almond, Banana, Bael, Litchi, Papaya and Pomegranate.

3) Vitamin B2 (Riboflavin) - Vitamin B2 is important for growth and health of the skin and for respirations of cornea. It is present in the retinal pigments of the eyes. Deficiency cause pellagra, swollen nose, and baldness, loss of appetite, loss in weight, sore throat, etc. The fruits like Bael, Custard apple, Jackfruits and Wood apple are rich source of vitamin B2.

4) Vitamin B3 (Pantothenic acid) - It is most important for digestion, skin formation and normal growth and developments of body. Deficiency causes dermatitis, ulcer and general weakness of the body.

5) Vitamin B6 (Pyridoxin) : It is essential for the formation of hemoglobin in blood and also helps in the digestion of protein food. Deficiency cause anemia, weakness of nerve and loss of reproductive ability.

5) Niacin (Nicotinic acid) : Deficiency of niacin in human diet causes roughness of skin, pellagra and abnormality in the tongue and cellular respirations. The fruits like Bael, Custard apple, Wood apple and Jackfruit are rich source of this vitamin.

6) Vitamin C (Ascorbic acid): It is water soluble and essential for growth, formation of bones and teeth, resistance to diseases and act as reducing agent making possible absorption of dietary iron. Deficiency causes scurvy disease, delay in wound-healing, enlargement of heart and damage to heart muscles. The fruits like Aonla, Guava, Citrus, Ber, Strawberry, Pineapple etc. are rich source of this vitamin.

Table 2. Vitamin content of some fruits (Mg/ 100g edible fruits)

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Name of fruits Crops</th>
<th>Vitamins A (IU)</th>
<th>Vitamin B1 (mg)</th>
<th>Vitamin B2 (mg)</th>
<th>Niacin (mg)</th>
<th>Vitamin C (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aonla</td>
<td>9</td>
<td>0.03</td>
<td>0.01</td>
<td>0.2</td>
<td>600</td>
</tr>
<tr>
<td>2</td>
<td>Apple</td>
<td>-</td>
<td>0.03</td>
<td>0.02</td>
<td>0.2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Banana</td>
<td>78</td>
<td>0.05</td>
<td>0.08</td>
<td>0.6</td>
<td>12</td>
</tr>
<tr>
<td>No.</td>
<td>Fruit</td>
<td>Calories</td>
<td>Protein</td>
<td>Lipid</td>
<td>Ash</td>
<td>Source (Gopalan et. al. 2004)</td>
</tr>
<tr>
<td>-----</td>
<td>-------------</td>
<td>----------</td>
<td>---------</td>
<td>-------</td>
<td>-----</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>4</td>
<td>Ber</td>
<td>21</td>
<td>0.02</td>
<td>0.05</td>
<td>0.7</td>
<td>140</td>
</tr>
<tr>
<td>5</td>
<td>Bael</td>
<td>186</td>
<td>12</td>
<td>1191</td>
<td>0.9</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>Cashew</td>
<td>23</td>
<td>0.02</td>
<td>0.05</td>
<td>0.7</td>
<td>180</td>
</tr>
<tr>
<td>7</td>
<td>Custard apple</td>
<td>-</td>
<td>0.13</td>
<td>0.18</td>
<td>0.8</td>
<td>37</td>
</tr>
<tr>
<td>8</td>
<td>Grape</td>
<td>-</td>
<td>0.04</td>
<td>0.03</td>
<td>0.2</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>Guava</td>
<td>-</td>
<td>0.03</td>
<td>0.02</td>
<td>0.4</td>
<td>250</td>
</tr>
<tr>
<td>10</td>
<td>Jackfruit</td>
<td>600</td>
<td>0.03</td>
<td>0.13</td>
<td>0.3</td>
<td>7</td>
</tr>
<tr>
<td>11</td>
<td>Jamun</td>
<td>48</td>
<td>0.03</td>
<td>0.01</td>
<td>0.2</td>
<td>18</td>
</tr>
<tr>
<td>12</td>
<td>Mango</td>
<td>2740</td>
<td>0.08</td>
<td>0.09</td>
<td>0.9</td>
<td>25</td>
</tr>
<tr>
<td>13</td>
<td>Orange</td>
<td>1100</td>
<td>0.10</td>
<td>0.04</td>
<td>0.4</td>
<td>40</td>
</tr>
<tr>
<td>14</td>
<td>Papaya</td>
<td>670</td>
<td>0.04</td>
<td>0.25</td>
<td>0.2</td>
<td>57</td>
</tr>
<tr>
<td>15</td>
<td>Pomegranate</td>
<td>-</td>
<td>0.06</td>
<td>0.10</td>
<td>0.3</td>
<td>13</td>
</tr>
<tr>
<td>16</td>
<td>Pineapple</td>
<td>18</td>
<td>0.20</td>
<td>0.12</td>
<td>0.1</td>
<td>39</td>
</tr>
<tr>
<td>17</td>
<td>Sapota</td>
<td>97</td>
<td>0.02</td>
<td>0.03</td>
<td>0.2</td>
<td>6</td>
</tr>
<tr>
<td>18</td>
<td>Strawberries</td>
<td>12</td>
<td>0.1</td>
<td>0.02</td>
<td>0.4</td>
<td>58.8</td>
</tr>
<tr>
<td>19</td>
<td>Walnut</td>
<td>10</td>
<td>450</td>
<td>-</td>
<td>1.6</td>
<td>-</td>
</tr>
<tr>
<td>20</td>
<td>Wood apple</td>
<td>-</td>
<td>-</td>
<td>170</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**B. As a source of minerals:** Minerals play an important role in human nutrition. At least 10 minerals are essential for the growth and developments of human body. Out of these calcium, iron, phosphorous are required on large scale.

1) **Calcium** - It is important for developments of bone and tooth formations. Absence causes rickets, osteomalacia, pigeon chest, retarded growth. The fruits like Date, Ber, Anola, Beal, Tamarind, Karonda, Phalsa and Wood apple etc. are rich source of calcium.

2) **Iron** - It is essential part of red blood cells and plays key role in respiration. It acts as an oxygen carrier in the body. Deficiency causes anemia in children and pregnant woman. Fruits like Sapota, Anola, Custard Apple, Karonda, Phalsa, Tamarind are rich source of iron.

3) **Phosphorus** - It is essential for cell multiplication of bones and soft tissues. It helps in the liberations of energy on oxidation of carbohydrates. Fruits like Wood Apple, Jackfruits, Ber And Tamarind are rich source of phosphorus.

4) **Magnesium (Mg)** - Magnesium is important in protein synthesis, release of energy from muscle storage and body temperature regulation. It is critical for proper heart function and plays a role in bone formation.

5) **Sodium (Na)** - Sodium is a systemic ion. It is important in electrolyte balance and essential in
Co-regulating ATP with potassium. In addition, it has an important role in the regulation of blood pressure.

6) **Potassium (K)** - A potassium-rich diet contributes to lower blood pressure, blunting the effects of salt. Inadequate levels of potassium intake have long been associated with higher blood pressure. Potassium also regulates heartbeat, assists in muscle contraction and is needed to send nerve impulses and to release energy from fats, carbohydrates and proteins.

C. **As a source of energy:** Carbohydrates and fats provide energy, while proteins besides providing energy are also responsible for building body tissue. Carbohydrates and proteins give about 4 kilocalories per gram while lipid give 9 kilocalories. Fruits are characterized as low calorie foods. The energy value of many fruits is less than 100 kilocalories / 100 gram of fruit.

Sources – Banana (36%), Grapes (20%), Custard apple (25%), Apples, etc.

1). **Proteins** - These are body building foods essential for growth. Proteins represent less than 1% of the fresh mass of fruit tissues. Fruits are low in proteins, but tree nuts are a good source of high-quality proteins. The protein content of fresh fruits is calculated by multiplying the total nitrogen content by a factor of 6.25. This calculation uses the fact that protein is comprised of about 16% nitrogen, and the assumption that all nitrogen present is protein. Senescent tissues, such as those of overripe fruits, usually contain especially high proportions of non-protein nitrogen. Apples as non-protein nitrogen fractions. Pears and oranges are rich in proline, and black and red currants in alanine. Deficiency of proteins causes retarded growth, physical and mental fatigue, delayed healing og wounds and complications during pregnancy. An adult needs 100-150 g protein per day in the diet. Fruits like Wood Apple, Custard Apple, Chironji, Jackfruits and Bael have high protein content.

2) **Carbohydrates** – These provide energy so that a person can carry out his work satisfactorily. Carbohydrates are broadly classified as soluble and insoluble carbohydrates. Digestible Carbohydrates like starch and sugar provide energy to the body and indigestible Carbohydrates like cellulose, gum, pectin and lignin are termed as dietary fibers that are necessary for digestion and eliminations of waste. Most of the fruits are high in sugars mostly dextrose and levulose and other sugars also. Sugars are important calorie yielding foods being easily digested and yield energy quickly, e.g. Mango, Potato, Sweet potato.

4. **Fibre** – Dietary fiber includes very diverse macromolecules exhibiting a large variety of physico-chemical properties. The main components included as fiber are cellulose, hemicelluloses, pectin, lignin, resistant starch and non-digestible oligosaccharides. The fibrous portions of fruits is found to exert beneficial effects by increasing the intestinal peristalsis and consequent relief from constipation, weight control, prevention of colon and rectal cancers, control of diabetes. The fiber content in fruits is low. The fiber content of most of the fruits ranges from 0.5 to 3.4%. Fruits like Guava, Sapota and Aonla contain relatively more fiber than others.

5. **Fats or Lipids** – Fat or lipids is a concentrated source of energy for plants during germination, forming components of cellular membranes and cuticular waxes, and they
are mainly present as triglycerides (esters of glycerol and three fatty acids) or phospholipids (in which one fatty acid has been replaced by a phosphate group). Some fats are known as essential fatty acids because of their importance in cell structure and functioning. The fats content of fruits is usually low (0.1-0.5%). Lipids form a natural coating on the fruits and protect them from insects, parasites and adverse environmental conditions.

Examples of fat content on a dry mass basis are:

1. Avocado: 35–70%;
2. Olive: 30–70%;
3. Grape: 0.2%;
4. Banana: 0.1%; and
5. Apple: 0.06%.

Table 4. Proximate composition of fruits.

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Name of fruits</th>
<th>Moisture (%)</th>
<th>Protein (g)</th>
<th>CHO (g)</th>
<th>Fibre (%)</th>
<th>Fat (g)</th>
<th>Minerals (g)</th>
<th>Energy value (Kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Aonla</td>
<td>82</td>
<td>0.6</td>
<td>13.7</td>
<td>3.4</td>
<td>0.1</td>
<td>0.6</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>2 Apple</td>
<td>84</td>
<td>0.2</td>
<td>15.0</td>
<td>0.7</td>
<td>0.5</td>
<td>0.3</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>3 Banana</td>
<td>70</td>
<td>1.2</td>
<td>27.0</td>
<td>0.5</td>
<td>0.3</td>
<td>0.8</td>
<td>116</td>
<td></td>
</tr>
<tr>
<td>4 Ber</td>
<td>82</td>
<td>1.2</td>
<td>15</td>
<td>1.0</td>
<td>0.3</td>
<td>0.3</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>5 Cashew</td>
<td>86</td>
<td>0.2</td>
<td>12.3</td>
<td>0.9</td>
<td>0.1</td>
<td>0.2</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>6 Custard apple</td>
<td>71</td>
<td>1.4</td>
<td>24.0</td>
<td>2.0</td>
<td>0.3</td>
<td>0.8</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>7 Grape</td>
<td>82</td>
<td>0.5</td>
<td>15.7</td>
<td>1.0</td>
<td>0.3</td>
<td>0.7</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>8 Guava</td>
<td>82</td>
<td>1.3</td>
<td>12.2</td>
<td>3.3</td>
<td>0.4</td>
<td>0.7</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>9 Jackfruit</td>
<td>76</td>
<td>1.9</td>
<td>19.3</td>
<td>1.1</td>
<td>0.1</td>
<td>0.9</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>10 Jamun</td>
<td>83</td>
<td>0.7</td>
<td>14.0</td>
<td>0.9</td>
<td>0.3</td>
<td>0.4</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>11 Mango</td>
<td>80</td>
<td>0.6</td>
<td>16.0</td>
<td>0.7</td>
<td>0.5</td>
<td>0.5</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>12 Orange</td>
<td>86</td>
<td>0.8</td>
<td>12.2</td>
<td>0.5</td>
<td>0.2</td>
<td>0.3</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>13 Pomegranate</td>
<td>77</td>
<td>1.6</td>
<td>17.2</td>
<td>2.1</td>
<td>0.1</td>
<td>0.7</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>14 Pineapple</td>
<td>82</td>
<td>0.4</td>
<td>13.7</td>
<td>2.1</td>
<td>0.1</td>
<td>0.4</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>15 Sapota</td>
<td>74</td>
<td>0.7</td>
<td>21.4</td>
<td>2.6</td>
<td>0.1</td>
<td>0.5</td>
<td>98</td>
<td></td>
</tr>
</tbody>
</table>

(Source: Gopalan et. al. 2004)
D. Moisture – Fruits are characterized by their higher (70-80%) moisture content. The maximum water content varies between individual fruits because of structural differences. Cultivation conditions that influence structural differentiation may also have a marked affect Pulpy fruits contain relatively less moisture and more nutrients than the juicy fruits.

E. As a source of Anti-nutritional compounds- Some fruits contain nutritionally undesirable constituents such as phenolic compound, Organic acids and phytate phosphorus in rich amount.

1) Phenolic compounds - Phenolic compounds form complexes with proteins, enzymes and minerals and reduces their bioavailability. The levels of these Phenolic compounds in most of the fruits is less than 1.0 per cent. However, certain varieties of Aonla contain as high as 4.5 % Phenolic compounds (tannies). The peel of Ber contains 3-4 % polyphenols. Fruits like Grape berries (380 mg /100gm fruit) and Jamun (410 mg/100 g of fruit) contain significant amount of polyphenols.

2) Organic acids- For proper digestion of foods organic acid play an important role. They also help for increasing appetite. The most abundant acids in fruits are citric acid, malic acid and oxalic acids. However, large amounts of tartaric acid occur in grapes. Malic acid is the major component in oranges and apples. The acid content of fruits generally decreases during maturation. Benzoic acid occurs in cranberries, quinic acid in bananas. Some fruits such as Aonla (210 mg/100g) Phalsa (200mh/100g ) and Jamun (89 mg/100g) contain significant amount of oxalic acid. The rich source citric and malic acids Are Ber, Sapota, Aonla and Jamun, etc.

3) Phytate Phosphorus – In some fruits such as jackfruit, phalsa and pomegranate about 30-40 per cent of the total phosphorus is present in the form of phytic acid.

F. As a source of phytochemicals - Phytochemical are naturally occurring, biologically active chemical compound in plant. In plant phytochemical act as a natural defence system for host plant and provide colour, aroma and flavour. Phytochemical are protective and disease preventing particularly for some forms of heart disease. The most important action of these chemical with respect to human being is somewhat similar in that they functions as oxidant that react with free oxygen molecule or free radical in our bodies.

How the phytochemical helps to prevent diseases?

1. Stimulate the immune system, the body’s defense against viruses, bacteria and other disease- causing agents
2. Block the potential for carcinogens (cancer causing substances) to be formed in the body from substances we eat, drink and absorb from the environment
3. Reduce oxidation, the damage to cells that occurs with aging and exposure to pollution. Oxidation, caused by molecules called “free radicals,” can cause abnormalities in cells that may eventually lead to cancer.
4. Reduce inflammation that provides a setting favorable for cancer growth
5. Trigger death (a process known as apoptosis) of damaged cells that may be
6. Precursors to cancer
7. Prevent DNA damage and help with DNA repair mechanisms
8. Help to regulate hormones, such as estrogen and insulin. Excess levels of these hormones are linked with increased risk for breast and colon cancer.

Table 5. Types of phytochemical which are present in different fruit and their functional role.

<table>
<thead>
<tr>
<th>Phytochemicals</th>
<th>Plant source</th>
<th>Possible benefit.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carotenoids (beta- carotene, lycopene, lutein, Zeaxanthin)</td>
<td>Red, orange and green fruits</td>
<td>May inhibit cancer cell growth, work as antioxidant and improve immune response.</td>
</tr>
<tr>
<td>Flavonoids (Anthocyanins, Quercetin)</td>
<td>Apples, citrus fruits, coffee and tea, etc.</td>
<td>May inhibit inflammation and tumour growth. may aid immunity and boost production of detoxifying enzymes in the body</td>
</tr>
<tr>
<td>Polyphenols (Ellagic acid, resveratrol)</td>
<td>Green tea, grapes, wine, berries, citrus fruits, apples, and peanuts.</td>
<td>May prevent cancer formation, prevent inflammation and work as antioxidants.</td>
</tr>
<tr>
<td>Terpenes (perillyl alcohol, limonene, carnosol)</td>
<td>Cherries, citrus fruit peel, rosemary</td>
<td>May protect cells from becoming cancerous, slow cancer cell growth, strengthen immune function.</td>
</tr>
</tbody>
</table>

(North Carolina Association, 2007).

REFERENCE


PROTECTED CULTIVATION OF HORTICULTURAL CROPS

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ABSTRACT

India is endowed with diverse agro-climatic conditions, which helps to grow all kinds horticultural crops almost all through the year, in one part of the country or the other but the quality of the horticultural crops under open field condition is not suitable due to natural calamities like high or low temperature, frost, heavy rainfall occur during growing period of plant result in deterioration of the quality of planting material, effect on fruit quality and result in reduced yield increase disease and pest attack. To overcome these problems there is need to adopt protected structure which provides proper environmental condition throughout the growing period of the fruit crop.

There are many forms of protected structure such greenhouse, shade net, high tunnel, low tunnel, lath house, cold frame and hot bed are used to grow plant under partial and fully controlled environmental condition to get optimum growth and productivity round the year. The demand of planting material increasing every year, it is important to produce it throughout the year and looking towards the demand of fresh fruits in early season or off season and extra seasonal product important to take successful production of fruit crop, this will be possible by taking the advantages of creating optimum temperature and relative humidity by using different protective structure. Protective structure give better response than open field condition with respect to minimum number of days taken to sprouting, highest graft success, graft survival, number of leaves and length of sprouted shoot and other growth parameters and congenial condition inside the structure prevent desiccation of the scion and help for better survival of grafts. (Chander et.al 2016)

If we adopt protective structure for fruit crop it will maintain healthy condition of plant with increase yield and high quality of fruit due to favorable environmental condition than the open field condition.(Gubbuk .H 2004). The present chapter gives a brief idea about protected cultivation of fruit crop.

INTRODUCTION:

India is endowed with diverse agro-climatic conditions, which helps to grow all kinds horticultural crops almost all through the year, in one part of the country or the other but the quality of the horticultural crops under open field condition is not suitable for international markets, at the same time there is no guarantee of consistent production from open cultivation as the crop is exposed to number of natural environmental factors which changes frequently. One such technology is Protected cultivation technique is enables cultivator to produce several fold of good quality
production which is difficult in normal conditions due to climatic and other constraints. If the recommended and needful package of practices is adopted skillfully with exactness, the any crop can be grown in any season, at any place using protected cultivation technique. It enables to control climate (temperature, humidity, wind, light intensity, etc), atmospheric gas composition (mainly CO₂ concentration), fertilization, watering, pest and diseases, etc which results in better plant growth, better reproduction, minimized harmful effects of different factors (climate and agronomy) and higher production with better quality of produce. (Bhatnagar 1988).

Many forms of protected structures such as greenhouse, net house, high tunnel, low tunnel, lath house and plastic mulch etc are used for growing fruit crop. In plastic mulch different colure mulch (red, yellow, black) affects on growth, fruiting and fruit quality of fruit under polyhouse cultivation. (Sharma et al 2013).

Greenhouse crop production is at present practiced in more than 50 countries. Area under greenhouse for a few countries if given in table 1. Netherlands is believed to have adopted plastic greenhouse technology to a great extent. Netherlands, with about 89,600 ha under plastic and glass greenhouse tops the list. The occurrence of smaller land holding and growing shorty growing seasons in Netherlands and Japan has been the reasons for adoptions of greenhouse from of intensive cultivation. Water conservations have been one of the reasons for greenhouse crops production in Israel and Middle Eastern countries. India has had greenhouse, mainly glasshouse, for 4 decades for research and off season storage plant material, the interest in commercial application is more recent.

**Table 1. Greenhouse area in different countries**

<table>
<thead>
<tr>
<th>Country</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands</td>
<td>89,600</td>
</tr>
<tr>
<td>China</td>
<td>51,000</td>
</tr>
<tr>
<td>Japan</td>
<td>42,000</td>
</tr>
<tr>
<td>Spain</td>
<td>28,000</td>
</tr>
<tr>
<td>South Korea</td>
<td>21,000</td>
</tr>
<tr>
<td>Italy</td>
<td>20,000</td>
</tr>
<tr>
<td>Israel</td>
<td>18,000</td>
</tr>
<tr>
<td>USA</td>
<td>15,000</td>
</tr>
<tr>
<td>Turkey</td>
<td>12,000</td>
</tr>
<tr>
<td>India</td>
<td>Only 100 (1995), 5730 (2012)</td>
</tr>
</tbody>
</table>

The choice of crops to be raised in a greenhouse is made on the basis of the physical size of the structure and the economics of crop production. As a result, high value horticultural crops have been more popular for cultivations in greenhouses. A list of commonly grown greenhouse crops is given in Table 2. In addition, raising of
seedlings and plant propagation are important commercial aspects of greenhouse technology.

Table 2. Commonly grown greenhouse crops

<table>
<thead>
<tr>
<th>No.</th>
<th>Category</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vegetables</td>
<td>Tomato, Cucumber, Lettuce, Onion, Cabbage, Beans, Peas, Spinach, Egg Plant, Peppers, Squash, Chili, Okra, Turnip, Radish and Melon</td>
</tr>
<tr>
<td>2</td>
<td>Fruits</td>
<td>Strawberries, Grapes Citrus, Banana, etc</td>
</tr>
<tr>
<td>3</td>
<td>Ornamental crops</td>
<td>Roses, Chrysanthemum, Gerbera, Lilies, Carnation, Orchids Anthodium’s, etc.</td>
</tr>
<tr>
<td>4</td>
<td>Other</td>
<td>Nurseries and Tobacco</td>
</tr>
</tbody>
</table>

❖ Need of Protected Cultivation of Fruit Crops:
- Crops could be grown under inclement climatic conditions when it is not possible to grow in open field.
- Protect the fruits against heavy rains, hails, birds etc occurred at the time of harvesting.
- We can produce superior quality fruits through protected cultivation.
- Off-season cultivation is possible and it’s better to reduce insect pest & diseases attack.
- In green houses having complete environmental control certain crops could be grown round the year it helps to meet the market demand.
- Reduced the expenditure on use weedicide and pesticide to control weed and pest respectively.
- Efficient utilization of precious inputs like water and nutrient.
- Hardening and acclimatization of tissue cultured plants is possible under protected structure.

❖ Principles of Protected Crop Production:
- The transparent cover acts as a radiation filter.
- Trapping of solar heat, thereby raising the greenhouse temperature.
- Lack of air exchange between ambient and greenhouse condition enhance the heat retention capacity.
- Natural rise in greenhouse temperature coupled with available sun light helps successful production crop.

❖ Characters of Fruit Crops for Protected Structure
- The tree should be rapid grower e.g. Papaya, Banana, Strawberries.
- It should have dwarfing character.
- Plant should give good response to training and pruning.
Single stemmed crop prefer for protected structure eg. Papaya, Banana.
If tree having branched species it should be having dwarfing character.
Crop varieties should be regular bearer with high yielder.
The tree should be free from biotic and a biotic stress.
The variety should be short durable and early maturable.

Different Types of Protected Structure for Fruit Crops: Different types of protected structure are used for growing of fruit crops. Some are low cost and some are high cost structure. These are as follows;

1. Plastic tunnel: Poly tunnels are available in different sizes and constructed as per customer requirement. The sizes vary from as small as 96 Sq. M to 500 Sq M and more. The degree of sophistication also varies from a simple Poly Tunnel with polyethylene film covering to highly sophisticated, fully automated drip and forgers systems, full scale computerized (fully automated) systems. Plastic tunnel which are two types:

A. High tunnel: High tunnels are simple, plastic-covered, passive solar-heated structures in which crops are grown in the ground. High tunnels are not conventional greenhouses. But like plastic-covered greenhouses, they are generally Quonset-shaped, constructed of metal bows that are attached to metal posts which have been driven into the ground about two feet deep. The height is more than low tunnel. They are covered with one layer of 6 mil greenhouse grade polyethylene and are manually rolling up the side each morning and rolling them in early in the evening, no permanent heating system is advisable to have a standby portable propane unit to protect against unexpected below freezing temperature. Establishment and maintenance cost is higher than low tunnel.

B. Low tunnel: Thin, clear plastic, usually 4ml or less, is supported by wire or pipe frames to resemble a tunnel. Height generally 1m or less. Small structure that provides temporary crop protection also called as row cover. A low tunnel is a structure built just high enough to cover the canopy of the plant. Low cost structure than high tunnel. Mostly used for strawberry cultivation.

2. Net house: The framed or an inflated structure covered with shade net. Prepared from high density polyethylene. Shade intensity varies between (25-75 %). Insect proof nets: 40-60 mesh free from viruses. It is helpful for controlling temperature, light, water and moisture of nature as per requirement resulting in best output and quality of crops. These are used to reduce adverse effect of scorching sun and rains.

3. Lath house: It is a structure which is made with the object of providing shade and thereby protecting the young tender seedlings or rooted cuttings which are sensitive to strong sunlight and high temperature. The transpiration and evaporation loss of moisture are directly related with temperature. So, in lath house the loss of moisture from leaf as well as soil surface is greatly reduced, due to low temperature and light intensity, resulting into less water requirements of plants. Seedlings are transferred for hardening from greenhouse or hot bed to lath house.
4. **Glass house:** Glass house have been known to last 100 years. They existed prior to 1950. They are more expensive types today and need proper maintenance. Earlier only glass house covering with were constructed because glass provide greater interior light intensity. These glasshouse have higher air infiltration rate which leads to lower interior humidity and better disease prevention. Such structure are provided with adequate ventilation and may even have temperature controlling facilities. Seedlings are raise inside the house on raised beds or plots. Most congenial conditions can be created for the growth and development of plant. They are expensive today and need proper maintenance. Average cost per year is still more than that of film plastic greenhouse.

5. **Polyhouse:** Polyhouse made up of tight, cheap, flexible and transparent polythene covering in which crop grow under polyhouse in any season of the year depending of there requirement because temperature and humidity easily controlled inside the polyhouse.

5.1 **Types of polyhouse:**

A. **Naturally ventilated polyhouse:** These polyhouse do not have any environmental controlled system except for the provision of adequate ventilation and foggers system to prevent the basically damage from weather aberrations and other natural agent.

B. **Environmental controlled polyhouse:** These type of polyhouse help to extend the growing season and permits off season production by way of controlling light, temperature, humidity and CO₂ level and nature of root medium.

6. **Mist chamber:** Mist propagation technique used in the rooting of cutting of difficult to root plants. In this system, an intermittent water mist is provided during day time over the cutting to rooting media which increases the relative humidity surrounding the leaf and lowers the air and leaf surface temperature, thus reduces the rates of transpiration and respiration the intermittent mist is controlled by an electrically operated timer mechanism, regulating a solenoid valve, spraying water for 5 seconds and then cut off till the leaves starts drying under the mist along with these cuttings to control the mist this technique is ideal for rooting of leafy cuttings.

7. **Hot bed:** It is a small fixed structure having three component, namely frame, cover and heating unit. It is also used for growing small tender seedling and rooting of cuttings. The cover is made of glass or transparent polyethylene sheet. The soil of the bed is dugout and 30 to 50 cm thick layer of raw cow dung, preferably house manure is spread and over this 15 to 20 cm thick rooting medium is placed. Decomposition of raw dung generates heat and temperature of the rooting medium is raised. In large sized modern nursery, improved heating arrangements like steam, piping, hot water piping, and electric cables are used for heating the bed. The frame can be made of wood or any light metal.

8. **Cold frame:** It is small and movable structure of glass, which encloses a ground bed. It is used for hardening or conditioning of rooted cutting and young seedlings before transferring them out. There is no bottom heating arrangement and heat is tapped from the solar energy. It should therefore, be located in a sunny place. For assured success, care has to be taken in respect of proper ventilation, shade, watering and winter
protection. The sash is removed during daytime of quick raising of temperature of growing medium.

**Different Types of Protected Structure for Fruit Crops**

![Figure 1. Glass house](image1)

![Figure 2. Poly house](image2)

![Figure 3. Net house](image3)

![Figure 4. Lath house](image4)

![Figure 5. Low tunnel](image5)

![Figure 6. High tunnel](image6)
Figure 7. Mist Chamber  
Figure 8. Cold Frame

9. **Greenhouse**: A greenhouse is a framed or inflated structure covered with a transparent or translucent material in which crops could be grown under the conditions of at least partially controlled environment and which is large enough to permit persons to work within it to carry out cultural operations.

- Average dimensions of structure for fruit crops production is 5-6 m high, covering 1.25 ha. Typical greenhouse structure is made of galvanized posts, 6 m high in the centre and 5.5 m high at the edges.
- The first greenhouse in the 1700s used glass on one side only as a sloping roof. Later in country, glass was used on both sides.
- The first use of polyethylene as a greenhouse cover was in 1948. when professor Emery Myers Emmert, at the University of Kentucky, used the less expensive material in place of more expensive glass.

▶ **Orientation and site selection for Greenhouse**

1. The orientation is always East to West for single span, North to South for multispans greenhouse.
2. The protective structure should not be constructed in shade.
3. The protective structure are kept cold or hot depending upon the season.
4. Away from water logging condition.
5. Supply of electricity and water should be regular.
6. Soil should be properly leveled, drained and well fertile.

▶ **Classification of greenhouse:**

Greenhouse structures of various types are used successfully for crop production. Different types of greenhouse are designed to meet the specific needs. Different types of greenhouse based on shape, utility, Construction and covering material.
A. Greenhouse type based on shape: The commonly followed types of greenhouse based on shape are lean- to type, even span, uneven span, ridge and furrow saw-tooth and Quonset types.

1. Lean- to type greenhouse: A lean- to type design is used when a greenhouse is Built against the side of other greenhouses or building. This design makes the best use of sunlight and minimizes the requirement of roof supports. The roof slopes to one direction usually facing south. It is used for bulb-forcing or seed starting operations. Lean-to type greenhouse is a half a greenhouse, split along the peak of the roof or ridge. This type of greenhouse is nice to have when space is a problem.

![Lean-to Type](image)

Figure 9. Lean to type greenhouse

2. Even span type greenhouse: These types of greenhouse design when owner is constructed leveled ground. In this type, the two roof slopes are of equal pitch and width. It is commonly used today for single houses or for several houses connected together to form one huge structure. For single houses type the span in general, varies from 5 to 9 m whereas the length is around 24 m. The height varies from 2.5 to 4.3 m. Usually have clear spans with truss supports rather than supporting columns without the columns the heat closures can be used to conserve energy.

![Even span type greenhouse](image)

Figure10. Even span type greenhouse
3. Uneven Span type Greenhouses: This type of greenhouse is constructed on hilly terrain. The roofs are of unequal width, which make the structure adaptable to the side slopes of hills. In this type One side of the roof is longer than the other side. When the longer side would face south, the sun’s heat could be used to maximum advantage. High fuel costs are causing growers to switch back to this type of greenhouse. This type of greenhouses is seldom used now a days as it is not adaptable for automation.

Figure 11. Uneven span type greenhouse

4. Ridge and Furrow Type Greenhouse: In this type, use of two or more A-frame greenhouse connected to one another along the length of the eave. The eave serves as a furrow or gutter to carry rain and melted snow away. The side wall is eliminated between the greenhouse which results in a structure with a single large interior. Consolidation of interior space reduces labour, lowers the cost of automation, improves personal management and reduces fuel consumption as there is less exposed wall area through which heat escapes.

Figure 12. Ridge and furrow type greenhouse

5. Saw Tooth type Greenhouse: These are also similar to the ridge and furrow type greenhouses except that there is provision for natural ventilation in this type specific natural ventilation flow path develop in a saw-tooth type greenhouse.
6. Quonset Greenhouse: In this type, the pipe arches or trusses are supported by pipe purlins running along the length of the greenhouse. Covering material used for this type of greenhouses is polyethylene. Such greenhouses are typically less based on the artificial cooling and heating.

B. Greenhouse type based on Utility: Based on utility greenhouses are classified as:

1. Greenhouse for Active Heating: During the night time, the air temperature inside greenhouse decreases and to avoid the cold bite to the plants due to freezing, some amount of heat to be supplied. The requirements for heating greenhouse depend on the rate at which the heat is lost to the outside environment. Various method are adopted to reduces the heat losses, viz., using double layer polyethylene, thermo pane glasses or to use heating system such as unit heaters, central heat, radiant heat and solar heating system.

2. Greenhouse for Active Cooling

During summer season, for plant survival it is necessary to reduce the temperature of greenhouse than the ambient temperature, for effective crop growth. Therefore, suitable modifications are made so that large volumes of cooled air are drawn into greenhouse. This type of greenhouse consists of evaporation cooling fan and pad system or fog...
colling. The greenhouse is designed in such way that it permits a roof opening of 40% and some cases nearly 100%.

C. Greenhouse type based on construction: Based on construction greenhouses are classified as:

1. Wooden framed structure: This kind of greenhouse is made with span less than 6 m only wooden framed structure is used. Side posts and columns are constructed of wood without use of a truss. Pine wood is commonly used as it is less expensive and possesses the required strength. Timber locally available, with good strength durability and machine ability also can be used for construction.

![Figure 15. Wooden framed structure of greenhouse](image)

2. Pipe framed structures: This kind of greenhouse is made when the clear span is around 12 m for this purpose pipes are used for the construction. In general the side posts and columns, cross-ties and purlins are constructed using pipes. In this type trusses are not used. The pipe components are not interconnected but depend on attachment of sash bars for support.

![Figure 16. Pipe framed structures of greenhouse](image)
3. **Truss framed structure:** This kind of greenhouse made when span is greater than or equal 15 m. In this type flat steel, tubular steel or angle iron is welded together to form a truss encompassing rafters, chords and struts. Struts are support member under tension. Angle iron purlins running throughout the length of greenhouse are bolted to each truss. Columns are used only in very wide frame houses of 21.3 m or more. Most of the glass houses are of truss frame type, as these frames are best suited for pre-fabrication.

![Figure 17. Truss framed structure of greenhouse](image)

**D. Greenhouse type based on covering material:** Various factors to be considered while selecting the greenhouse covering material are light transmission, weight, resistance to impact, durability to outdoor weathering and thermal stability over wide range of temperatures.

The ideal greenhouse selecting covering material should be the following:

1. It should be transmit the visible light portion of the solar radiation which is utilized by plants for photosynthesis.
2. It should be absorb the small amount of UV in the radiation and convert a portion of it to fluoresce into visible light, useful for plants.
3. It should be reflect or absorb IR radiation which is not useful to plants which causes greenhouse interiors to overheat.
4. It should be of minimum cost.
5. It should be usable life of 10 to 20 years.

Based on covering material greenhouses are classified as:

1. **Glass greenhouses:** Glass as covering material was used for greenhouse construction because glass provides greater interior light intensity. These greenhouses have higher air filtration rate, which leads to lower interior humidity and better disease prevention. Lean-to type, even span, ridge and furrow type design are used for construction of glass greenhouse.
2 Plastic film greenhouses: Flexible plastic films including polyethylene, polyester and polyvinyl chloride (PVC) are used as covering material for greenhouse. Plastic covering is popular because it is cheap and cost of healing is less as compared to glass greenhouse but plastic films have short life as the covering material. Quonset design and gutter-connected design is suitable for using this covering material.

3. Rigid panel greenhouse: Polyvinyl chloride rigid panels, fiber glass reinforced plastic (FRP), acrylic and polycarbonate rigid panels are used as covering material. These panels can be used in the Quonset type frames or ridge and furrow type frames.

This material is more resistant to breakage and the light intensity is uniform throughout the greenhouse as compared to glass or plastic but the panels tend to collect dust as well as harbor algae which results in darkening of the panels and subsequent reduction in the light transmission. High grade panels have long life even up to 20 years. There is significant danger of fire hazard.
E. Classification of greenhouse based on suitability and cost:

a) Low cost or low tech greenhouse:

Low cost greenhouse is a simple structure constructed with locally available materials such as bamboo timber etc. The ultra violet (UV) film is used as cladding materials. Unlike conventional or hi-tech greenhouses, no specific control device for regulating environmental parameters inside the greenhouse are provided. Simple techniques are, however, adopted for increasing or decreasing the temperature and humidity. Even light intensity can be reduced by incorporating shading materials like nets. The temperature can be reduced during summer by opening the side walls. Such structure is used as rain shelter for crop cultivation, otherwise, inside temperature is increased when all side walls are covered with plastic films. This type of greenhouse is mainly suitable for cold climate zone.

b) Medium – tech greenhouse:

This type of greenhouse is constructed using galvanized iron (GI) pipes. The canopy cover is attached with structure with the help of screws. Whole structure is firmly fixed with the ground to withstands the disturbance against wind. Exhaust fans with thermostat are provided to control the temperature. Evaporative cooling pads and misting arrangements are also made to maintain a favorable humidity inside the greenhouse. As these systems are semiautomatic, hence require a lot of tension and care, and it is very difficult and cumbersome to maintain uniform environment throughout the cropping period. Theses greenhouses are suitable for dry and composite climatic zones.

❖ CLIMATE CONTROL IN GREEN HOUSE:

The control of climate inside greenhouse means control of temperature, light, humidity and CO₂ enrichment air composition and nature of the root medium, etc. Climate control in greenhouse can be done by following steps:

1. Manual controlling
2. Thermostats
3. Active summer cooling systems
   A. Fan and pad cooling system
   B. Fog cooling system
4. Active winter cooling system
   A. Convection tube cooling
   B. Horizontal air flow cooling
5. CO₂ enrichment method.

1. Manual controlling:

1. During the half of the 20" century, it was common for greenhouse firms to employ a night watch person to regulate temperature
2. This person made periodic trips through greenhouse during night, checking the temperature in each greenhouse and controlling it by opening or closing valves of heating pipes are required.

3. During the day, employees opened or closed ventilators by hand to maintain temperature.

4. Hence temperatures had to be manually controlled throughout the day during cropping season.

5. The success of manual control based on skill experience of person.

2. **Thermostat's**

   1. Thermostat is automatic devices which senses the temperature and activates/deactivates the attached equipment, with reference to set a temperature.

   2. It may make use of a bimetallic strip or thin metal tube filled with liquid or gas as sensor and it produced some physical displacement according to sensed temperature.

   It not highly accurate need for equal calibration.

3. **Active summer cooling systems:** Active summer cooling achieved by evaporation cooling process evaporative cooling system developed to reduce excess heat in greenhouse. The two cooling summer cooling system used presently are as following types.

   1. **Fan and pad cooling system:**

      1. In this method one side wall of greenhouse water is passed through pad usually vertically in wall nowadays it made up of cellulose matter similar appearance to corrugated card board box.

      2. Exhaust fans are placed on opposite wall then warm air drawn outside through pad.

      3. Wet of pad absorb heat from greenhouse air pass through outside fan cooling effect.

   2. **Fog cooling system:**

      The fog cooling system based on same cooling principle as fan and padsystem but arrangement is different.

      1. A high pressure pumping apparatus generates fog containing water droplets with a mean size of less than 10 micron using nozzle.

      2. The droplets are sufficiently small to stay suspended in air i.e. fog dispered through the greenhouse cooling air everywhere.

      3. This system not wet foliage so there is less scope for disease and pest attack.

      4. It also useful for seed germination cutting propagation.

      5. It lowers the temp nearly 100 % than fan pad cooling system.

Comparison of Fan and pad cooling system and fog cooling system:
The fan and pad system can lower the temperature of incoming air by about 80% of the difference between dry and wet bulb temperature while the fog cooling system can lower the temp by nearly 100% of difference.

This is due to the fact that complete evaporation of the water is not taking place because of bigger droplet size in fan and pad whereas in the fog cooling system there will be complete evaporation because of the minute size of the water droplets. Thus, lesser the dryness of the air, greater evaporative cooling is possible.

![Fan and pad cooling system](image1.jpg) ![Fog cooling system](image2.jpg)

**Figure 20. Fan and pad cooling system**  **Figure 21. Fog cooling system**

### 4. Active Winter Cooling System:

During winter excess heat is a problem for maintaining heat in the greenhouse than entrapment of solar heat rise inside temperature. The actual process of Winter cooling is the mixing of low temperature ambient air with warm inside air, which cools the greenhouse environment. Two active winter cooling systems:

A. Convection Tube Cooling

B. Horizontal Air Flow (HAF) Cooling

a. Convection Tube Cooling

The convection tube cooling are louvered air inlet, a polyethylene connection tube with air distribution holes, a pressurizing fan direct air into the tube under pressure and an exhaust fan to create vacuum.

1. When the air temperature inside greenhouse exceeds the set point, the exhaust fan starts functioning thus creates vacuum inside greenhouse.

2. The pressuring fan at the end of clear polyethylene convection tube, operated to pick up cool air entering the louver.

3. Cold air mixes with warm greenhouse air above the plant height.

4. The cooled mixed air, being heavier gently flows down to floor level effects the complete cooling of the plant area.

5. When cooling is not required, the inlet louver closes and the pressurizing fan continues to circulate the air within the greenhouse. This process minimized the temperature gradient at different levels.
b. Horizontal air How (HAF) cooling

- It uses small horizontal fans for moving the air mass and is considered to be an alternative to convection tube for the air distribution.
- In this method, the greenhouse may be visualized as a large box containing air and fans located strategically moves the air in a circular pattern.
- The HAF system makes use of the same exhaust fans, inlet lauves and control as the convection tube system.

C. Carbon Dioxide enrichment method:

Methods of increasing CO2 levels in greenhouse:

1. Production of carbon gas by burning method: In this method fton natural oil, puffin oil and kerosene are burned and produce CO2 gas which is utilized in greenhouse.

2. Liquid carbon dioxide: Under certain pressure CO2 gas can be converted into liquid form and passed inside greenhouse using regulating valve.

Solid C02 (also called dry ice): under high pressure and low temperature CO2 gas can be converted into solid i.e. dry ice. By using it can increase CO2 level in the greenhouse.

Light control: For photosynthetic activities of the plant, light are essential. Primarily, the 3 components of sun rays are important i.e. light intensity, light frequency and light period. Greenhouse crops are subjected to light intensities as high as 120K lux on clear summer days to below 3.2K hour on cloudy winter days. It is primarily the visible spectrum of light that is used for photosynthesis i.e. 400-700nm wavelength range. In the black and red bands of visible spectrum photosynthetic activity is higher when the blue light (short wavelength) alone is supplied to plant, the growth is retarded and plant become hard and dark in colour. When plant are grown under red light (longer wavelength), growth is soft and internodes are long resulting in tall plants.

Advantages of Greenhouse for fruit crop:

1) Under the green house crops could be grown under inclement climatic conditions when it is not possible to grow in open field.
2) Precious inputs like water and nutrients can be efficiently utilized.
3) We can produce early nursery and early crop.
4) Greenhouse growing ensures higher productivity of crops.
5) It provides effective control against diseases, insect pests and heavy rains, hails, birds etc.
6) It reduces expenditure on weed control.
7) It provide good environment for hardening and acclimatization of tissue cultured plants.
8) Greenhouse produces quality wise superior produce.
9) Under minimum space one can have maximum production of crop plants. Single person can have control over thousands of plants.

**Disadvantages of Greenhouse for fruit crop:**

1. High cost of initial installation
2. Non-availability of various components
3. There is also increased incidence of mites and powdery mildew
4. Little or no natural pollination of female flowers.

**Reference:**

CULTURE OF VEGETABLE GARDENING

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Kitchen garden or nutrition garden

Kitchen garden or home garden or nutrition garden is primarily intended for continuous supply of fresh vegetables for family use. A number of vegetables are grown in available land for getting a variety of vegetables. Family members do most of works. Area of garden, lay out, crops selected etc. depend on availability and nature of land. In rural area, land will not be a limiting factor and scientifically laid out garden can be established. In urban areas, land is a limiting factor and very often crops are raised in limited available area or in terraces of buildings. Cultivation of crops in pots or in cement bags is also feasible in cities.

The unique advantages of a kitchen garden or home garden are:

- Supply fresh fruits and vegetables high in nutritive value
- Supply fruits and vegetables free from toxic chemicals
- Help to save expenditure on purchase of vegetables and economize therapy
- Induces children on awareness of dignity of labour
- Vegetables harvested from home garden taste better than those purchased from market.

Market garden

Market gardens are established within 15-20 km of city to supply fresh vegetables to nearby local market. Cropping pattern in a market garden depends on demands of local market. Mostly high value crops, early varieties and varieties or crops which do not stand long distance transport (amaranth, yard long bean, bitter gourd etc.) are grown on an extensive manner in market garden. High cost of land and labour is compensated by high price of produce, low transport cost and availability of municipal compost. Due to increasing cost and pressure on land near big cities and fast developing transportation facilities, market vegetable gardens in big cities are on verge of extinction.

Truck garden

Truck gardens are usually established in rural areas for supplying a few vegetable crops to a distant market. Here cultivation of a few specialized crops is done on an extensive scale in large area under ideal soil and climatic conditions. Relatively cheap labour and land, mechanical cultivation and high yield result in low production cost in a truck garden. However, involvement of middlemen in marketing and cost of transportation reduce net income.
Vegetable garden for processing

Vegetables like tomato, peas, potato, sprouting broccoli, spinach, lima bean, gherkin and onion are utilized by processing industries for canning, dehydration, freezing, pickling and for making other processed products in developed countries. For regular supply of specialized varieties and crops to processing industries, vegetable gardens are established near processing factories. In India, this type of gardens is found in Punjab and a few other states for supplying tomato for processing industries. Varieties meeting processing requirements only are cultivated here and supply of seeds for sowing, cultivation practices and supply of vegetables to processing industry are mostly based on some agreement between factory owners and farmers.

Vegetable garden for seed production

Annual seed requirement of major vegetables in India is around 51,000 tonnes. Major share of requirement is met with home saved seeds of farmers. With advancement of technologies, especially development of improved varieties and hybrids, seed production has become a specialized job requiring great expertise.

Vegetables for seed production are grown in ideal soil, climate and disease-free conditions. Each crop / variety is grown in specified isolation distance meeting all the field and crop standards. Timely inspection and rouging are also done to maintain seed purity. Handling of seed crop curing, threshing, cleaning, package and storage are specialized jobs requiring thorough knowledge. Since pests and diseases affect seed field more than that of vegetable field, timely crop protection measures are to be taken, especially for control of seed borne diseases.

Special Systems of Vegetable Farming

Vegetables are cultivated during specific seasons in areas where soil and climatic conditions are ideal and water is available in plenty. It is also grown as rainfed crop depending on receipt of rain. Specific regions and villages scattered throughout the country are famous for cultivation of specific vegetables. To meet increasing demand of vegetables cultivation is also undertaken in adverse climatic conditions by adjusting time of planting or creating favorable situations for growth of plants under natural conditions or by constructing temporary or permanent structures.

Special systems of cultivation followed in India are:
1. Cultivation in protected structures like glass houses, poly houses, rain shelters etc.
2. Hydroponics
3. Floating type of cultivation
4. River bed cultivation
5. Organic farming
Hydroponics

Hydroponics is the technique of growing crops in soil-less media using nutrient solutions. It provides a method of growing plants in areas where soil is lacking or soil is present but contaminated with disease causing organisms or toxic substances. This technology is suited for growing high value vegetables like tomato, capsicum, lettuce, water melon, musk melon etc. Here roots of plants are floated in nutrient solution provided with circulating air or bubbling air. The plants are kept in proper position with supports.

The Defense Research Laboratory, Haldwani in Uttaranchal made extensive works on hydroponics and has suggested the following model for a hydroponics system.

The basic components of hydroponics are:

- Shallow fibre glass trays / plastic trays (60 cm length x 40 cm width x 12.5 cm depth) in which plants are grown.
- A collection tank / nutrient solution storage tank.
- A pump which circulates the nutrient solution from reservoir to growing trays through polyethylene tubes.
- A sequential timer to control operation of pump.
- An aerator connected to reservoir through polyethylene tube, to aerate nutrient solution to maintain oxygen level in nutrient solution.

Seedlings are planted on trays covered with thermocol sheets which provide support to young plants and keep roots of plants and nutrient solution in darkness. A uniform slope is maintained in trays for free flow of nutrient solutions and to avoid water stagnation in trays. For proper growth, plants must be supplied with all nutrients. To prepare nutrient solution, various fertilizers are mixed in a particular proportion and dissolved in water.

Cultivation of vegetables in floating bases in lakes

In Dal lakes of Kashmir, vegetables are cultivated in floating bases made up of roots of Typha grass growing wild in the lakes. The base is first prepared by weaving of roots of Typha grass. Then fertile soil rich in humus is placed on the grass base and seeds are sown. All the intercultural operations including watering are done with the help of boats. The floating garden can be dragged to different places for specific purposes. Most of the summer vegetables supplied to Srinagar are from these floating gardens.

Cultivation of vegetables in river bed

Growing of cucurbits in river beds or river basins constitute a distinct type of farming. These areas are called “diara lands” in UP and Bihar. In river beds of Jamuna, Ganga, Goamti, Sarayu and other tributaries in Haryana, UP and Bihar and other rivers in the remaining states, cucurbits like bottle gourd, ash gourd, parval, pumpkin and melona
are commonly grown. It is a type of vegetable forcing during winter from November-February in North India. In Kerala, fertile basins of rivers Pamba and Manimala are utilized for growing crops like yard long bean, bitter gourd and snake gourd. Cucurbits like ash gourd, pumpkin, bottle gourd and water melon are cultivated during summer season in river beds of Bharathapuzha in Kerala.

River beds are formed by alluvial and diluvian action of rivers and due to inundation caused by swollen river during South West monsoon. Fresh silt and clay deposited every year during monsoon months make the land suitable, for growing vegetables literally on sand. Even though upper layer of sand seems unsuitable for cultivation, subterranean moisture seeped from adjacent river streams, makes it possible to grow early crops. Cucurbits are adapted to this situation due to long tap root system.

The system consists of identification of areas where there is silt deposit and water level is around 2.0 m below. After identifying the areas, trenches at 2.0-3.0 m spacing or pits at 4.0 m distance are dug after cessation of South West monsoon, late in October. Making pits in sand is a skilled work. Individual pits of 1.0 m diameter are taken to a depth of 1.0-1.5 m. After removing top layer of sand, lower silt is dug and raised almost ¾ height of the pit. Finally it takes the shape of a pillar inside the pit surrounded by sand on all sides. A handful of assorted seeds are sown on this silt. Most cucurbits are grown in November-December. Before sowing, trenches are manured with farmyard manure / cakes or other decomposed wastes. Since winter temperature in North India falls down to 1-2oC, protection is done by planting grass stubbles (Saccharum spp.).

Organic farming

The basic principles to be followed in organic farming are:

- Cultivate crops in the ideal cropping season: The ideal time of sowing for each vegetable crop is standardized for different agro-climatic zones. However, minor alterations are to be made to suit to specific localities.
- Avoid off-season cultivation of vegetables in traditional growing areas since it may result in heavy incidence of pests and diseases.
- Cultivate varieties already acclimatized in the locality. Priority should be given to medium yielding varieties tolerant to pests and diseases rather than high yielding varieties.
- Select pest and diseases resistant varieties in areas and seasons when severe incidence of pests or diseases are expected.
- Follow scientific crop rotation practices regularly in vegetable cultivation.
- Raise a leguminous crop and plough back to soil at its pre flowering stage before cultivating a heavy feeding vegetable crop in particular site.
- Practice shifting type of cultivation and keep land fallow at least one season in a year.
- Plough back all the crop residues to the soil whenever a crop is over.
- Practice composting regularly for converting biodegradable wastes to organic manures. Fungi like *Pleurotus* sp., and earthworms (*Eudrillus eugineae*) can be effectively utilized for making compost at a faster rate and for making it nutrient rich.
- Locally available organic materials like farmyard manure, poultry manure, goat manure, green leaves, organic cakes, fish meal, bone meal, etc. may be given priority for use in the organic farming. Apply farmyard manure or compost as basal dose and organic concentrates like organic cakes, poultry manure, vermin-compost etc. as top dressing.
- Use weeds as mulches or cover it with soil for converting to organic matter.
- In organic farming, native strains of bio-fertilizers like *Rhizobium*, *Azotobacter*, blue green algae, azolla, phosphate solubilizing bacteria and fungi, mycorrhizal fungi, etc. may be utilized for fixing nitrogen and increasing availability of phosphorus to plants. The enzymes and hormones produced by microorganisms also impart favourable effects on growth and productivity of crops.
- Burning pits before sowing or practice solarisation to control soil borne pests and diseases.
- Remove alternate hosts of pests and diseases and follow eco-friendly pests and disease control measures like cutting and removal of pests and diseased plants or plant parts, trap cropping, use of colour, sticky and other traps for attracting and killing insects.
- Promote biological control of pests and diseases by promoting parasites and predators.
- Home made insecticides like neem oil – garlic mixture, neem kernel suspension, tobacco decoction, etc. have wide use for control of pests and diseases in organic farming of vegetables. Plants like *Andrographis* sp., *Clerodendron*, *Eucalyptus* etc. also have values in pest control.
- Micro organisms like viruses, fungi, bacteria etc. are currently utilized in pest control under organic farming. Nuclear polyhedrosis viruses (NPV) for control of *Heliotis armigera*, bacteria like *Pseudomonas fluorescens* against diseases incited by *Phytophthora*, *Pythium*, *Rhizoctonia*, *Fusarium*, *Colletotrichum*, *Rolstonia*, and *Xanthomonas*; *Bacillus thuringiensis* for control of insect pests *Plutella* sp., *Heliothis* sp., *Earias* sp. etc.; fungi like *Fusarium pallidoroseum* for control of aphids are useful in organic farming. Fungal antagonists like *Trichoderma* sp. For control of soil borne diseases caused by *Pythium* and *Phytophthora*, and *Pseudomonas fluorescens* for control of specific fungal, bacterial and viral diseases are also effective.
- Insects like *Trichogramma brasiliensis*, *T. chelonis* and *Chrysoperla carnea* can also be utilized in eco-friendly pest control in vegetables.
• Cultivators also should lead a life in tune with nature to produce pesticide free vegetables and to practice a farming system, which is eco-friendly and sustainable.

Reproductive Biology and Flowering Behavior of *Ailanthus excelsa* Roxb.

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The arid regions of India lies between latitude 24°30’ and 30° N longitudes 69°30’ and 76° E, occupies nearly 32 million hectare, of which 28.6 million hectare consists of the Thar Desert of western India in Rajasthan, Gujarat, Haryana, Maharashtra, Punjab, Andhra Pradesh and Karnataka (Shankarnaryan *et al.*, 1987). It is predominantly a sandy desert, and hence, it is also known as great Indian Sand Desert. These regions are characterized by hostile environmental conditions such as low and erratic rainfall, intense solar radiation and high evaporation (Dhir *et al.*, 1992). Soils of these areas are immature, structureless and very coarse in texture with low water holding capacity, highly impermeable and poor nutrient status.

The extreme scarcity of water, sandy duney terrain, wind erosion and recurring droughts have been driving farmers to despondency. In absence of favorable conditions for intensive agriculture, livestock rearing is an alternative source of livelihood of majority of the rural population in arid ecosystems of different states of India. The problem is becoming more and more acute with simultaneous increase in livestock population. Therefore, to meet the increasing demand for fodder (green and dry) for livestock and food, fuel wood and timber, etc. for human population on sustainable basis without degradation of land resources, the only alternative is parallel advancement in the land productivity and agroforestry. After *khejri* (*Prosopis cineraria*), *mahaneem* (*Ailanthus excelsa*) is the only tree that not only feed to the animals but also used in manufacturing of plywood, match-sticks, toy and packing materials, medicine, etc. Mahaneem reflects wider adaptability and higher tolerance to biotic and abiotic stresses hence, a potential species during drought/ climate change. The selection of mahaneem for commercially important agroforestry modelsto obtain higher productivity holds significance in producing fodder, fuel wood, timber, etc. in arid ecosystems. Realizing its multiple uses, its cultivation in various systems extended and came out to be as profitable venture in case of agroforestry and silvi-pastoral system (Mann, 1994). Mahaneem plantation on community land, farm boundary, road avenues and in agroforestry system helped in maintaining the ecosystem by slowing down the variations in climatic parameters due to climate change. Foliage of mahaneem is used by small ruminants to meet the green fodder requirement during lean period and it is also sold in the market to earn some income to meet the farmer’s expenditure to sustain their livelihood in harsh climate. Its wood is very light, soft and perishable. The timber is used for packing cases, fishing floats, boats, spear sheaths, sword handles, toys and drums. The bark is bitter, astringent, anthelmintic and it is used in diseases like dysentery, bronchitis, asthma, dyspepsia and ear ache (Lavhale and Mishra, 2007), antifertility (Dhanashekaran *et al.*, 1993 and Ravichandran *et al.*, 2007) insect feeding, antifungal, antimicrobial, antibacterial, hypoglycemic, hepatoprotective,
antiproliferative (Tripathi and Jain, 1993 and Joshi et al., 2003). Inspite of it’s such a high value, required efforts have not been made for its genetic improvement. For any tree improvement programme knowledge of flowering behaviour and reproductive biology is pre-requisite, which also helps in understanding the evolutionary dynamics of a species.

1. Flowering Behaviour (Phenology):

Phenology is described as the art of observing the phases of the life cycles or activities of organisms as they occur throughout the year by Leith (1973). Different species of plants differ in the seasonal periodicity and sequential pattern of their phenological activity. Environment has a profound effect on the phenology of plants. Phenological study is useful in combating afforestation and in plant management, understanding floral biology, estimation of reproductive, regeneration (Mulik and Bhosale, 1989) and above all are good indicator for changing climate i.e., referred as biological clock. Phenological phenomenon was firstly reported by Harper (1906) and then Keolmeyer (1959) and was reviewed by Leith (1973) in different forest tree species.

The phenological observations were made on the selected trees at different phenophages viz. leaf fall, sprouting and development, flowering and fruit set, fruit development and maturity. The observations were made throughout the year at 15 days interval for broad phenological changes. However, from the panicle initiation to fruit maturation regular observations were recorded daily.

1.1 Leaf fall, sprouting and development:

The critical observations on leaf fall pattern in mahaneem indicated that mild defoliation started in mid of March and continued up to end of May. However, in young seedlings in nursery sever leaf fall was noticed during first week of March. In majority of trees, the leaves turned to yellowish brown colour during the first week of March followed by light to moderate defoliation. However, rigorous leaf fall was observed in May and bulk of defoliation occurred from May 13-28. There was complete defoliation before the initiation of new vegetative growth and the new leaves started coming up after all the leaves had shed off. At the terminal end of the branches, initiation of leaf primordial was noticed during second to third week of January in different selected trees. After 3-4 days of leaf bud emergence, new leaves light green in colour arose and within one week these new leaves turned into dark green colour. The leaves attained their full size in about three weeks.

1.2 Flowering and pod set:

Within a week of leaf primordial emergence, panicle initiation started during second fortnight of January and continued throughout January in the randomly selected trees. Observations on flowering habit indicated that bud begins to appear as small protruding structures with the commencement of new leaves. Inflorescence was a cymose panicle which is often axillary. Maximum well developed buds were observed on all the trees from February 8- February 20. The floral buds started to open during last week of February. The flowering pattern was asynchronous i.e. new flowers were developing at different times on the same tree. The trees were in full bloom during first fortnight of March. Peak period of flowering varied from 9-13
days. Flowering gets completed by March end. On all the marked trees, natural pod setting was noticed during last week of March.

1.3 Pod development and maturity:

The period of pod development and maturity ranged from 63 - 74 days. The pod maturity was observed from the last week of May to first fortnight of June. Duration of panicle initiation to pod maturity varied from 132 to 140 days.

2. Reproductive Biology:

Tree breeding work largely depends on our knowledge of genetics and reproductive biology of a species. Studies on reproductive biology and breeding systems are therefore important. The breeding systems, through reproduction and pollination mechanisms and the degree of compatibility, regulates the amount of recombination. This further helps in the understanding of genetic makeup of natural variation. Eldridge (1976) stressed the importance of obtaining information on reproductive biology of tree at an early stage. It is pre-requisite for successful planning and development of breeding strategies. All improvement programs are based on regulating natural variation through the control of reproductive systems.

The morphological changes in the shape and size of flower buds during their development were observed from the time of their appearance to the opening stage. Based on distinct characteristic features, different stages of bud development were identified. For this study, 50 buds on each of ten trees were tagged just after their emergence for recording data on floral bud development and time taken to pass from one stage to another as well as the total time taken to develop into fully develop flower. To observe the time of anthesis, three branches on three trees were tagged during February- March and the numbers of bud opening at different hours of day were noted from 0700 h to 1500 h. For observing the time of flower opening, fully mature buds on the selected branches, which were likely to open the following morning, were tagged in the afternoon of the same day and the immature buds on the same branches were removed. Beginning at 0700 h, the number of fully open flowers was noted at one hour interval upto 1500 h and after that next observation was taken at 0700 h on next day. All the opened flowers after each interval were plucked to avoid the possibility of recounting. These observations were recorded for five days successively during both the years. The pollen morphology and viability study was done by mounting pollens in 1 per cent acetocarmine stain. For pollen stainability, pollen from freshly opened flower was dusted on a clean slide and 1-2 drops of acetocarmine solution were added to the pollen mass. The slides were then left for 10-15 minutes to allow the pollen to take the stain. The deeply stained normal looking grains were recorded as stainable which are usually considered viable. Unstained pollen grains were recorded as non-viable. The observations were repeated for five days. The receptivity of stigma was adjudged by visual observations of stigma surface. The change in the appearance of the stigma was observed from 12 h before opening of bud and 12 h after opening of flower. The shiny stigma was considered receptive, while the stigma having dull and dark brown appearance was considered as non-receptive.
The study was done when flower opening had just begun. For this purpose, unopened flower buds were counted and covered with muslin cloth bag and tied tightly in different sides of selected plants. Already open and very small flower buds were removed before bagging. Percent pod setting was then calculated. Approximately, an equal number of flower buds were kept open in close vicinity of the covered branch of each ten trees. All these buds were counted. Numbers of pod set on these branches were recorded and fruit setting in per cent was calculated. For apomictic mode of reproduction, about one hundred buds on each tree were emasculated and bagged. Pod set on them was recorded.
Andromonoecy (male, female and hermaphrodite flowers) and 1-5 pods formation from single female flower of Ailanthus excelsa

2.1 Flower bud development:

The buds of all the sizes from appearance to flower opening were examined. During the period of their development, they were divisible into five distinct stages. The different development stages of the flower bud are briefly described below:

**Stage- I:** Buds at this stage appeared as very small structures of meristematic tissue. These were 0.98 ±0.05 mm in length and 0.65±0.02 mm in diameter and were green in colour. The buds in panicle were overlapping.

**Stage- II:** The bud at this stage also looked green. The calyx enveloped the corolla. The buds were globular in structure. The size at this stage was 2.23±0.12 mm in length and 1.57±0.08 mm in diameter. The buds took about 4-5 days from stage- I.

**Stage- III:** Corolla became slightly visible and enlarged enough. The size of bud was 3.54 ±0.10 mm and 2.01 ±0.05 mm in length and diameter, respectively. The buds at this stage looked cylindrical in structure. Greenish colour at the base and yellowish at the apex of bud was observed. These buds took about 7-8 days from stage- II.

**Stage- IV:** Corolla became clearly visible and enlarged enough. The average length and diameter of the bud at this stage was 5.46 ± 0.17 mm and 2.63 ±0.11 mm, respectively. The buds took about 3-4 days from stage- III.

**Stage- V:** The buds of IV stage took about 4-5 days to reach the V stage. At this stage, the development of bud was complete. The average length was 7.69 ±0.19 mm and diameter was 2.86±0.06 mm. The flower buds opened towards end of this stage.

The flowers are small in size yellow in colour and arranged in panicles. The flowers appear in the large open clusters among the leaves. The male, female and bisexual flowers were observed on the same tree. Calyx lobes are ovate triangular. Corolla 5, ovate lanceolate reflexed, glabrous. Stamens 10 in the male flowers and 0 in the female flowers; filaments glabrous. Ovary 2-5 partite.

2.2 Anthesis time:

The observations regarding the time of flower opening were recorded from 0600- 1400 h at one hour interval. Flower opening start between 0600-0700 h and the maximum flowering, ranging from 85.71 to 92.85 per cent was recorded between 0800-0900 h. Maximum buds opened up to 1000 h, however, anthesis continued till noon hours. The dehiscence of anther started at about 0830 h and continued up to 1130 h with maximum frequency between 0900-0950 h.

2.3 Pollen morphology and stainability:

Pollens were round in shape. Pollen stainability in 1 per cent acetocarmine ranged from 85.58 to 91.49 per cent.
2.4 Receptivity of stigma:

The shiny surface of the stigma was taken as measure of receptivity. It was observed that the receptivity started half hour before flower opening and remained receptive upto 24 hours after flower opening.

2.5 Selfing/ bagging (Autogamy):

Pod setting resulting from selfing vis-à-vis open pollination was observed. A considerable variation in per cent pod setting under selfing (bagging) on different trees was observed. It ranged from 0.0 to 10.39 per cent with an average pod set of 5.26 per cent.

2.6 Open pollination:

The average pod setting of 12.60 per cent was recorded under open pollination which ranged from 8.51 to 19.05 per cent on different trees. By using paired ‘t’ test, it was clear that average pod setting under selfing and open pollination differ significantly even at 5 per cent level of significance. Therefore, the results of present study indicate that mahaneemis capable of producing pod through geitonogamy and xenogamy. Such type of breeding system represents facultative xenogamy.

2.7 Apomixis:

Apomixes, i.e., pod and seed setting without fertilization was observed in by bagging the emasculated floral buds. Since, no pod set was observed under such situation, it suggests that apomixes is absent in mahaneem.

Summary:

- Mild defoliation started in mid of March and continued up to end of May. However, in young seedlings in nursery sever leaf fall was noticed during first week of March. In majority of trees, the leaves turned to yellowish brown colour during the first week of March followed by light to moderate defoliation. However, rigorous leaf fall was observed in May and bulk of defoliation occurred from May 13-28. There was complete defoliation before the initiation of new vegetative growth and the new leaves started coming up after all the leaves had shed off.

- Within a week of leaf primordial emergence, panicle initiation started during second fortnight of January. Development of floral buds to flower opening was divisible into five distinct phases. The trees were in full bloom during first fortnight of March. Peak period of flowering varied from 9-14 days. Maximum flower opening ranging from 85.71 to 92.85 per cent was recorded between 0800-0900 h.

- The period of pod development and maturity ranged from 63 - 74 days. The pod maturity was observed from the last week of May to first fortnight of June. Duration of panicle initiation to pod maturity varied from 132 to 140 days.

- Pollen stainability at the time of flower opening varied from 85.58 to 91.49 per cent.

- The average pod setting of 12.60 per cent was recorded under open pollination which ranged from 8.51 to 19.05 per cent on different trees. However, in
selfing/bagging, pod setting varied from 0 to 10.39 per cent with a mean of 5.26. Pod setting under selfing and open pollination differ significantly. Therefore, the results indicate that mahaneem is capable of producing pod through geitonogamy and xenogamy. Such type of breeding system represents facultative xenogamy in mahaneem.

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References:
- Mann, J.S. (1994). Role of ardu (*Ailanthus excelsa*) and another trees in agroforestry


EFFECT OF GROWTH REGULATORS AND MICRONUTRIENTS SPRAY ON YIELD ATTRIBUTING CHARACTER OF LITCHI (*LITCHI CHINENSIS*SONN.) CV. CALCUTTIA

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ABSTRACT

The present experiment was laid out at the Regional Horticulture Research and Training Station, Dhaulakuan, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-Solan (HP). The experiment consisted of 19 treatments with three replications laid out in Randomized Block Design. The growth regulators and micronutrients applied were GA₃ (T₁=25 ppm, T₂ = 50 ppm, T₃ = 75 ppm), CPPU (T₄ = 5 ppm, T₅ = 10 ppm, T₆ = 15 ppm), ZnSO₄ (T₇ = 0.25%, T₈ = 0.50%, T₉ = 0.75%), Boric acid (T₁₀ = 0.25%, T₁₁ = 0.50%, T₁₂ = 0.75%), GA₃ + CPPU (T₁₃ = 25+5 ppm, T₁₄ = 50+5 ppm, T₁₅ = 75+5 ppm), Boric acid + ZnSO₄ (T₁₆ = 0.25+0.50%, T₁₇ = 0.50+0.50%, T₁₈ = 0.75+0.50%) and T₁₉ control. The results revealed that growth regulators and micronutrients significantly improved yield and yield attributing characters. Decrease in fruit drop and increase in the yield was found with application of zinc at 0.50 % and 0.75 % respectively. Fruit set and fruit retention was found to be maximum with treatment number T₁₂. CPPU @10 ppm has decreased the fruit cracking percentage.

Key word: Boric acid, Zinc Sulphate, CPPU, GA₃

1. INTRODUCTION

Litchi recognized as “Queen of the fruits” is the most important subtropical fruit crop which belongs to family Sapindaceae. It is a subtropical evergreen tree and is adapted to the areas of cool dry winters and warm wet summers. It usually likes low elevations but can be grown up to an altitude of 800 meters above mean sea level with varying degree of success. Due to its exact climatic requirements, its cultivation is restricted to few states in our country. Being one of the finest fruit, litchi still need a major attention towards the problem like irregular flowering, poor fruit set, heavy fruit drop, low yield, fruit cracking and poor quality to meet the growing demand of national and international market.

In India 5,83,400 metric tonnes of litchi is produced annually from 92,100-hectare area. (Anonymous, 2017a). In Himachal Pradesh, it is being cultivated commercially in Kangra, Sirmour, Bilaspur and Una districts, occupying an area of 5,673 hectare and production 5,469 metric tonnes, out of which maximum area and
production is under Kangra district (Anonymous, 2017b). Recent studies on fruit physiology and nutrition have focussed attention on significance of plant growth regulators and micronutrients in overcoming the problems by modifying various physiological and metabolic processes.

Plant growth regulators have been used for many years to alter the behaviour of fruit or fruit plants for the economic benefits. It is also reported that growth substances like Gibberelllic acid, NAA and CPPU have great influence on litchi. Hota et al. (2017 a, b, c, d, e & f) conducted a research trial in 26-year-old apricot cv. New Castle by using CPPU and NATCA at Department of Fruit Science, Dr. Y.S. Parmar University of Horticulture and Forestry during the years 2015 and 2016. He found that CPPU at petal fall stage increases the tree height, tree spread, tree volume, annual shoot growth, trunk girth, leaf area, fruit length, fruit diameter, fruit weight, fruit volume, pulp weight, stone weight and pulp to stone ratio, fruit firmness and yield significantly then the control in both the years. CPPU stimulated cell expansion in the pericarp sufficiently to explain the measured increase in total fruit volume.

Micronutrients plays specific role in improving the growth, yield and quality of litchi even though these elements are needed in small quantities. Boron and Zinc is essentially required for growth and development in litchi and is involved in diverse range of enzyme system. Considering the importance of plant growth regulators and micronutrients in fruit production, the present investigation is carried out on cv. Calcuttia to observe the effect of Gibberelic acid (GA3), CPPU (N-(2-Chloro-4-pyridyl)-N-phenylurea), Boric acid and ZnSO4 (Zinc sulphate) on chemical composition of litchi.

2. Materials and Methods

The experiment was conducted on 12-year-old trees of litchi cultivar Calcuttia, at Regional Horticulture Research and Training Centre, Dhaulakuan, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, NauniSolan (Himachal Pradesh). Fifty-seven uniform bearing trees with uniform vigour and size, planted at a spacing of 8m x 8m were selected for study. The required amount of each plant growth regulators was taken and final volume was made to one litre with water to serve as stock solution. Two to three drops of surfactant (Teepol) per litre of solution was added to reduce surface tension and to facilitate the absorption of solution. Spraying was done with the help of foot sprayer, till the leaves were wet and droplets of solution started trickling down, on clear and calm day during the morning hours at fruit set stage and repeated after one weak, during 2014 and 2015. The experiment consisted of 19 treatments [GA3 (25,50 &75 ppm), CPPU (5,10 &15 ppm),ZnSO4(0.25 %, 0.50 % & 0.75 %), Boric Acid (0.25 %, 0.50 % & 0.75 %),GA3 + CPPU (25+5, 50+5 & 75+5 ppm), Boric acid+ ZnSO4 (0.25+ 0.50, 0.50+0.50 & 0.75+0.50) & Control]and 3 replications with Randomized Block Design. The data generated from these investigations were appropriately computed, tabulated and analyzed by applying Randomized Block Design (RBD). The level of significance was tested for different variables at 5 per cent level of significance.
Four panicles were selected randomly in all four directions (one in each direction) at each tree. The number of fruits was counted after 15 days of full bloom, from the marked panicle taken for flower count. The per cent fruit set was calculated as per formula given below:

\[
\text{Fruit set} \, (\%) = \frac{\text{Total number of fruits set on panicle}}{\text{Total number of flower on panicle}} \times 100
\]

The number of fruits was counted after 30 days after full bloom on marked panicle on each tree. The fruit drop was calculated and expressed in percentage according to the formula

\[
\text{Fruit drop} \, (\%) = \frac{\text{Total number of fruit dropped from fruiting panicle}}{\text{Total number of fruit set on panicle}} \times 100
\]

Total number of fruits retained on the marked panicles was counted at the time of harvest and the percentage of fruit retention was calculated according to the formula

\[
\text{Fruit retention} \, (\%) = \frac{\text{Total number of fruit retained on fruiting panicle}}{\text{Total number of fruit set on panicle}} \times 100
\]

Total number of fruits having cracking was counted in each marked panicle and per cent fruit cracking was worked out by following relation

\[
\text{Fruit cracking} \, (\%) = \frac{\text{Total number of fruit cracked on fruiting panicle}}{\text{Total number of fruit retained on panicle}} \times 100
\]

The yield of fruits in kg per tree under different treatments was recorded on the basis of total weight of fruits harvested from each tree under each treatment.

3. Result and Discussion

Fruit Set (%)

The pooled data in table 1 revealed that the maximum fruit set (32.65 %) was recorded with \( T_8 \) (ZnSO\(_4\) 0.50 %) treated trees which was statistically at par with \( T_2 \), \( T_4 \), \( T_5 \), \( T_6 \), \( T_{11} \) and \( T_{16} \), while the minimum fruit set (25.90 %) was observed in \( T_3 \) (GA\(_3\) 75 ppm) which was statistically at par with control and less than \( T_1 \), \( T_9 \), \( T_{10} \), \( T_{12} \), \( T_{13} \), \( T_{14} \) and \( T_{18} \) having statistically similar effect on fruit set. The trend obtained during the year 2013-14 and 2014-15 were almost similar as in case of the pooled data except that during the 2013-14 the minimum fruit set (24.10%) was recorded in untreated control trees.

The positive influence might be referred to the good absorption and uptake of zinc through the litchi leaves. Zinc is an important micronutrient associated especially with several enzymatic activities and growth regulators biosynthesis in all photosynthetic plants (Ved et al., 2002). It is considered a functional, structural or regulatory factor of a large number of enzymes (Bowler et al., 1994). The fruit retention was also found to be increased with the application of zinc sulphate which might be attributed to the fact that zinc stimulated IAA synthesis in plant cells which prevented the fruit drop by ceasing the formation of abscission layer (Kachave and Bhosle, 2007).
The present findings are in conformity with many other investigators who worked on litchi (Barun and Kumar, 2003; Sharma et al., 2005).

**Fruit Drop (%)**

It is evident from the pooled data (Table 1) that the minimum fruit drop (53.50%) was recorded with T_{12} (Boric acid 0.75 %) treatment which was less than all other treatments and followed by T_{11} (Boric acid 0.50 %) and T_{10} (Boric acid 0.25 %) with (55.60%) and (57.20 %) fruit drop respectively, while the maximum fruit drop (76.60%) was recorded in T_{19} (Control). Similar trends were observed during both the years 2013-14 and 2014-15.

**Fruit Retention (%)**

The pooled data from table 2 revealed that the maximum fruit retention (44.00 %) was recorded with T_{12} (Boric acid 0.75 %) which was statistically higher than all other treatments and was statistically at par with T_{11} (Boric acid 0.50 %) (42.40%) and followed by T_{10} (Boric acid 0.25 %) (41.20 %) and T_{8} (ZnSO_{4} 0.50 %) (37.30 %), while T_{3}, T_{4} and T_{15} had statistically similar values having similar effect on fruit retention. The minimum fruit retention (25.50 %) was observed in T_{19} (Control) which was statistically at par with combined application of GA_{3} 25 ppm and CPPU 5 ppm (27.90 %). All other treatments significantly improved the fruit retention over control. The results obtained during both the year were almost similar as in case of the pooled data.

Boron plays an important role in pollen production, germination and pollen tube growth in fruit trees, which may have caused least fruit drop and henceforth maximum fruit retention. Results of present investigation are in accordance with the findings of Sharma et al., (2005) and Dixit et al., (2013) on litchi.

**Fruit Cracking (%)**

It is also evident from table 2 that the pooled data that the minimum fruit cracking (0.10%) was recorded with T_{5} (CPPU 10 ppm) treatment which was statistically at par with T_{11} and T_{14} and all other treatments recorded more cracking than T_{5} (CPPU 10 ppm), while the maximum fruit cracking (0.77%) was recorded in untreated control trees. The cytokinin like action of CPPU may continue the cellular division upto the optimum growth stage and hence reduced the cracking in litchi.

**Yield (kg/tree)**

The perusal of data presented in table 2 reveals that there were significant differences with respect to yield per tree among different treatments during both the years. Pooled data showed that the maximum yield (41.00 kg per tree) was observed in plants treated with T_{8} (ZnSO_{4} 0.50%), which was superior to all other treatments. It was statistically at par with T_{1}, T_{6} and T_{7}, while all other treatments recorded higher yield than T_{13} (GA_{3} 25 ppm + CPPU 5 ppm), which recorded minimum yield (28.20kg/tree). The results obtained during the years 2013-14 and 2014-15 were almost
similar as in case of the pooled data except that during 2014-15 the minimum fruit yield (28.33 kg/tree) was recorded from control trees.

The present findings are supported by the work of Brahmachari et al., (1997) and Barun and Kumar (2003) who have reported that application of zinc sulphate increased the fruit yield in litchi fruits. Langthasa and Bhattacharya (1993) reported increase in fruit yield with the application of zinc sulphate in lemon. The increase in fruit yield with zinc sulphate was possibly due to increased fruit retention and higher number of fruits per plant.

4. Conclusion

Application of plant bio-regulators are effective way to increase the fruit productivity to fulfil the growing demand of the country. From the above experiment it may be concluded that both Boron @0.75% and Zinc @0.50% increased the fruit yield component and hence increased the yield.
Table 1. Effect of growth regulators and micronutrients spray on fruit set and fruit drop in litchi.

<table>
<thead>
<tr>
<th>TREATMENT</th>
<th>Fruit Set (%)</th>
<th>Fruit Drop (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 GA₃ (25 ppm)</td>
<td>29.40(32.81)</td>
<td>28.60(33.6)</td>
</tr>
<tr>
<td>T2 GA₃ (50 ppm)</td>
<td>30.70(33.63)</td>
<td>31.20(35.0)</td>
</tr>
<tr>
<td>T3 GA₃ (75 ppm)</td>
<td>26.70(31.06)</td>
<td>25.00(31.1)</td>
</tr>
<tr>
<td>T4 CPPU (5 ppm)</td>
<td>31.70(34.24)</td>
<td>31.90(34.4)</td>
</tr>
<tr>
<td>T5 CPPU (10 ppm)</td>
<td>31.00(33.80)</td>
<td>32.70(36.1)</td>
</tr>
<tr>
<td>T6 CPPU (15 ppm)</td>
<td>31.30(33.99)</td>
<td>31.50(34.2)</td>
</tr>
<tr>
<td>T7 ZnSO₄ (0.25 %)</td>
<td>31.70(34.21)</td>
<td>29.20(35.3)</td>
</tr>
<tr>
<td>T8 ZnSO₄ (0.50 %)</td>
<td>32.20(34.54)</td>
<td>31.80(34.9)</td>
</tr>
<tr>
<td>T9 ZnSO₄ (0.75 %)</td>
<td>29.40(32.81)</td>
<td>30.20(33.4)</td>
</tr>
<tr>
<td>T10 Boric acid (0.25 %)</td>
<td>28.10(31.99)</td>
<td>30.40(33.5)</td>
</tr>
<tr>
<td>T11 Boric acid (0.50 %)</td>
<td>31.00(33.81)</td>
<td>32.30(34.6)</td>
</tr>
<tr>
<td>T12 Boric acid (0.75 %)</td>
<td>31.60(34.19)</td>
<td>27.30(31.5)</td>
</tr>
<tr>
<td>T13 GA₃ (25 ppm) + CPPU (5ppm)</td>
<td>29.90(33.13)</td>
<td>29.90(33.2)</td>
</tr>
<tr>
<td>T14 GA₃ (50 ppm) + CPPU (5 ppm)</td>
<td>28.50(32.24)</td>
<td>30.80(33.7)</td>
</tr>
<tr>
<td>T15 GA₃ (75 ppm) + CPPU (5 ppm)</td>
<td>24.80(29.81)</td>
<td>27.50(31.6)</td>
</tr>
<tr>
<td>T16 Boric acid (0.25 %) + ZnSO₄ (0.50 %)</td>
<td>31.30(34.00)</td>
<td>32.20(34.6)</td>
</tr>
<tr>
<td>T17 Boric acid (0.50 %) + ZnSO₄ (0.50 %)</td>
<td>30.10(33.25)</td>
<td>30.40(33.5)</td>
</tr>
<tr>
<td>T18 Boric acid (0.75 %) + ZnSO₄ (0.50 %)</td>
<td>27.70(31.70)</td>
<td>30.70(33.5)</td>
</tr>
<tr>
<td>T19 Control (Water spray)</td>
<td>24.10(29.33)</td>
<td>29.60(28.6)</td>
</tr>
<tr>
<td>C.D0.05</td>
<td>2.88</td>
<td>2.71</td>
</tr>
</tbody>
</table>

*Figures in the parentheses are arc sine transformed value*
### Table 2. Effect of growth regulators and micronutrients spray on fruit retention and fruit cracking in litchi.

<table>
<thead>
<tr>
<th>TREATMENT</th>
<th>Fruit Retention (%)</th>
<th>Fruit Cracking (%)</th>
<th>Fruit Yield (kg/tree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>GA₃ (25 ppm)</td>
<td>36.80(37.33)</td>
<td>37.40(37.68)</td>
</tr>
<tr>
<td>T2</td>
<td>GA₃ (50 ppm)</td>
<td>34.30(35.82)</td>
<td>35.80(36.73)</td>
</tr>
<tr>
<td>T3</td>
<td>GA₃ (75 ppm)</td>
<td>29.50(32.88)</td>
<td>32.90(34.98)</td>
</tr>
<tr>
<td>T4</td>
<td>CPPU (5 ppm)</td>
<td>30.20(33.31)</td>
<td>33.40(35.26)</td>
</tr>
<tr>
<td>T5</td>
<td>CPPU (10 ppm)</td>
<td>27.30(31.48)</td>
<td>31.50(34.09)</td>
</tr>
<tr>
<td>T6</td>
<td>CPPU (15 ppm)</td>
<td>26.30(30.83)</td>
<td>30.80(33.61)</td>
</tr>
<tr>
<td>T7</td>
<td>ZnSO₄ (0.25 %)</td>
<td>38.10(38.09)</td>
<td>38.10(38.10)</td>
</tr>
<tr>
<td>T8</td>
<td>ZnSO₄ (0.50 %)</td>
<td>37.00(37.44)</td>
<td>37.50(37.74)</td>
</tr>
<tr>
<td>T9</td>
<td>ZnSO₄ (0.75 %)</td>
<td>35.60(36.61)</td>
<td>36.60(37.21)</td>
</tr>
<tr>
<td>T10</td>
<td>Boric acid (0.25 %)</td>
<td>42.00(40.37)</td>
<td>40.40(39.41)</td>
</tr>
<tr>
<td>T11</td>
<td>Boric acid (0.50 %)</td>
<td>43.50(41.24)</td>
<td>41.20(39.87)</td>
</tr>
<tr>
<td>T12</td>
<td>Boric acid (0.75 %)</td>
<td>45.50(42.39)</td>
<td>42.40(40.56)</td>
</tr>
<tr>
<td>T13</td>
<td>GA₃ (25 ppm) + CPPU (5ppm)</td>
<td>25.50(30.30)</td>
<td>30.30(33.34)</td>
</tr>
<tr>
<td>T14</td>
<td>GA₃ (50 ppm) + CPPU (5 ppm)</td>
<td>26.50(30.95)</td>
<td>31.00(33.79)</td>
</tr>
<tr>
<td>T15</td>
<td>GA₃ (75 ppm) + CPPU (5 ppm)</td>
<td>29.90(33.13)</td>
<td>33.10(35.10)</td>
</tr>
<tr>
<td>T16</td>
<td>Boric acid (0.25 %) + ZnSO₄ (0.50 %)</td>
<td>34.30(35.82)</td>
<td>35.80(36.73)</td>
</tr>
<tr>
<td>T17</td>
<td>Boric acid (0.50 %) + ZnSO₄ (0.50 %)</td>
<td>36.00(36.85)</td>
<td>36.90(37.39)</td>
</tr>
<tr>
<td>T18</td>
<td>Boric acid (0.75 %) + ZnSO₄ (0.50 %)</td>
<td>37.00(37.44)</td>
<td>37.50(37.74)</td>
</tr>
<tr>
<td>T19</td>
<td>Control (Water spray)</td>
<td>22.60(28.32)</td>
<td>28.30(32.12)</td>
</tr>
<tr>
<td>C.D₀.₀₅</td>
<td>1.96</td>
<td>3.94</td>
<td>2.48</td>
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</tbody>
</table>

*Figures in the parentheses are arc sine transformed value*
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POST HARVEST TECHNOLOGY AND VALUE ADDITION IN SPICES

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India is known as the "Home of Spices" and produces a large number of spices. About 60 spices such as pepper, cardamom, ginger, turmeric, coriander, cumin etc are grown in the country. India exports only a small quantity of spices (10% of the total produce) to 137 countries in the world. The rest is consumed in the Indian market, as there is an immense domestic demand. The average production of spices in India is over 63.24 lakh tons and area under cultivation of spices is approximately 35.41 lakh ha. In the quality front, the major consuming countries like Europe and USA are demanding more and more quality compliance by the producing countries. To meet this challenge we have to equip ourselves to produce, process and market high quality spices, with internationally accepted food safety standards. Hence precautions has to be taken from the harvesting to primary processing which includes, washing, threshing, blanching, drying, cleaning, grading and packaging in order to meet the standards. The improvements in post harvest processing, mechanisation and value addition in major spice crops are presented here.

1. Black pepper

Harvesting in Black pepper should start when one or two berries turn yellow (Purseglove et al. 1981). The spikes are nipped by hand and collected in bags. Three models of pepper harvester were fabricated and evaluated on the basis of efficiency in the cutting action and easiness in operation (Aneeshya et al. 2013). The most efficient and user friendly was the second model due to its light weight, easiness in operation and minimum loss. Recent advances in product diversification have necessitated harvesting of the berries at different stages of maturity (Natarajan 1981). The primary processing in black pepper involves threshing, blanching, drying (sun drying or mechanical drying), grading and packing.

a) Threshing, Blanching and Drying

Harvested green spikes are heaped for a day, before threshing for easy separation of the berries. Spikes with fully matured and green stage, fully ripened stage and partly dried stage will be available in the harvested lot. The labourer will separate them into various lots, viz., berries, spikes suitable for threshing, ripe ones for production of white pepper and partly dried ones for direct drying. Threshing is done by manual trampling. Traditional manual processing has given way to mechanization in majority of the processing stages. Mechanical threshers are used now to improve the quality of the product and to increase the efficiency of operations. Threshers developed by various agencies are compared (Amaladhas & Korikanthimath 2003). The quality of the black pepper can be improved by blanching, a simple treatment of dipping the mature berries taken in perforated vessel in boiling water for a minute before drying. Pepper has
moisture content of 60 to 70% at harvest, which should be brought to safer levels of 10-12 per cent by adequate drying. The green colour of matured pepper is due to the presence of chlorophyll pigment. During drying, enzymatic browning sets in and the phenolic compounds are oxidized by atmospheric oxygen under the catalytic influence of the enzyme phenolase and eventually turn black. Sun drying is the conventional method followed in order to bring the moisture content below 10%. The average dry recovery varies between 33-37% depending on the varieties. Recently, various types of dryers such as solar and mechanical dryers have been developed by different agencies which are highly efficient for drying pepper. Solar tunnel drying in a cylindrical tunnel shaped drying chamber of size 2 m x 3 m to a height of 2m for drying 100 kg pepper was reported by Thirupathi & Visvanathan (2008). A natural convection reverse air flow mechanical drier developed by Regional Research Laboratory, Trivandrum are used by the farmers and small scale industries for drying of black pepper. Models of varying capacities operated either electrically or by burning agricultural wastes can also be used for drying. An electrically operated drier of 100 kg capacity has been developed by TNAU, Coimbatore (Sreenarayanan et al. 2003).

b) Cleaning and grading
Cleaning and grading are basic operations that enhance the value of the produce and help to get higher returns. The dried pepper is cleaned to get rid of the extraneous matter such as dirt, stalks, leaves etc. Magnetic separator is used to remove metallic contamination such as iron fillings and stray nails. Vibratory conveyors with inclined decks in combination with air classification are used for efficient de-stoning of spices. Broken pepper and light pepper grades are separated pneumatically. Pinheads which come along with garbled pepper are separated by sieving. Cleaning on a small scale is done by winnowing and hand picking which removes most of the impurities. Grading of black pepper is done by using sieves and sifting black pepper into different grades based on size. TNAU has developed a hand operated cleaner cum grader suitable for cleaning and grading operations (Thirupathi and Visvanathan, 2008). At an operating speed of 25 rpm, the unit had a maximum effectiveness of 66.4% and capacity of 430 kg/h.

c) Packaging and Storage
Whole pepper is generally packed and transported in gunny bags and polyethylene lined double burlap bags. The bags are arranged one over the other on wooden pallets after laying polypropylene sheets.

2. Cardamom
Cardamom, known as the 'queen of spices', is one of the highly prized spices of the world. As the flowering continues over a long period several pickings are needed. Harvesting should be taken up only at a time when the capsules reached the maturity stage. Immediately after harvesting on each day, capsules are washed to get rid of dirt and treated with 2% washing soda (Sodium Carbonate) for 10 minutes to retain green colour and reduce mould growth in RCC tanks. The treated capsules are spread in a single layer on portable drying trays for draining ofwate and later for drying.
a) Curing
Cardamom curing or drying is the process in which the moisture content of green cardamom is reduced to 8-12%. Cardamom capsules should be subjected to drying within 24-36 hours of harvest to avoid deterioration. Drying is one of the important unit operations as it determines the colour of the end product, which is the attractive and most important quality character. There are mainly two types of drying viz. sun drying and artificial drying. In sun drying it is difficult obtain good green colour and requires 5-6 days or more depending up on the availability of sun light. Artificial drying can be done either by electrical or conventional flue pipe drier.

b) Garbling
The dried cardamom is then subjected to garbling. Garbling is the process of removal of flower stalks from the dried cardamom. Traditionally this is achieved by rubbing the cardamom capsules against coir mat or wire mesh and winnowed to remove any foreign matter. An oscillatory type semi mechanical garbling unit developed by Tamil Nadu Agricultural University, Coimbatore has a capacity of 2-3 kg per batch whereas the rotary type garbler will take about 2-3 minutes to garble one batch of about 5 kg. Its capacity is 100kg/h and the efficiency was 98% (Sreenarayanan et al. 2003).

3. Ginger
India and China are the world's largest producers and exporters of ginger. In India, domestic market prefers fresh green ginger for culinary uses while two other types of dried ginger i.e. bleached and unbleached are also produced for export purpose. The fresh ginger immediately after harvest is subjected to washing, which is performed to remove dirt, residues of farm chemicals and other foreign materials.

a) Peeling and drying
After washing the ginger rhizomes are subjected to peeling operation. The outer skin of ginger is scrapped off with a bamboo splinter or wooden knife having pointed ends. Iron knife is not recommended as it may leave black stains on the peeled surface, affecting the appearance, or may lead to colour fading. During peeling, it should be ensured that the cortical parenchyma, which is rich in essential oil bearing cells, are not removed or cut as it would cause loss of volatile oil and thereby, decrease the aroma of the peeled rhizome. The scrapped or peeled rhizornes are again washed welland dried in sun for a week or more and then rubbed again to give a polish. A mechanical brush type ginger peeling machine has been developed by Rajasthan Agricultural University. The peeling efficiency of the machine was 85% and the capacity was 200kg/h (Agarwal et al. 1987). Another mechanical ginger peeler was developed with its peeling drum made of diamond cut mesh (Jayashree&Visvanathan 2013) which has a peeling efficiency of 59%. The sun dried ginger is brown in colour, more or less irregular wrinkled surface and when broken, shows a dark brownish colour. However, it is reported that the quality of dry ginger cured in the bright sun is better than the quality of ginger cured in a closed oven with artificial heat.

b) Polishing
Polishing of dried ginger is done to remove the wrinkles developed during drying
process. In the indigenous method the dried ginger is rubbed against a hard surface. However, hand or power operated polishers similar to turmeric polishers are also employed for the purpose of polishing dried ginger. In the case of hand operated polishers an output of 5-6 quintals per day of 8 hours is obtained with the help of two persons. The dried ginger rhizomes are manually graded. The machines of various capacities to pulverize dried ginger from 25 kg per batch to continuous powdering of 2-3 t/day for large scale production are available.

c) Cleaning and grading

Once the ginger is dry it is cleaned, sorted and graded. Grading takes into consideration the size of the rhizome, its colour, shape, extraneous matter, the presence of light pieces and the extend of residual lime (in the case of bleached ginger). Two types of Indian dried ginger entering the International market are Cochin and Calicut ginger, named after the two major production centers in Kerala. Both Cochin and Calicut gingers are graded according to the number of fingers in the rhizomes: grade-B, three fingers; grade-C, two fingers and grade-D, pieces. In addition to these well known types of Indian ginger, another type, Calcutta ginger, is occasionally seen in the market.

4. Turmeric

Maturity of the crop is indicated by complete drying of the aerial plants including the base of the stem. The leaves and stem are cut close to the ground. Two days earlier to digging out the rhizomes, irrigation is given. In case of ridge method of planting, plough is used to lift the rhizomes. Otherwise the rhizomes are dug out with manually. The harvested rhizomes have to be cured within 2-3 days after harvest for securing maximum out turn. In the turmeric growing regions of Tamil Nadu, mechanical harvesting of turmeric is being practiced. Tamil Nadu Agricultural University (TNAU), Coimbatore has developed a power tiller operated mechanical turmeric harvester with a capacity to harvest 0.6 ha per day (TNAU, 2009a). Tractor drawn turmeric harvester mounted on 35-45 hp tractor with a capacity to harvest 1.6 ha per day have been developed by TNAU (TNAU, 2009b). The tractor mounted harvester may be adjudged as the best mechanical harvester for saving of time and reduced the percentage of damaged rhizome apart from the removal of drudgery in harvesting of quality rhizome.

a) Post harvest operations

The harvested turmeric rhizomes before entering into the market is converted into a stable commodity through a number of post harvest curing processes like boiling, drying, polishing and colouring. Curing of turmeric is taken up within 3 or 4 days after harvest. The fingers and mother rhizomes are separated and are cured separately, since bulbs take longer time to cook. The recommended practice is to use clean water for boiling turmeric rhizomes in mild steel or galvanized iron pans and takes about 60-90 minutes. Boiling destroys the vitality of fresh rhizomes, avoids the raw odour, reduces the drying time and yields uniformly coloured product. Boiling of turmeric rhizomes is carried out till froth forms and white fumes come out of the boiling pan with a characteristic odour. Boiling is considered complete by pressing a pointed stick in to the rhizomes with slight pressure. The other indications for completion of boiling
process are softness and easy breaking of rhizomes when pressed between the forefinger and thumb and a yellow interior instead of red one. The cooked fingers areheaped on a cleaned drying floor and left undisturbed for 4-5 hours and later sun dried for 10-15 days by spreading in 5-7 cm thick layers on bamboo mat or on the drying floor. Tamil Nadu Agricultural University TNAU), Coimbatore, has developed an improved turmeric boiler using steam boiling technique (Visvanathan et al. 2002). The capacity of the boiler is about 200 - 300 kg per batch and 40 q per day of 8 hours. Fuel used is 70-75 kg of agricultural waste materials. Curing of turmeric for 60 min by steam cooking was considered optimum to produce quality dried turmeric with minimum losses. The use of large scale steamer for boiling large quantities of turmeric rhizomes at farm level was also available (Visvanathan 2008).

b) Polishing

Poor appearance of dried turmeric is improved by smoothening and polishing the outer surface by manual or mechanical rubbing. Manual polishing gives rough appearance and dull colour in the dried rhizome. A mechanical polisher for turmeric has been developed in the Agricultural University at Andhra Pradesh, India (Sukumaran & Satyanarayana 1999). The unit consists of 88 cm diameter mild steel drum with meshes and is operated by a 2 hp electrical motor. The drum speed was maintained at 30-32 rpm and the capacity of the polisher is about 600-700 kg/h. A pedal operated hexagonal drum having six polishing plates of size 30 x 60 cm has been developed at QUAT (Pal et al. 2008). The capacity of the polisher is 100 kg/h and 6% polishing is achieved.

c) Cleaning, grading, packing and storage

Turmeric of commerce is described in three ways- fingers, bulbs, and splits. Very little grading of the spice is done at the growers end. Cleaned and graded material is packed generally in new double burlap gunny bags and stored over wooden pallets in a cool, dry place protected from light.

5. Seed spices

Out of 20 seed spice crops cumin, coriander, fennel, fenugreek, dill and ajwain contribute more than 95 per cent towards area and production. Cumin and fennel are dominant seed spices of Gujarat while coriander and fenugreek are important in Rajasthan. India exports raw as well as value added items to nearly 70 countries in the world and meet around 45% of the global demand and earns 361.5 crores of foreign exchange. For exporting the seed spices, quality is the most important criterion. The quality of seed spices is assessed by mean of its intrinsic (Moisture, volatile oil, oleoresins content, major chemical constituents) as well as extrinsic (size, appearance, colour) quality. The produce must be safe, free from any health hazards substances and contaminants. The contaminants can be classified into three categories.

1. Physical contaminants Immature or shriveled seed, berries, insect
infested product, presence of live or dead insect
2. Chemical contaminants Added colour material, preservatives, antioxidants,
fumigants, aflatoxin, pesticides/insecticide residue.
3. Microbial contaminants Presence of Salmonella, E. coli, yeast and mould
a) Stage of harvest

Harvesting is one of the major important factors that determine the quality of the produce. The major deterioration and post harvest losses take places at this stage. The objective of proper harvesting is to enhance the processable character of produce and to achieve the quality and safe raw material for processing. This will also provide better income to the farmer, less losses in transport to urban areas for processing as well as creation of gainful employment at rural level. The stage of harvest varies from crop to crop. The crop of coriander matures in 90 to 135 days. The stage of maturity of the fruit at harvest is when central umbels are about to attain yellow colour. Cumin is harvested in about 100-110 days. Fennel takes 170-175 days to mature and harvesting is done before the fruits are fully ripe, umbel attains a slight greenish yellow' colour. A good quality fennel for chewing purposes, commonly known as 'Lucknowwaisamifis produced by harvesting the umbel 30 to 40 days after pollination. In fenugreek, the harvest time is judged when the colour of leaves and pods turn yellow. The right time of harvesting is usually done in the morning hours to avoid shedding losses.

b) Threshing of seed spices

Traditionally, threshing of seed spices is performed by treading the crop under the tyre of tractor or by stick beating and then the threshed stocks is cleaned by winnowing in natural air stream or in the artificial air streaming the processed products. The new modified threshers were tested in the adopted villages for threshing of cumin and fennel crop by CRSS, Jagudan and it was found that net return of 3.25 and 3.00 Rs per kg for cumin &fennel threshing respectively can be obtained as compared to traditional method.

c) Drying

Sun drying is usually adequate to dry to produce but there is a chance of contamination of the material by dust and dirt and volatile components will be lost. Mechanized drying could enhance the quality and post harvest losses. At CRSS, SDAU, Jagudan low cost poly solar drying method was the best for faster drying (32 hr) as compared to other drying methods. Shade drying is the best to maintain green colour of fennel. Higher net return (75.50 Rs/ kg) was obtained in low cost poly solar dryer as compared to shade drying method (64.84 Rs/ kg) and open sun drying (58.80 Rs/ kg).

d) Cleaning /Grading

Various machines are used for special functions. Spiral separator is used to separate round seeds and flat seeds. Magnet drum/pulley is used to separate iron particles. Magnet seed separator/electrostatic seed separator is being used to separate identical weed seed from product. Electronic colour sorters are used to separate discoloured seed to enhance colour value of final product. Gravity separator/destoner is to separate undesirable material on the basis being used of gravity.

e) On farm processing through mobile seed processing unit

Value addition at farm level is urgent need of the time because major deterioration and post-harvest losses occurs at this stage. The Mobile Seed Processing Unit was demonstrated by Centre for research on Seed Spices, Jagudan in adopted villages under
NAIP Component-II "Value chain in Major Seed Spices for Domestic & Export Promotion" project for on farm processing of Fennel & Cumin crop. Average higher price of Rs. 725 and 491 per quintal, respectively for fennel and cumin was obtained as compared to unprocessed product. The farmers are realizing 10-15% higher prices of their processed produce as compared to traditionally unprocessed produce, such type of processing unit are also established in nearby the villages. A mobile agro processing unit developed at CIPHET on a four wheeled trailer could be used for processing of seed spices at farm level. The different machines suitable for processing of seed spices including cleaner grader, horizontal burn mill, vertical burr mill etc. could be installed and operated by a DG set. These types of mobile processing machine were also tested at Research Farm of NRCSS, Ajmer and at Farmers' fields and the results are encouraging. This machine is very much beneficial for small and marginal farmers as the produce can be processed at their door step.

f) Packaging and storage

To standardize proper packaging materials for coriander an experiment has been tried with following eleven packaging materials for bulk and retail packing at CRSS, Jagudan. For bulk package jute bag, jute bag with LDPE lining, HDPE bag, HDPE bag with LDPE lining, Paper bag each with 50 kg capacity, LDPE, HDPE, PP, PET+LDPE laminate, metalized PET +LDPE laminate. From the above packaging treatment, paper bag is found best followed by jute bag with LDPE lining in case of bulk packages (50 kg bags) while in the case of consumer packages (500 gm), metalised PET + LDPE laminate is found best followed by PET + LDPE laminate. The whole dried seeds are usually packed into jute or poly bags and stored in cool dry places at 25°C-28°C room temperature. Biodeterioration due to storage fungi and storage pests will occur if the moisture of the produce is more than 10%.

Value added products from spices

a) Black pepper

A variety of products have been made from pepper like Green pepper based products, Black pepper and white pepper based products and Pepper by- products. The major green pepper based products are Canned green pepper, Green pepper in brine, Bulk-packaged green pepper in brine, Cured green pepper, Frozen green pepper, Freeze dried green pepper, Dehydrated green pepper, Green pepper pickle, Mixed green pepper pickle, Green pepper sauce and Green pepper-flavoured products. Black pepper and white pepper based products include Whole black pepper, Sterilized black pepper, Ground black pepper, Cryoground black pepper powder, Pepper oil and Oleoresin, white pepper and white pepper powder. Other miscellaneous products from pepper are Pepper-flavoured products, Pepper extract, curry powder spice blends, peppersal, Pepper mayonnaise, pepper cookies and pepper tofu.

(b) Cardamom

Major products of cardamom are bleached cardamom, Decorticated seeds and seed powder, Cardamom volatile oil and Cardamom oleoresin. In addition to this, CFTRI, Mysore has developed the following products: Encapsulated cardamom, cardamom tea, cardamom coffee and cardamom soft drink mix.
(c) Ginger
Ginger powder, ginger oil, Ginger oleoresins, encapsulated ginger, Ginger preserves and salted ginger are the value added product from ginger.

(d) Turmeric
Major value added products are Ground turmeric, Turmeric oil, Turmeric Oleoresin and curcuminoids,

(e) Seed spices
In seed spices value addition may be adopted in following way:

1. Ground spices:
The ground spices can be incorporated in food dishes more uniformly as compared to whole spices. In spite of these attributes they have limited shelf life and are subject to oxidation, flavour loss and degradation on long storage due to microbial contamination. For small scale production up to 100 kg/day manual grinders are adequate. For large scale production a small powered grinding mill needed and models are available that can grind 25 kg/hr. The high heat evolved at the time of grinding (42-95°C) resulting in flavor loss. To overcome this, spices are milled at low temperature using liquid nitrogen cryogenic grinding. Coriander powder was prepared by cryogenic grinding at four temperatures - 30°C, -80°C, -120°C and -180°C at CRSS, Jagudan. By cryogenic grinding at -180°C had smallest particle size, more uniformity and high volatile oil content (0.9%). Coriander powder obtained from cryogenically grinding method is found greener than that obtained from traditional grinding method. The major disadvantage of cryogenic grinding is high cost.

2. Spices extractives
Spices extractives can be categorized into three groups:

Essential oils
These are major flavouring constituents of spices, highly concentrated about 75-100 times than the fresh spice

Coriander: Major component of volatile oil is linalool (67.7%) followed by alphapinene (10.5%), arama- terpinene (9.0%), geranyl acetate (4.0%), camphor (3.0%) and geraniol (1.9%). Minor components include beta-pinene, camphene, myrcene, limonene, p-cymene, borneol etc. Indian coriander oil differs from European oil in Possessing a lower linalool contents and comparatively higher linalyl acetate contents.

Cumin: The main constituent is cuminaldehyde and three other aldehydes up to 70%. Dominant monoterpenes hydrocarbons (total about 50-55%) are b-pinene, g-terpinene and p-cymene, plus myrcene a-and b-phellandrene and limonene, with minor amounts of sesquiterpenes hydrocarbons (Baser et al 1992). Cumin oil is sometimes adulterated with synthetic cuminaldehyde, which is difficult to detect. The oil is a raw material for the production of thymol.

Fennel: Fennel seed oil, usually traded as fennel oil, is mainly obtained by steam distilling whole or crushed fruit with a yield of 1.5-6.5%, and more recently by
supercritical carbon dioxide extraction. In general, oil content is greatest in European and lowest in Asian varieties. The main constituents are trans-anethole (60-65%, but up to 90%), fenchone (2-20%) estragol (methyl chavicol), limonene, camphene, a-pinene and other monoterpenes, fenchyl alcohol and anisaldehyde. Oil produced in Nigeria from fennel of Indian origin had 80% anethole content but no fenchone.

**Fenugreek:** Major constituents are the dihydroactinidiolide, 2-3-dihydrobenzofuran and I-heanol totaling 7-9% with 20 other constituents at less than 3% and the remainder below 1%. The furanone derivative, sotolon, is reportedly mainly responsible for the characteristic fenugreek odour.

**Oleoresins**

Oleoresin represents the complete flavour and non-volatile resinous fraction present in the spices. The aroma and taste fractions are proportionally blended to constitute the 'true essence' of the natural spice. The oleoresin can be obtained in a single step by elimination of the steam distillation process.

**Derivatives of essential oil and oleo resins**

They include plated encapsulated forms of spice extractives, seasonings in dry carrier such as dextrose, salt or rusk powder. They impart the strength of good quality freshly ground spices and can be easily incorporated in the food.

**3. Curry Powders/blends and mixes**

Curry powder is an indigenous seasoning made from various spices (coriander, cumin, fennel, fenugreek are common) constitute the raw materials used in quality curry powder. The ingredients of curry change according to different needs. The colour, form and taste of various curries are in accordance with the custom of various nations and regions. Consumers all over the world demand different curry powder. The export trade in curry powder at present is dominated by India. Curry powder is made from a blend of several spices, the number vary from a minimum of 5 to more than 20 depending on end uses.

**4. Consumer packed Spices**

The exported spices are consumed in three main segments namely, industrial, institutional and retail. Different packaging media are used according to the consumer's preference. The packaging has gained considerable importance as it increases the shelf life of spices. The development of new and improved plastic films, aluminium foil, laminations, high speed film sealing machines etc. has created new opportunities for packaging the spices as instant spices, spices pastes, spices powder etc. By exporting consumer packed spices, higher unit value for the same quantity can be earned. The price of such retail spice packs is higher between 50-100 per cent as compared to prices of bulk spices.

**5. Organic spices**

Exporters specializing in organic production have been successful in achieving the international standard prescribed for spices. The growing demand for organic crop products has led to the development of international trade for organic spices.
Post harvest operations like harvesting, procession, packing, extraction and development of value added products etc play a major role in maintaining quality of spices to the specifications of international trade. In addition to reducing the labour, mechanization helps in maintaining the quality and food safety standards. Improvements in hygiene, packing and storage facilities will not only help in keeping quality of spice flavours but also play a major role in reducing aflatoxin and salmonella contamination of our spices and spice products. The present deficiency in on farm primary and secondary processing of spices need to be bridged for quality up gradation and greater emphasis on product diversification to the newer requirements of domestic as well as global marketing. Thus post harvest processing and management of spices have great scope considering the present international trade scenario.

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