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Effect of tillage practices at different levels of soil moisture on some soil properties and maize productivity

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ABSTRACT

A field experiment was carried out during the early summer seasons of 2018, at Agricultural Research Centre (ARC) Giza, Egypt. This study aims to examine the effect of three tillage treatments under three different moisture contents on some soil properties and on maize crop production. The experiments included three moisture contents of (MC_1, 27.2 %), (MC_2, 15.4 **%)** and (MC_3, 7.2 %); as well as three tillage treatments, no-tillage control (NT), minimum tillage (MT) and conventional tillage (CT). The experimental was laid out in split-split plot design with four replications. The results showed that, there was significant effect of tillage at different moisture levels on soil physical and chemical properties. It was also indicated that the effect of tillage practices was significantly on soil bulk density, total porosity, hydraulic conductivity and moisture constants, where the conventional tillage at soil moisture level 15.4% (MC_2) helped in improving soil bulk density, hydraulic conductivity and total porosity. Soil organic C, cations exchange capacity CEC, available N, P and K were improved in the soil surface layer of NT and decreased with depth. Clod mean weight diameter of soil was improved with 15.4-% of soil moisture content regardless of tillage depth and enhanced root proliferation by increasing density roots compared with minimum and no tillage in maize plant. The grain yields of maize were improving more under conventional tillage at moisture content 15.4% compared with other treatments. It was found that plant height and roots value increased by using conventional tillage compared with other tillage treatments.

KEYWORDS

Minimum Tillage, Conventional Tillage, Deep Tillage, Soil Moisture, Soil Properties, Maize Yield

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The soil work ability status is considered as the optimum soil water content where the tillage operation has the desired effect of producing the greatest proportion of small aggregates (Dexter and Bird, 2001). Workability timing is related to land management planning at a farm level. Automating and application of procedures using soil resources survey data are used to predict soil moisture and workability timing. Several studies (Mueller *et al.,* 2003) found the best disaggregating effect of tillage implements to occur at the water content corresponding to maximum proctor test which it is the density of a given soil can be compacted varies with water content and force of compaction. Tillage is the mechanical disturbance of the soil for the purpose of crop production. Over the decades, focus has been drawn to the effects of different tillage practices on some physical and hydraulic properties of soils around the globe. Legahri, *et al.* (2016) found that the bulk density of the soil before tillage were 1.28, 1.29 and 1.33 $Mg.m^{-3}$ when the soil moisture level amount were 11-13%, 14-16% and 17- 19%, respectively, which reduced considerably to 1.14, 1.18 and 1.27 $Mg.m^{-3}$. Among the crop production factors, tillage contributes up to 20% (Khurshid *et al.,* 2006) and affects the sustainable use of soil resources through its influence on soil properties (Lal and Stewart, 2013).

Bogunovic and Kisi (2017) reported that tillage practice led to improve soil physical properties such as bulk density, soil porosity and penetration resistance, compared with initial soil physical properties of soil (before tillage Practice). Millington *et al*. (2016) decided that, soil response to compaction depends on traffic quality, soil properties and moisture. When the traffic occurs, soil compaction is usually expressed by the means of bulk density, porosity (Javadi and Spoor, 2006, Loghavi and Khadem, 2006, Rashidi, *et al.,* 2007). The knowledge outcome of conservation tillage on soil moisture conditions and soil compaction has become a major concern among producers considering adopting this tillage system (Licht and Al-Kaisi, 2005). Continuous use of NT (no-tillage) can cause measurable changes in soil hydrological, mechanical, physical, chemical and biological properties (Lal and Elder, 2008). The conventional tillage (CT) practices lead to breakdown of soil structure which subsequently affects soil water transmission characteristics, soil organic matter depletion, microbial activity and crop productivity.

High bulk density values are a sign of a higher compaction level detected that conventional tillage systems caused significant increases in bulk density and soil compaction compared to no-tillage systems (Birkas *et al.,* 2004). Therefore, evaluating the effects of conservation tillage practices on soil moisture and compaction can help to explain some of the differences in plant growth and development under different tillage practices (Licht and Al-Kaisi, 2005). Astier-Calderon *et al.* (2002) also recommended that, indicators such as soil organic matter, infiltration capacity, soil aggregation, bulk density and soil salinity can be used to evaluate soil quality. Tillage systems have been compared in terms of soil quality and environment in a great deal of research. Many studies concur that, soil organic matter is a good soil quality indicator because of its influence on soil quality and productivity. This practice also improves economic performance, energy use efficiency and reduces production risks (Zentner *et al.,* 2002, Lal and Stewart, 2013). Agbede (2006) Mounding and ridging resulted in higher leaf N, P and K tuber length and girth compared with zero tillage and manual clearing. Zero tillage had significantly higher concentrations of organic C, N, P, K, for surface soil (0–20 cm).

Generally, soil tillage is considering one of the most important factors influencing soil properties and crop yield.

Materials and Methods

A field experiment was conducted at the farm, with clay loam soil texture, of Agri. Res. Center, Giza, Egypt during the summer season 2018 on maize as a test crop. Common soil chemically characteristics were tested at 0-30 cm of the experimental site. Also, soil bulk density was measured using core samplers and drying samples at 105C^{o} for 24 hours in the oven. Meanwhile, soil bulk density was calculated, while total porosity, hydraulic conductivity and soil aggregates were estimated. Analyses of the experimental soils site are listed in (table 1).

The Experimental Treatments Included

- Three tillage practices of no tillage (NT), minimum tillage (MT) till the depth of 0-10 cm and conventional tillage (CT) till the depth of 0-30 cm.
- Three soil moisture contents of 27.2% (MC_1), 15.4% (MC_2) and 7.2% (MC_3).

The experimental trial was performed as a split-split plot design with nine treatments and four replications. Recommended doses of N, P and K (120, 200 and 50 kg fad^{-1}) were applied. Maize, as attested crop of the current study, was sown with the recommended seed rate of 20 kg fed. All treatments were received all the recommended locally agriculture practices. After harvesting the crop, soil samples were also collected from each plot following standard procedures. Then, soil bulk density (g cm^{-3}), soil organic carbon (%), total porosity (%) and soil saturated hydraulic conductivity (cm hr^{-1}). Hydrometer method was applied to examine Sand %, Silt %, and Cay %.

Surface soil (0-30 cm) samples were collected for Aggregate size analysis. Aggregate status of soil was determined by wet sieving method (Yoder, 1936). After obtaining the extract from saturated soil paste with the help of vacuum pump soil EC was measured using a digital Jen way electrical conductivity meter (Deltaville, 1992). Soil pH was recorded with a digital pH meter, after making a standard soil and standardizing pH meter with 4.0 and 9.2 pH buffer solutions (Deltaville, 1992).

Soil organic carbon was estimated using (Jha *et al.,* 2014) rapid titration method, using a di-phenyl amine indicator. Also available soil-N, P and K (mg kg^{-1}) were determined. On the other hand, a lot of tests were conducted on maize as a test crop used in this study. Plant height of ten randomly selected plants from each plot was measured with the help of meter scale from ground surface to apex of the plant at 120 days after sowing (DAS) in maize. The root was measured at 120 DAS. Samples were taken in between the plant rows. Roots were carefully separated from the soil by washing the nets under water.

Table 1. Some soil physical and chemical properties at depth of (0-30 cm) at the experimental site

Parameter	Values	Parameter	Values
	Depth 0 -10 cm		
Sand (%)	30.9	EC (dS m^{-1})	1.97
Silt (%)	29.5	CEC (me $100g^{-1}$)	12.3
Clay (%)	39.6	OC (%)	1.2
Textural Class	**Clay loam**	**Aggregates stability**	
pH	7.53	>2mm	52.5
Bulk density(g cm^{-3})	1.37	>0.25	37.3
Total porosity (%)	48.30	<0.25	10.1
Hydraulic Conductivity (cm hr^{-1})	2.11	Mean weight diameter (MWD)	1.428
Field capacity (FC, %)	38.2	N mg kg^{-1}	75
Wilting point (WP, %)	14.4	P mg kg^{-1}	9.40
Available water (AW, %)	23.8	K mg kg^{-1}	208
	Depth 10 – 20 cm		
Sand (%)	30.8	EC (dS m^{-1})	1.95
Silt (%)	29.5	CEC (me $100g^{-1}$)	21.13
Clay (%)	39.7	OC (%)	1.45
Textural Class	**Clay loam**	**Aggregates stability**	
pH	7.68	>2mm	55.5
Bulk density(g cm^{-3})	1.36	>0.25	36.2
Total porosity (%)	48.68	<0.25	11.3
Hydraulic Conductivity (cm hr^{-1})	1.28	MWD	1.363
Field capacity (FC, %)	37.0	N mg kg^{-1}	83.6
Wilting point (WP, %)	14.5	P mg kg^{-1}	10.4
Available water (AW, %)	22.5	K mg kg^{-1}	208.2
	Depth 20 – 30 cm		
Sand (%)	30.8	EC (dS m^{-1})	2.2
Silt (%)	29.5	CEC (me $100g^{-1}$)	21.4
Clay (%)	39.7	OC (%)	1.26
Textural Class	**Clay loam**	**Aggregates stability**	
pH	7.85	>2mm	54.5
Bulk density(g cm^{-3})	1.37	>0.25	33.3
Total porosity (%)	48.3	<0.25	12.2
Hydraulic Conductivity (cm hr^{-1})	0.98	MWD	1.372
Field capacity (FC, %)	35.5	N mg kg^{-1}	73.
Wilting point (WP, %)	13.6	P mg kg^{-1}	8.5
Available water (AW, %)	21.9	K mg kg^{-1}	191.2

The washed roots were cleaned and dried then root dry weight (g/plant) was measured. A sample of maize grains was taking from each plot at time of harvesting and air dried, then weighed. Grain yield were recorded in kg from 2 m^2 area in each plot and finally expressed in Kg fed^{-1}.

The collected data on various aspects of the investigations were statistically analyzed as prescribed by (Cochran and Cox, 1967) and adapted by (Cheema and Singh, 1991) in statistical package CPCS-I. The treatment mean comparisons were made at level of significance 5 % LSD.

Results and Discussion

Effect of Tillage Practices on Bulk Density (BD), Total Porosity (TP) and Hydraulic Conductivity (Ks)

Effects of the experimental treatments on soil physical characteristics of bulk density (BD), total porosity (TP) and hydraulic conductivity (Ksat) show in table (2) and fig (1). Data showed low values of bulk density (BD) and hence high values of total porosity (TP) with tillage treatments in all soil layers compared with no tillage (NT), this trend could be attributed to the effects of tillage practices type.

Table 2. Effects of tillage practice on Bulk density, Total porosity and hydraulic conductivity at the depths of 0-10, 10-20 and 20-30 cm under different soil moisture levels

Soil moisture contents (%)	Tillage Practice (T)											
	NT	MT	CT	Means	NT	MT	CT	Means	NT	MT	CT	Means
	Bulk Density (g cm^{-3})				Total Porosity (%)				Ksat cm/h			
Depth (0-10 cm)												
MC1 (27.2%)	1.35	1.28	1.26	1.30	49.06	51.70	52.45	50.94	2.11	3.23	3.48	2.94
MC2 (15.4%)	1.35	1.22	1.20	1.26	49.06	53.96	54.72	52.45	2.11	4.84	5.10	4.50
MC3 (7.2%)	1.35	1.27	1.24	1.29	49.06	52.08	53.21	51.32	2.11	4.06	4.74	3.76
Means	1.35	1.26	1.23		49.06	52.45	53.58		2.11	4.18	4.47	
L.S.D(0.05)	MC=0.04, T=0.052, MCxT=0.03				MC=1.4, T= 1.9, MCxT=1.720				MC=0.96, T=1.70, MCxT=2.33			
Depth (10-20 cm)												
MC1 (27.2%)	1.36	1.35	1.30	1.34	48.68	49.06	50.94	49.43	1.28	2.86	3.54	2.56
MC2 (15.4%)	1.36	1.32	1.23	1.30	48.68	50.19	53.58	50.94	1.28	3.64	4.9	3.50
MC3 (7.2%)	1.36	1.35	1.29	1.33	48.68	49.06	51.32	49.81	1.28	3.18	3.91	2.82
Means	1.36	1.34	1.27		48.68	49.43	52.08		1.28	3.18	3.91	
L.S.D(0.05)	MC=0.048, T=0.038, MCxT=ns				MC=1.814, T=1.46, MCxT=ns				MC=1.091, T= 0.703, MCxT=ns			
Depth (20-30 cm)												
MC1 (27.2%)	1.37	1.36	1.31	1.35	48.30	48.30	50.57	49.06	0.98	2.56	3.24	2.26
MC2 (15.4%)	1.37	1.35	1.24	1.32	48.30	49.06	53.21	50.19	0.98	3.34	4.6	3.20
MC3 (7.2%)	1.37	1.35	1.30	1.34	48.30	49.06	51.32	49.43	0.98	2.88	3.61	2.52
Means	1.37	1.36	1.28		48.30	48.68	51.70		0.98	2.88	3.61	
L.S.D(0.05)	MC=0.015,T=0.013,MCxT=0.024				MC=0.015, T= 0.0136, CxT=0.0237				MC=0.015, T= 0.0136, CxT=ns			

Bulk Density (D g/cm^3)	Total Porosity (TP %)	Hydraulic Conductivity (Ksat. cm/h)

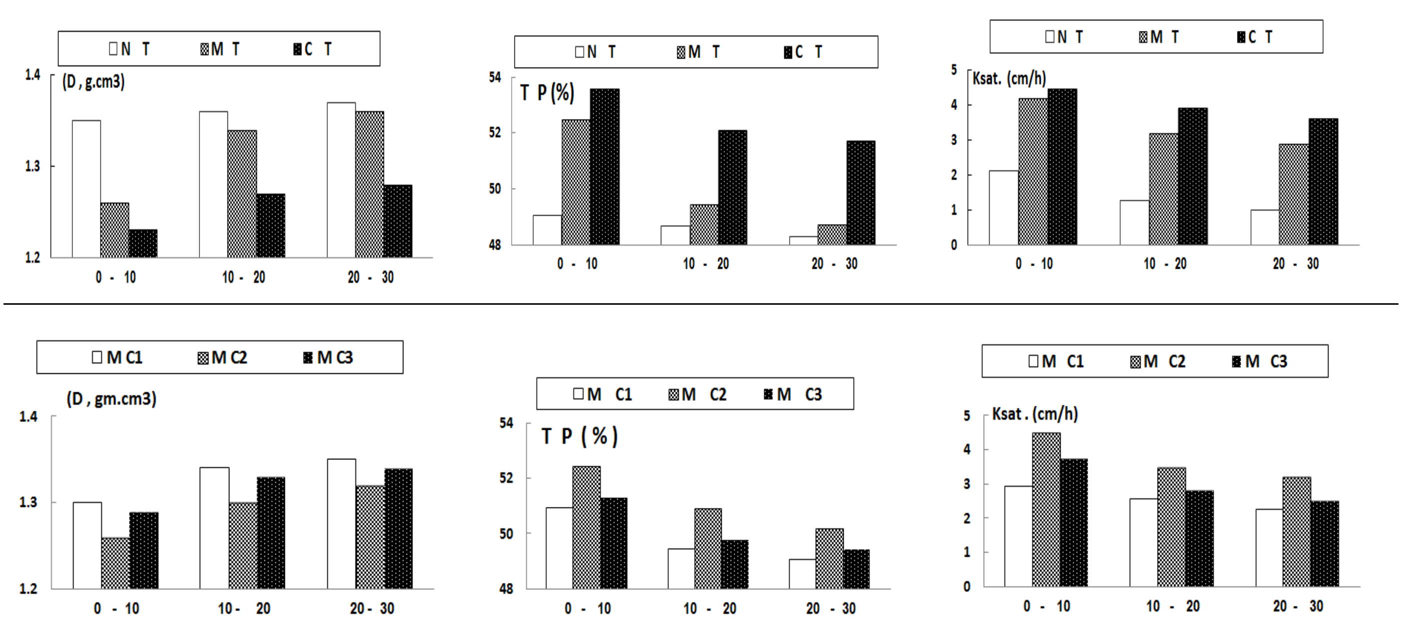
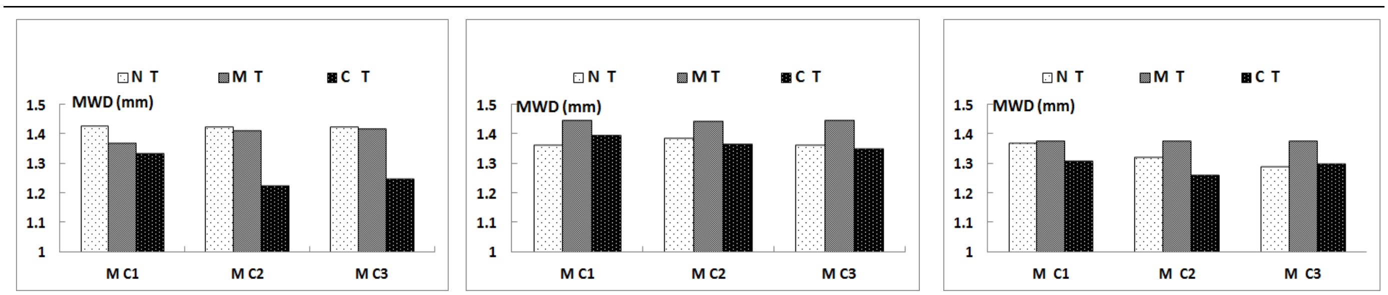


Fig 1. Individual effects of the experimental treatments of tillage types and soil moisture contents (%) on soil bulk density (D g / cm^3), Total Porosity (TP %) and Hydraulic Conductivity (Ksat. cm / h) at different depths of the experimental soil

This increase in bulk density could be due to a combination of soil compaction due to repeated human traffic during weeding, data collection and other crop management activities. You can point out to (BD) values were slightly higher in NT than CT and MT at sub-layers. On the other hand the BD values under any of tillage practice and any depth were lower at moisture content 15.4% (MC_2) than with (MC_1) and (MC_3).

Table 3. Effects of tillage practice on aggregate size classes as a percentage under different soil moisture levels

Soil Moisture Contents (%)	Tillage System	>2mm (%)	> 0.25 mm (%)	< 0.25 mm (%)	MWD mm
Depth (0-10 cm)					
MC1 (27.2%)	NT	36.2	55.5	11.3	1.363
	MT	35.4	52.3	13.2	1.446
	CT	32.5	50.3	18.2	1.395
	Means	34.7	52.7	14.2	
MC2 (15.4%)	NT	36.2	55.4	11.3	1.388
	MT	34.4	51.5	14.1	1.445
	CT	30.3	50.4	19.1	1.367
	Means	33.6	52.4	14.8	
MC3 (7.2%)	NT	36.2	55.5	11.3	1.364
	MT	35.2	48.5	16.3	1.446
	CT	33.1	48.5	18.4	1.351
	Means	34.8	50.8	16.3	
Depth (10-20 cm)					
MC1 (27.2%)	NT	37.3	52.5	10.1	1.428
	MT	35.4	50.4	13.1	1.371
	CT	34.2	48.6	17.3	1.335
	Means	35.6	50.5	13.5	
MC2 (15.4%)	NT	37.3	52.4	10.1	1.426
	MT	38.1	49.6	12.3	1.413
	CT	30.1	46.5	17.3	1.227
	Means	35.17	49.5	13.2	
MC3 (7.2%)	NT	33.3	54.5	12.2	1.291
	MT	31.2	50.4	18.2	1.378
	CT	28.2	47.6	24.2	1.300
	Means	30.9	50.8	18.2	
Depth (20 – 30 cm)					
MC1 (27.2%)	NT	33.3	54.5	12.2	1.372
	MT	31.1	51.7	17.2	1.378
	CT	30.1	50.7	19.2	1.311
	Means	31.5	52.3	16.2	
MC2 (15.4%)	NT	33.3	54.5	12.2	1.324
	MT	30.2	48.4	21.4	1.378
	CT	29.1	47.5	22.3	1.263
	Means	30.9	50.1	18.6	
MC3 (7.2%)	NT	37.3	52.4	10.1	1.426
	MT	37.3	51.5	11.2	1.418
	CT	32.0	45.8	14.2	1.248
	Means	35.5	49.9	11.8	



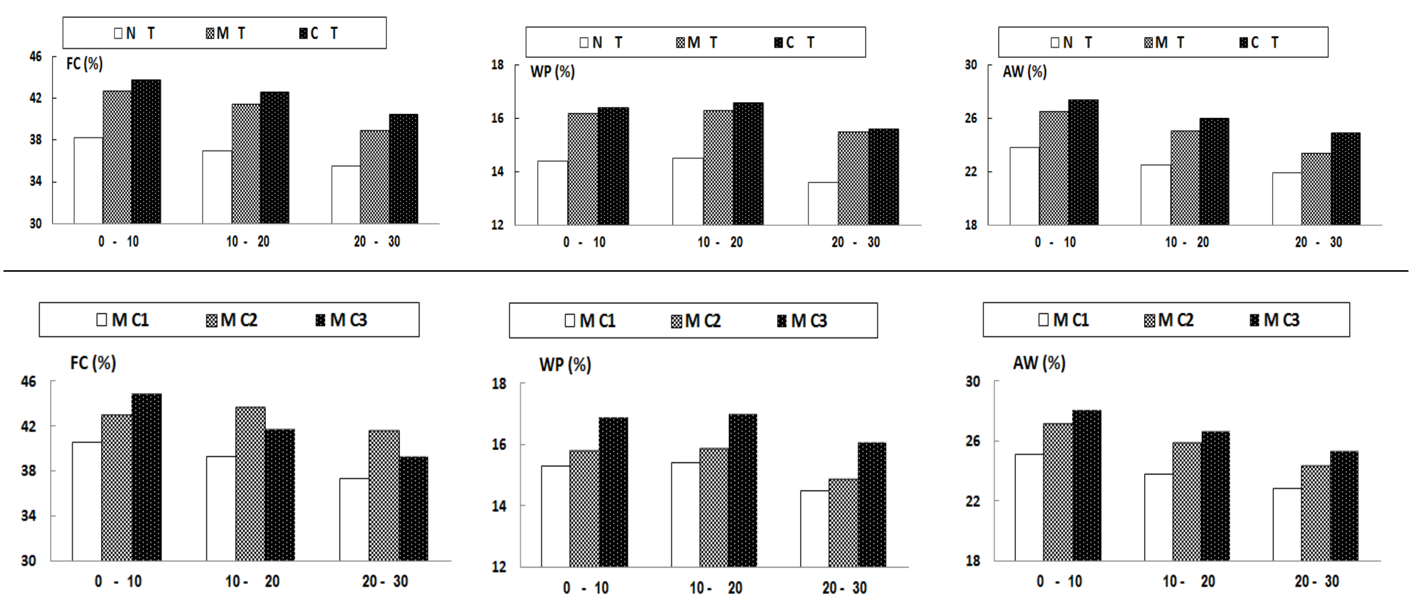
Soil Depth (0- 10 cm) **Soil Depth (10- 20 cm)** **Soil Depth (20- 30 cm)**

Fig 2. Individual effects of the experimental treatments of tillage types and soil moisture contents (%) on Mean Weight Diameter (MWD, mm)

Table 4. Effects of tillage practice on field capacity, wilting point and available water at the 0-10, 10-20 and 20-30 cm depth under different soil moisture levels

Soil Moisture Contents (%)	Tillage Practice (T)											
	NT	MT	CT	Means	NT	MT	CT	Means	NT	MT	CT	Means
	Field Capacity (FC %)				Wilting Point (WP %)				Available Water (AW %)			
Depth (0-10 cm)												
MC1 (27.2%)	38.2	40.3	42.9	40.5	14.4	15.4	16.2	15.3	23.8	25.0	26.7	25.1
MC2 (15.4%)	38.2	43.6	43.3	43.0	14.4	16.4	15.9	15.8	23.8	27.2	27.4	27.2
MC3 (7.2%)	38.2	44.1	45.2	44.9	14.4	16.9	17.2	16.9	23.8	27.2	28.0	28.1
Means	38.2	42.7	43.8		14.4	16.2	16.4		23.8	26.5	27.4	
L.S.D(0.05)	MC=0.66 , T=0.86 , MCxT=0.10				MC=0.07 , T= 0.19 , MCxT=0.34				MC=0.84 , T=0.85 , MCxT=1.47			
Depth (10-20 cm)												
MC1 (27.2%)	37.0	39.1	41.7	39.3	14.5	15.5	16.3	15.4	22.5	23.7	25.4	23.8
MC2 (15.4%)	37.0	42.9	44.0	43.7	14.5	16.5	16.0	15.9	22.5	25.9	26.1	25.9
MC3 (7.2%)	37.0	42.4	42.1	41.8	14.5	17.0	17.4	17.0	22.5	25.9	26.6	26.7
Means	37.0	41.5	42.6		14.5	16.3	16.6		22.5	25.1	26.0	
L.S.D(0.05)	MC=0.82 , T=0.87 , MCxT=1.50				MC=0.07 , T=0.19 , MCxT=0.34				MC=0.74 , T= 0.64 , MCxT=1.39			
Depth (20-30 cm)												
MC1 (27.2%)	35.5	36.7	39.7	37.3	13.6	14.5	15.4	14.5	21.9	22.2	24.2	22.8
MC2 (15.4%)	35.5	40.7	42.0	41.6	13.6	15.5	14.9	14.9	21.9	24.0	24.9	24.4
MC3 (7.2%)	35.5	39.4	39.8	39.3	13.6	16.5	16.5	16.1	21.9	24.1	25.5	25.4
Means	35.5	38.9	40.5		13.6	15.5	15.6		21.9	23.4	24.9	
L.S.D(0.05)	MC=1.33 , T=0.71 , MCxT=1.23				MC=0.33 , T= 0.31 ,,, CxT=0.02				MC=1.38 , T= 0.79 , CxT=1.37			

Field Capacity (%) Wilting Point (%) Available Water (%)



Soil Depth (cm) Soil Depth (cm) Soil Depth (cm)

Fig 3. Individual effects of the experimental treatments of tillage types and soil moisture contents (%) on soil field capacity (%), wilting point (%) and available water (%) at different depths of the experimental soil

These results showed that, the lower bulk density and hence high porosity at the start of the season could be attributed to the loosening effects of tillage. Also (Bogunovic and Kisi, 2017) reported that tillage practice led to improve soil physical properties such as bulk density, soil porosity, and penetration resistance, compared with initial soil physical properties of soil, *i.e.* before tillage Practice. Conventional tillage (CT) had improved soil porosity by increasing the macro porosity. On the other hand (Karuku *et al*., 2012) stated that, for any given soil, the higher the bulk densities, the more compacted the soil and the less the pore space as also observed in this study. With regard to hydraulic conductivity (Ksat), it was found that as the same behavior of bulk density, where tillage at soil moisture content (MC_2) gave the highest values of hydraulic conductivity compared with other treatments. The same trends were shown in all studied layers.

Effects of Tillage Practice on Aggregate Stability and Mean Weight Diameter (MWD)

Aggregate Stability

A soil with good soil structure typically has a mix of micro, and macro-pores. Therefore, with more aggregation, you would expect to have a higher total porosity compared to a poorly aggregated soil. The used tillage systems showed obvious effects on aggregate stability at all depths table 3 and figure 2. Soil aggregate stability increased in all plots as the depth increased. Also, data showed differences between aggregate stability means of tillage systems in all layers. The highest values of aggregate stability >2mm were found for (NT) at all depths. The highest quantity of fine aggregates (< 0.25 mm) noticed with moisture content ($MC_{2,}$ 15.4%) at soil depth (0-10cm). The number and size of water-stable aggregates decreased with increased soil depth from 0-30cm under all treatments.

Data showed that the stability of macro-aggregates (>0.25 mm) was controlled by soil management (tillage, rotations, etc.), but the stability of micro-aggregates (<0.25 mm) depended on the amount and stability of organic cementing agents and seemed to be independent of soil management. From the point of view of the average percentage of ASD of tillage systems, about 30% of the aggregates were larger than 2 mm, about 50% were arrange from 2 mm to 0.25 mm and 13% were <0.25 mm with tillage under different moisture content (Heinonen, 1985). Hajabbasi and Hemmat (2000) also pointed out that, tillage practices showed a similar effect on ASD. Aggregates >2 mm in CT were lower than those in NT and MT. Zhang *et al.* (2012) found that, the >2.0 mm aggregate size in a clay loam soil was higher under no-tillage in comparison to conventional tillage.

Mean Weight Diameter (MWD)

Conventional tillage (CT) practices develop soil structure. Also, no-tillage (NT) enhanced soil structure development more than the other conventional tillage practices. The lowest value of MWD was obtained in the (CT) at (0 -10 cm and 10 - 20) soil depth and the highest value of MWD were obtained with (MT). When numerically considered, the (NT) method at 0-10 cm depth provided higher development of soil structure compared to (CT). The (NT) practice also had higher contribution to soil structure development compared to (CT) in all soil depth at soil moisture content (MC_2, 15.4%). The reason for the high MWD values in no-tillage (NT) compared to conventional tillage (CT) is most likely due to the high organic carbon contents obtained in the former. Celik *et al.* (2012) found that MWD values under no-tillage (NT) and reduced tillage were higher than conventional tillage (CT). Abdollahi and Munkholm (2014) reported that reduced tillage systems increased MWD values, penetration resistance and water-stable aggregates.

Effect of Tillage Practice on Soil Moisture Retentive

Soil moisture retentive includes of field capacity (FC), wilting point (WP) and available water (AW). The individual and interaction effects of different tillage practices treatments and soil moisture contents (%) on soil Field capacity (FC), wilting point (WP) and available water **(**AW) at the different studied soil depths, were significant as shown in table 4 and figure 3.

Field Capacity (FC)

Field capacity (FC) values varied from 35.5 to 45.2% at different soil depths. The lowest (FC) value was 35.5 % which recorded in the no- tillage (NT) at (20-30cm) depth at all the tested soil moisture content. The highest value of (FC) was 45.2% which noticed with (CT) at (MC_3, 7.2%) at (0-10cm) depth. Mostly, (FC) as affected with moisture content (MC) follows the order of (MC_3) > (MC_2) > (MC_1) at depth of (0-10cm), while at the depth of (10-20 and 20-30cm) the FC followed the descending order MC_2) > (MC_3) > (MC_1). In addition, the individual effects of tillage practices followed the order (CT) > (MT) > (NT).

Wilting Point (WP)

Wilting point (WP) values varied significantly due to different tillage depths, cropping patterns, and their interaction. The results showed that, the lowest (WP) value was (13.6%) which found in the no- tillage (NT) at (20-30cm) soil depth with the same value at all the tested soil moisture content. The highest (WP) value of 17.4% was recorded with conventional tillage (CT) at moisture content (MC_3, 7.2%).

Available Water (AW)

Available water (AW), it was found that (AW) affected by different tillage practices and moisture contents, where the order of tillage (CT) > (MT) > (NT) in all studied depths, while in case of moisture content (MC) follows the order of (MC_3) > (MC_2) > (MC_1). However, available water showed increase trend at (0- 10cm) depth and minimum trend at (20-30) cm tillage depth. This indicated that tillage depth 20-30 cm may help increase the available water contents as shown clearly in figure 3. By manipulating soil moisture dynamics with tillage could be one of the more feasible ways of increasing yields of crops (Rahman and Islam, 1998). Aikins *et al.* (2010) who demonstrated that conventional tillage had more moisture than zero tillage. No tillage reduced moisture loss by developing a thick layer which restricted upward movement of water to evaporative surface by reducing diffusivity gradient. While conventional tillage improved water infiltration, it also tended to increase evaporation in control plots.

Effects on Organic Carbon (OC), Cations Exchange Capacity (CEC) and Electrical Conductivity (EC) of Soil

The data pertaining to OC, CEC and EC of the soil as affected by tillage type under different moisture contents and presented in table 5 and figure 4.

Soil Organic Carbon (OC)

Soil (OC) values showed significantly affected by tillage practices and moisture levels of the experimental soil. Its worth to mention that, the highest (OC) content (1.61%) was noticed at the surface layer of soil (0-10 cm) than the other two sub-surface layers. Generally at any soil depth, the highest (OC) values were noticed under (NT) followed with (MT) and the lowest values were noticed with (CT). Also, the highest values of (OC) were found under (MC_1) followed by (MC_2) or (MC_3). At (0-10) soil depth and under any (T) or (MC) treatment, the (OC %) values were higher than the corresponding values in other layers of (10-20 cm) and (20-30 cm). Hazarika *et al.,* (2009), Zentner *et al.,* (2004) and Bhattacharyya *et al.,* (2006) reported that, 14-17 % higher OC in surface soil under NT and MT than CT practices.

Cation Exchange Capacity (CEC)

With respect to the effect of tillage practices, values of (CEC me /100g soil) mostly followed the descending order of (CT) > (MT) > (NT) at all depths. With regard to the effect of soil moisture content on (CEC me/100g soil) can be mostly, arranged in the descending order of (MC_2) > (MC_3) > (MC_1) at depth of (0-10cm) and (10-20 cm) respectively.

The interaction effects of tillage practices in combination with moisture content of soil showed the highest value of CEC (27.57me/100g soil) was found at 0-10 cm with (MT) and (MC_2). While the lowest value of CEC (21.13 me /100 g soils) was found at 10-20 cm with (NT) under all moisture content. Soil surface accumulation of organic matter has been reported to increase CEC as compared to sub-surface (Karathanasis and Wells, 1989).

Electrical Conductivity (EC)

With respect to the effect of tillage practices, values of (EC dS/m) followed the descending order of (NT) > (MT) > (CT) at all studied depths. With regard to the effect of soil moisture content on (EC dS/m) can be arranged in the descending order of (MC_1) > (MC_3) > (MC_2). The highest values of EC (2.42 dS/m) were noticed at (20-30cm) under (CT) with (MC_1), while the lowest values of EC (1.03 dS/m) were noticed at (0-10cm) under (CT) with (MC_2). In comparison of the conductivity data, the highest electrical conductivity goes to the no tillage system while the lowest level was observed in the conventional tillage. Patni *et al.,* (1998) also reported decrease in soil EC under NT which might be due to more downward movement of salts along with water infiltration into deeper layers.

Table 5. Effects of tillage practice on OC, C.E.C and EC at the 0-10, 10-20 and 20-30cm depth under different soil moisture levels

Soil Moisture Contents (%)	Tillage Practice (T)											
	NT	MT	CT	Means	NT	MT	CT	Means	NT	MT	CT	Means
	OC (%)				CEC (me / 100 gm)				EC (dS / m)			
Depth (0-10 cm)												
MC1 (27.2%)	1.61	1.59	1.54	1.58	22.33	23.30	24.13	23.26	1.8	1.72	1.79	1.78
MC2 (15.4%)	1.61	1.54	1.50	1.55	22.33	27.57	27.40	25.77	1.8	1.07	1.03	1.10
MC3 (7.2%)	1.61	1.58	1.53	1.57	22.33	26.27	26.70	24.10	1.8	1.32	1.17	1.38
Means	1.61	1.57	1.53		22.33	25.71	26.08		1.8	1.37	1.33	
L.S.D(0.05)	MC=0.01 , T=0.01 , MCxT=0.01				MC=0.25 , T= 0.23 , MCxT=0.40				MC=0.10 , T=0.08 , MCxT=0.13			
Depth (10-20 cm)												
MC1 (27.2%)	1.45	1.41	1.40	1.42	21.13	22.10	22.93	22.06	1.9	1.82	1.89	1.88
MC2 (15.4%)	1.45	1.32	1.30	1.33	21.13	26.37	26.20	24.57	1.9	1.17	1.13	1.20
MC3 (7.2%)	1.45	1.29	1.21	1.26	21.13	25.07	25.50	23.90	1.9	1.42	1.27	1.48
Means	1.45	1.34	1.30		21.13	24.51	24.88		1.90	1.47	1.43	
L.S.D(0.05)	MC=0.01 , T=0.01 , MCxT=0.01				MC=0.26 , T=0.23 , MCxT=0.40				MC=0.25 , T= 0.23 , MCxT=0.12			
Depth (20-30 cm)												
MC1 (27.2%)	1.26	1.23	1.16	1.21	21.40	24.30	23.13	22.94	2.20	2.35	2.42	2.41
MC2 (15.4%)	1.26	1.19	1.15	1.18	21.40	24.57	24.40	24..46	2.20	1.70	1.66	1.73
MC3 (7.2%)	1.26	1.20	1.16	1.21	21.40	23.27	23.70	22.79	2.20	1.95	1.80	2.01
Means	1.26	1.20	1.16		21.40	22.71	23.08		2.20	2.00	1.96	
L.S.D(0.05)	MC=0.02 , T=0.01 , MCxT=0.02				MC=0.25 , T= 0.24 , CxT=0.31				MC=0.24 , T= 0.20 , CxT=0.08			

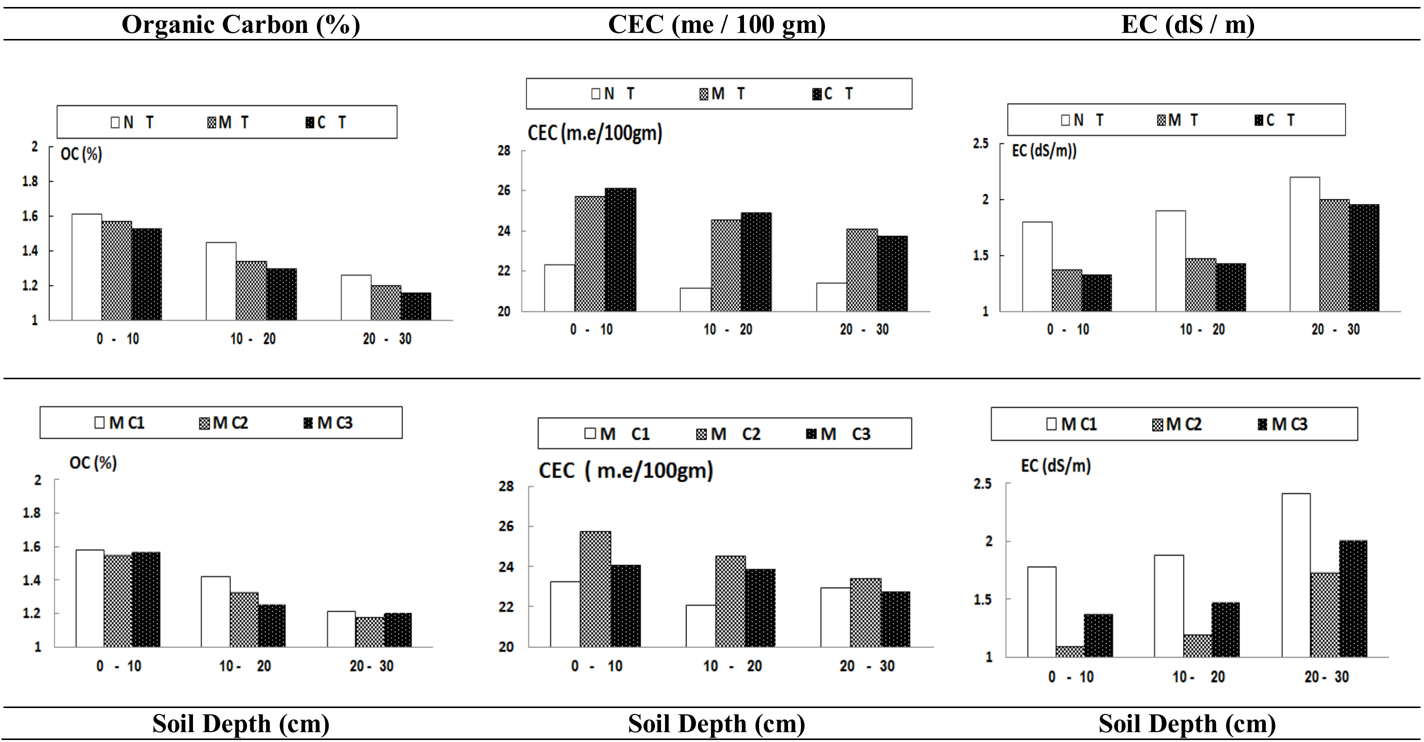


Fig 4. Individual effects of the experimental treatments of tillage types and soil moisture contents (%) on soil OC (%), CEC (me /100 gm) and EC (dS / m) at different depths of the experimental soil

Effect of Tillage Practice at Different Moisture Content on Soil Available of N, P and K

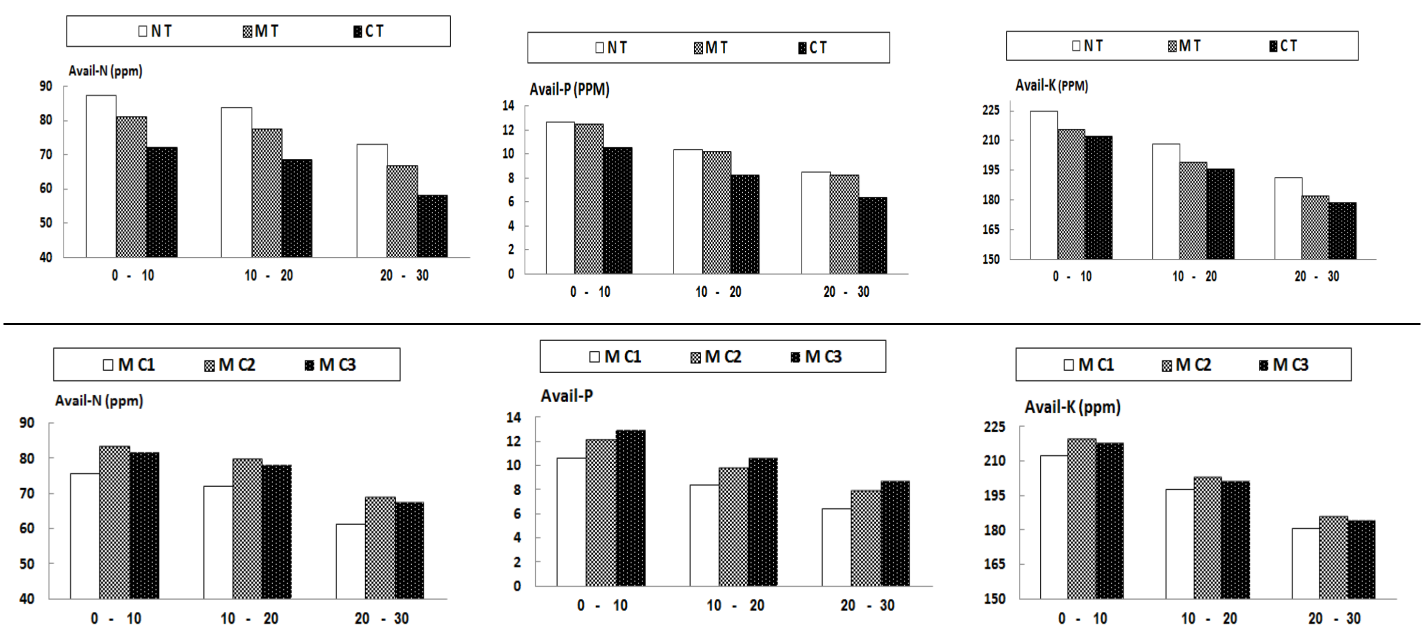
Available Nitrogen (mg kg^{-1})

The mean effect of used tillage practices, as illustrated in figure 5. The mean was followed the descending order (NT) > (MT) > (CT). Furthermore, moisture content (MC) effects followed the descending order (MC_2) > (MC_3) > (MC_1). Available-N as affected by tillage practices under different soil moisture content was showed in table 6.

Table 6. Effect of tillage practice on available N, P and K (mg kg^{-1}) of soil at the 0-10, 10-20 and 20-30 cm depths under different soil moisture levels

Soil Moisture Contents (%)	Tillage Practice (T)											
	NT	MT	CT	Means	NT	MT	CT	Means	NT	MT	CT	Means
	Avail-N (mg kg^{-1})				Avail-P (mg kg^{-1})				Avail-K (mg kg^{-1})			
Depth (0-10 cm)												
MC1 (27.2%)	87.20	71.30	68.00	75.50	12.70	10.40	8.80	10.63	224.7	207.7	210.0	212.5
MC2 (15.4%)	87.20	85.60	77.30	83.40	12.70	12.80	11.00	12.17	224.7	219.7	215.4	219.9
MC3 (7.2%)	87.20	86.70	71.70	81.90	12.70	14.20	11.90	12.93	224.7	218.7	210.7	218.0
Means	87.20	81.20	72.30		12.70	12.47	10.57		224.7	215.4	212.0	
L.S.D(0.05)	MC=6.42, T=3.63, MCxT=6.29				MC=0.59, T= 0.25, MCxT=0.89				MC=0.67, T=0.86, MCxT=1.49			
Depth (10-20 cm)												
MC1 (27.2%)	83.60	67.70	64.40	71.90	10.40	8.10	6.50	8.33	208.2	191.2	193.5	197.6
MC2 (15.4%)	83.60	82.00	73.70	79.80	10.40	10.50	8.70	9.87	208.2	203.2	198.9	203.4
MC3 (7.2%)	83.60	83.10	68.10	78.30	10.40	11.90	9.60	10.63	208.2	202.2	194.2	201.5
Means	83.60	77.60	68.70		10.40	10.17	8.27	9.61	208.2	198.9	195.5	
L.S.D(0.05)	MC=5.32, T=2.43, MCxT=ns				MC=0.45,T=0.17,MCxT=0.79				MC=0.44, T=0.69 , MCxT=1.22			
Depth (20-30 cm)												
MC1 (27.2%)	73.00	57.10	53.80	61.30	8.50	6.20	4.60	6.43	191.2	174.2	176.5	180.6
MC2 (15.4%)	73.00	71.40	63.10	69.20	8.50	8.60	6.80	7.97	191.2	186.2	181.9	186.4
MC3 (7.2%)	73.00	72.50	57.50	67.70	8.50	10.00	7.70	8.73	191.2	185.2	177.2	184.5
Means	73.00	67.00	58.10		8.50	8.27	6.37		191.2	181.9	178.5	
L.S.D(0.05)	MC=4.12, T=2.53, MCxT=ns				MC= 0.28, T= 0.9, CxT=0.18				MC=0.41, T= 0.54, CxT=0.98			

Avail - N (mg kg^{-1}) Avail - P (mg kg^{-1}) Avail - K (mg kg^{-1})



Soil Depth (cm) Soil Depth (cm) Soil Depth (cm)

Fig 5. Individual effects of the experimental treatments of tillage types and soil moisture contents (%) on soil available nutrients of N (mg kg^{-1}), P (mg kg^{-1}) and K (mg kg^{-1}) at different depths of the experimental soil

The highest values of available N (87.2 mg kg^{-1}) was observed under (NT) at 0- 10 cm depth with all soil moisture content, while, the lowest available N (53.8 mg kg^{-1}) was recorded at 20- 30 cm depth under (CT) with (MC_1). This results was in agree with that found by (Arshad *et al.,* 1990) who's stated that available N content of surface soil was 25% higher under NT than CT plots. Moussa - Machraoui *et al.,* (2010) also reported more available N under NT due to more organic matter accumulation in surface soil layer.

Table 7. Effect of different tillage treatments on root, plant height and grain of maize under different soil moisture levels

Moisture Content (%)	Tillage System											
	NT	MT	CT	Means	NT	MT	CT	Means	NT	MT	CT	Means
	Root Mass Density (g/plant)				Plant Height (cm/plant)				Grain Yield (Kg/fed)			
MC1 (27.2%)	24	26	27	26	143	152	153	149	1873	2238	2201	2104
MC2 (15.4%)	24	29	34	29	143	165	186	164	1873	2298	2327	2166
MC3 (7.2%)	24	27	28	27	143	161	182	162	1873	2244	2320	2117
Means	24	27	29		143	160	174		1873	2276	2283	
L.S.D$_{0.05}$	MC=0.71, T=1.40, MCxT=1.23				MC=0.88, T=2.47, MCxT=1.53				MC=8.96, T=13.53, MCxT=15.52			

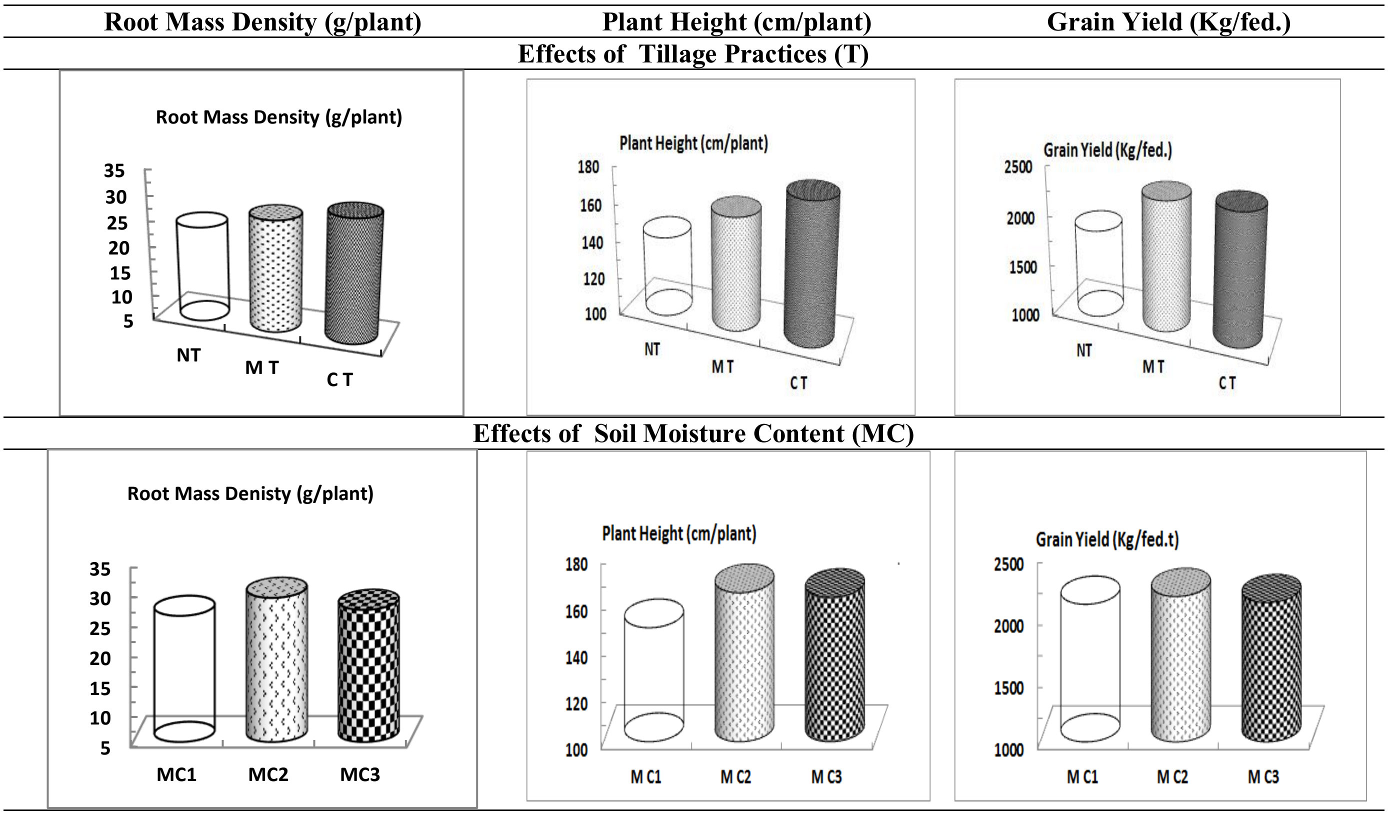


Fig 6. Individual effects of the experimental treatments of tillage types and soil moisture contents (%) on Root Mass Density (g/plant), Plant Height (cm/plant) and Grain Yield (Kg/fed)

Available Phosphorus (mg kg^{-1})

The results indicate that tillage practices had significant effect on available P in as illustrated in fig (5). The effect of tillage on available of P was fallowed the order of (NT) > (MT) > (CT), while the moisture content effects on available P fallowed the order of (MC_3) > (MC_2) > (MC_1). Available P as affected by tillage practices under different soil moisture content in was showed in table 6. The highest values of available P was (12.70 mg kg^{-1}) which observed under (NT) at 0- 10 cm depth with all soil moisture content. The lowest value of available P was (4.60 mg kg^{-1}) which recorded at 20- 30 cm depth under (CT) with (MC_1). Accumulation of phosphorus contributing to increased P availability through release of inorganic P from decaying residues (Palm *et al.,* 2001).

Available Potassium (mg kg^{-1})

Tillage and residue management practices had significant effect on available K in all treatments, as shown in figure 5. The tillage practices effects on available K in the order of (NT) > (MT) > (CT). While the moisture content effects on avail-K in the order of (MC_2) > (MC_3) > (MC_1). Available K as affected by tillage practices under different soil moisture content was showed in table 6.

The highest values of avail-K (224.70 mg kg^{-1}) was observed under (NT) at 0- 10 cm depth with the different soil moisture levels. The lowest avail.-K (174.20 mg kg^{-1}) was recorded at 20- 30 cm depth under (MT) with (MC_1). Franzluebbers and Hons (1996) also reported that soil managed by NT had greater available K concentrations in the surface soil layer than with CT. Concerning moisture content, the highest values of available K was observed under MC_2 followed by MC_3 and lowest under MC_1. Increased available K in untilled soil was correlated with increased organic matter content (Karathanasis and Wells, 1989).

Effect of Tillage Practice on Root Mass Density, Plant Height and Grain Yield of Maize Yield

Root Mass Density (g/plant)

Root Mass Density of maize (gm/plant) was also significantly influenced by the tillage practices. The root values were increasing significantly with different tillage treatments in the descending order (CT) > (MT) > (NT), while the effects of moisture contents followed the order of MC_2 >MC_3 > MC_1. Root Mass Density of maize (gm/plant) as affected by tillage practices under different soil moisture content as showed in table 7 and figure 6. The highest value of root (34 gm.) was observed under (CT) with (MC_2). The lowest root (24 gm) was recorded under (NT) at all moisture content.

Plant Height (cm)

Plant height (cm) of maize as affected by tillage practices under different soil moisture content was showed in table 7 and figure 6. The results showed that plant height values were increasing significantly with different tillage treatments in the descending order (CT) > (MT) > (NT), while the effects of moisture contents followed the descending order MC_2 > MC_3 > MC_1. The highest value of plant height (186cm) was observed under (CT) with (MC_2). The lowest value of plant height (143 cm) was recorded under (CT) at all soil moisture content.

Grain Yield (Kg/fed)

The results on grain yield under different tillage treatments are given in table 7. Conventional tillage system gave maximum grain yield compared to minimum tillage and no-tillage. The grain yield of 2283 kg fed^{-1}, 2276 kg $fed.^{-1}$ and 1873 kg $fed.^{-1}$ was obtained under CT, MT, and NT, respectively. Concerning the soil moisture content, the highest grain yield was found in MC_2 followed by MC_3 and MC_1 table 7 and figure 6. The difference between the yield obtained from (MT) and (NT) methods was also significant so that minimum tillage (MT) had higher grain yield compared to the no till (NT) method. Memon *et al.,* (2013) also reported higher maize grain yield in CT than MT and NT treatments. There was higher maize yield in conventional tillage (CT) compare with other tillage this was reported by (Liao *et al.,* 2002 and Xue *et al.,* 2005). Rashidi and Keshavarzpour, (2007) it is expected that improving soil physical properties in the conventional tillage methods will improve corn yield in the coming years of this experiment performance. Data showed that a highest value of grain yield (2327 kg/fed.) was recorded with (MC_2) under (CT), while no tillage had the least values (1873 kg/fed.).

Conclusion

Workability timing is related to land management planning at a farm level. Automating and application of procedures using soil resources survey data are used to predict soil moisture and workability timing. The results confirmed that clay loam soil are prone to crust formation and compaction which lead to unfavorable soil hydro-physical properties especially when the tillage is done at very low or very high moisture content. Tillage at different moisture contents was tested to study the effect of these treatments on selected soil physical, chemical properties and maize grain yield. Tillage at MC_2 (15.4%) resulted in improvement of soil surface hydraulic conditions. The tillage practice also improved soil quality through improved soil physical properties. The conventional tillage followed by minimum tillage was the best treatments which led to improve soil physical properties in addition to grain yield of maize. The highest grain yield was recorded on treatments MC_2 and MC_3 as a result of favorable soil moisture at which the tillage were carried out. Thus, it can be suggested that tillage operations done at moisture content 15.4% produces optimum soil conditions and maize yield on the studied.

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