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Effect of Tillage and Mulch on Soil Physical Properties and Growth of Maize

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ABSTRACT

A field experiment was conducted to evaluate the effect of different tillage systems and mulch levels on soil physical properties and growth of maize. Three tillage systems (minimum, deep & conventional tillage) and four mulch levels (control, wheat straw @ 4, 8 & 12 Mg ha^{-1}) were used. Tillage methods significantly affected the soil physical properties as increase in soil moisture contents and decrease in bulk density of soil was noted. The soil moisture contents (18.51%) were maximum in conventional tillage and bulk density (1.38 Mg m^{-3}) was minimum in case of deep tillage as compared to minimum tillage. Organic matter contents (0.87%) were found maximum in minimum tillage. The maximum value of plant height (214.94 cm), number of grains per cob (659.5) and 1000-grain weight (410.71 g) was observed in case of conventional tillage, while maximum total dry matter (32.13 Mg ha^{-1}) and grain yield (5.57 Mg ha^{-1}) was noted in case of deep tillage as compared to minimum tillage. Mulch significantly affected the soil physical properties and growth of maize. The soil moisture contents (18.43%), organic matter contents (0.88%), plant height (217.67 cm), total dry matter (27.18 Mg ha^{-1}), number of cobs per plant (1.06), number of grains per cob (610.55), and 1000-grain weight (398.68 g) of maize were maximum when mulch was applied @ 12 Mg ha^{-1}, while maximum values of grain yield (5.77 Mg ha^{-1}) and soil bulk density (1.53 Mg m^{-3}) were obtained when mulch was applied @ 8 Mg ha^{-1} and in control, respectively. Tillage (deep & conventional) and mulch (8 & 12 Mg ha^{-1}) have pronounced effect on soil physical properties and growth of maize.

Key Words: Tillage; Mulch; Soil physical properties; Growth; Maize

INTRODUCTION

Tillage practices that maintain crop residue on the soil surface have been shown to increase maize yields in numerous studies (Triplett *et al*., 1968; Lal, 1974, 1978, 1995; Unger, 1986; Wicks *et al*., 1994). The yield increase was correlated with increase in water contents in the soil due to reduced evaporation. Among the crop production factors tillage contributes up to 20% (Ahmad *et al*., 1996). The most effective way to reduce compaction is tillage (Bowen, 1981). Subsoil compaction may reduce the availability and uptake of water and plant nutrients, thereby lowering crop yields. Among the management options for remediation subsoil compaction are deep tillage and the selection of crop rotations with deep-rooted crops (Motavalli *et al.*, 2003). Deep tillage breaks up high-density soil layer, improves water infiltration and movement in the soil, enhances root growth and development and increases crop production potential (Bennie & Botha, 1986). Deep tillage of the soil results in increased corn grain yields with the greatest yield always being obtained with tillage depth of 90 cm (Varsa *et al.*, 1997). The use of minimum tillage management practices for maize production is increasing because it reduces time, fuel as well as labour requirements and also reduces soil erosion on slopes. Chaudhary *et al.* (1992) compared conventional tillage system to zero tillage and concluded that higher moisture retention and 13% more income was obtained in case of zero tillage. But minimum tillage could not compensate the adverse effects of fine texture, very low organic matter and an overall initial weak structure of soil.

Among the management practices for increasing water use efficiency (WUE) one of them is mulching. Any material spread on the surface of soil to protect it from rain drop, solar radiation or evaporation is called mulch. Different types of materials like wheat straw, rice straw, plastic film, grass, wood, sand etc. are used as mulch. It moderates soil temperature and increases water infiltration during intensive rain (Gajri *et al*., 1994). Agriculture crops in Pakistan are facing serious water shortage. About 10.24 million hectare meters is diverted into canals, which is not enough to fulfill the 15.54 million hectare meter water requirements (Anonymous, 2002).

The present investigation was planned to determine the effect of different tillage systems in combination with mulch application on soil physical properties and growth of maize.

MATERIALS AND METHODS

A field experiment was conducted to evaluate the effect of different tillage systems and mulch levels on soil physical properties and growth of maize, at research area, Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad. Three tillage systems (minimum, deep & conventional tillage) and four mulch levels control, wheat straw @ 4, 8 and 12 Mg ha^{-1} were used. The soil and plant sampling was done at crop harvest. Crop was grown up to maturity. Data regarding plant height, fresh and dry

shoot weight, number of cobs plant^{-1}, number of grains cob^{-1}, 1000 grain weight, grain yield, soil bulk density, soil moisture and organic matter contents was determined at crop harvest. Tine cultivator and chisel plow were used for deep tillage operation and rigger for making ridges in conventional tillage. Recommended levels of N (200 kg ha^{-1}), P (125 kg ha^{-1}) and K (60 kg ha^{-1}) were used as Urea, DAP and SOP, respectively. Maize was sown with the help of dibble, maintaining plant to plant 22 cm and row-to-row 70 cm distance. Weedicides was used to control weeds like Itsit, Jangli Jai etc.The data so collected was analyzed statistically using Completely Randomized Block Design (Steel & Torrie, 1980).

RESULTS

Data on plant height at harvest as influenced by tillage and mulch application (Table I) indicated that plant height was affected significantly by various levels of mulch. As regards tillage methods, mean maximum value of plant height 214.94 cm was observed in conventional tillage followed by 211.68 cm in case of deep tillage and 193.15 cm in minimum tillage. So, mean increase in plant height was 11.28 and 9.59% in case of conventional tillage and deep tillage, respectively over minimum tillage. Regarding mulch level, the mean maximum height 217.67 cm of plant was obtained, when mulch was applied @ 12 Mg ha^{-1} followed by 217.35 and 205.71 cm in 8 and 4 Mg ha^{-1} where as minimum plant height 185.63 cm was obtained in control treatment. Mean increase in plant height was 17.26, 17.08 and 6.2% in treatments where mulch was applied @ 12, 8 and @ 4 Mg ha^{-1}, respectively. There was significant difference in plant height when mulch was applied @ 12, 8 and 4 Mg ha^{-1} as compared with control but there was no significant difference between mulch applied @ 8 and 12 Mg ha^{-1}.

Data pertaining to grain yield of maize are listed in Table I, which showed the influence of tillage and mulch levels on grain yield of maize. As regards tillage, the maximum mean value of grain production was 5.57 Mg ha^{-1} observed in deep tillage followed by 5.38 Mg ha^{-1} in conventional tillage with minimum mean value 5.37 Mg ha^{-1} in case of minimum tillage. There was 3.7 and 1.85% increase in deep and conventional tillage, respectively as compared to minimum tillage. Conventional and minimum tillage were statistically non-significant with each other but were significant with respect to deep tillage. As regards mulch, the mean maximum grain yield 5.77 Mg ha^{-1} was observed in treatment where mulch was applied @ 8 Mg ha^{-1} followed by 5.70 Mg ha^{-1} in treatment where mulch was applied @ 12 Mg ha^{-1} and 5.38 Mg ha^{-1} in treatment, where mulch was applied @ 4 Mg ha^{-1} with mean minimum value 4.92 Mg ha^{-1} was observed in case of control. There was significant difference in grain yield when mulch was applied @ 12, 8 and 4 Mg ha^{-1} as compared with control but there was no significant difference between mulch applied @ 8 and 12 Mg ha^{1}.

Data regarding number of grains cob^{-1} of maize (Table I) showed the influence of tillage and mulch levels on number of grains cob^{-1} of maize. As regards tillage, the mean maximum value of number of grains cob^{-1} was 659.5 observed in conventional tillage followed by 611.83 in deep tillage with mean minimum value 552.50 in case of minimum tillage. There were 19.2 and 10.7% increase in conventional and deep tillage as compared to minimum tillage. Conventional, minimum and deep tillage were statistically significant with each other. As regards mulch, the mean maximum number of grains 610.55 were observed in treatment where mulch was applied @ 12 Mg ha^{-1} followed by 609.55 in control treatment, 608.55 in treatment, where mulch was applied @ 4 Mg ha^{-1} and minimum mean value 603.11 in treatment where mulch was applied @ 8 Mg ha^{-1}. There was no significant difference between the different mulch levels applied.

Data regarding 1000-grain weight of maize are presented in Table I, which revealed that both tillage methods and mulch levels have significant effect on 1000-grain weight of maize. As regards tillage, the mean maximum value of 1000-grain weight 410.71 g was observed in conventional tillage followed by 379.44 g in case of deep tillage, while minimum value was observed in case of minimum tillage (362.03 g). Mean increase in 1000-grain weight observed was 13.4 and 4.9% in conventional tillage and deep tillage, respectively as compared to minimum tillage. As regards mulch, the mean maximum value of 1000- grain weight 398.68 g was observed in treatment where mulch was applied @ 12 Mg ha^{-1} followed by 390.76 g in treatment where mulch was applied @ 8 Mg ha^{-1} and 386.16 g in treatment, where mulch was applied @ 4 Mg ha^{-1} while mean minimum value 360.63 g was observed in case of control. There was no significant difference observed in the three mulch levels applied, but they were significantly different from control.

It is evident from Table I that both tillage methods and mulch levels have significant effect on total shoot dry matter of maize crop. As regards tillage, the mean maximum value of plant dry biomass 32.13 Mg ha^{-1} was observed in deep tillage system followed by 23.40 Mg ha^{-1} in conventional tillage system with mean minimum value 20.50 Mg ha^{-1} in minimum tillage. There was 56.71 and 14.16% increase in deep and conventional tillage, respectively as compared to minimum system. There was significant difference between the tillage systems. As regards mulch, the mean maximum

Table I. Effect of tillage and mulch on growth parameters of Maize

	Treatment	Plant height (cm).	Grain Yield (Mg ha^{-1})	No. of grains cob^{-1}	1000 grain weight (g)	Plant biomass (Mg ha^{-1})	No. of cobs per plant
Tillage	Minimum Tillage	193.15C	5.37B	552.50C	362.03B	20.50C	1.08^{NS}
	Deep tillage	211.68B	5.57A	611.83B	379.44B	32.13A	1.02^{NS}
	Conventional tillage	214.94A	5.38B	659.5A	410.71A	23.40B	1.01^{NS}
Mulch	Mulch@0 Mg ha^{-1}	18.63C	4.92C	609.55^{NS}	360.63B	20.54B	1.00B
	Mulch@4 Mg ha^{-1}	205.71B	5.38B	608.55^{NS}	386.16A	27.10A	1.05A
	Mulch@8 Mg ha^{-1}	217.35A	5.774A	603.11^{NS}	390.76A	26.55A	1.02AB
	Mulch@12 Mg ha^{-1}	217.67A	5.709A	610.55^{NS}	398.68A	27.18 A	1.06A

plant dry biomass 27.18 Mg ha^{-1} was observed in treatment where mulch was applied @ 12Mg ha^{-1} followed by 27.10 Mg ha^{1} in treatment where mulch was applied @ 4 Mg ha^{-1} and 26.55 Mg ha^{-1} in treatment where mulch was applied @ 8 Mg ha^{-1} with mean minimum value 20.54 Mg ha^{-1} was observed in control. There was 31.95%, 32.34% and 29.26% increase in plant biomass than control. There was no significant difference between the different mulch levels.

The data regarding number of cobs $plant^{-1}$ of maize Table I indicates that tillage methods have non-significant, while mulch levels have significant effect on number of cobs $plant^{-1}$ of maize. As regards tillage, the maximum mean value of number of cobs $plant^{-1}$ 1.08 was observed in minimum tillage followed by 1.02 in deep tillage with minimum mean value 1.01 in case of conventional tillage. There was 7.2 and 1.08% increase in minimum and deep tillage, respectively as compared to conventional tillage. Conventional, minimum and deep tillage were statistically non-significant with each other. As regards mulch, the maximum mean number of cobs $plant^{-1}$ was 1.06 observed in treatment, where mulch was applied @ 12 Mg ha^{-1} followed by 1.05 in treatment where mulch was applied @ 4 Mg ha^{-1} and 1.02 in treatment where mulch was applied @ 8 Mg ha^{-1} with minimum mean value 1.00 was observed in control. There were 6.9, 5.6 and 2.0% increase in number of cobs $plant^{-1}$ than control. There was no significant difference between the different mulch levels but significantly different from control.

Data related to soil bulk density after harvesting of maize are given in Table II. Analysis of Variance clearly indicated that both the tillage methods and mulch had a significant effect on bulk density of soil. As regards tillage methods, higher mean value for bulk density 1.47 Mg m^{-3} was observed in case of minimum tillage followed by 1.41 Mg m^{-3} and 1.38 Mg m^{-3} in case of conventional tillage and deep tillage, respectively. Mean decrease in bulk density observed was 6.86 and 3.53% in case of deep tillage and conventional tillage, respectively as compared to minimum tillage, indicating that deep tillage decreases the bulk density compared to minimum tillage. As regards mulch levels, the maximum mean value 1.53 Mg m^{-3} was observed in control followed by 1.44 and 1.37 Mg m^{-3} in treatment where mulch was applied @ 4 and 12 Mg ha^{-1}, respectively. Minimum mean value 1.34 Mg m^{-3} was found in treatment where mulch was applied @ 8 Mg ha^{-1}. There was significant difference in bulk density when mulch was applied @ 12, 8 and 4 Mg ha^{-1} as compared with control but there was no significant difference between mulch applied @ 8 and 12 Mg ha^{-1}.

The data pertaining to organic matter concentration (%) in soil at harvest of maize are listed in Table II, which shows that both tillage and mulch have significant effect on organic matter concentration in the soil. Regarding tillage methods, maximum mean value of organic matter (0.87%) was noted in minimum tillage followed by deep tillage (0.84%). Minimum mean value of organic matter was

Table II. Effect of tillage and mulch on soil physical properties

	Treatment	Soil bulk Density (Mg cm^{-3})	Soil organic matter contents (%)	Soil moisture contents (%)
Tillage	Minimum tillage	1.47A	0.87A	16.80B
	Deep tillage	1.38B	0.84A	17.14B
	Conventional tillage	1.41AB	0.73B	18.51A
Mulch	Mulch@0 Mg ha^{-1}	1.53A	0.74B	16.15B
	Mulch@4 Mg ha^{-1}	1.44B	0.79AB	17.71A
	Mulch@8 Mg ha^{-1}	1.34A	0.84AB	17.66A
	Mulch@12 Mg ha^{-1}	1.37A	0.88A	18.43A

observed in case of conventional tillage (0.73%). Mean increase in organic matter was 18.8 and 14.13 % in case of minimum tillage and deep as compared to conventional tillage. As regards mulch, the maximum mean value 0.88% was observed in treatment where mulch was applied @ 12 Mg ha^{-1} and the minimum mean value 0.74% was observed in control treatment. The mean organic matter value of the three treatments were statistically similar but were different from that of control. The mean increase of 18.74% was observed in treatment, where mulch was applied @ 12 Mg ha^{-1} as compared to control.

The data pertaining to soil moisture content (%) in soil at harvest of maize are listed in Table II, which shows that both tillage and mulch have significant effect on soil moisture concentration (%) in the soil. Regarding tillage methods, maximum mean value of moisture content (18.51%) was noted in conventional tillage followed by deep tillage (17.14%). Minimum mean value of moisture content was observed in case of minimum tillage (16.80 %). Mean increase in moisture content was 10.17 and 2.02% in case of conventional tillage and deep as compared to minimum tillage. As regards mulch levels, the maximum mean value 18.43% was observed in treatment, where mulch was applied @ of 12 Mg ha^{-1} and the minimum mean value 16.15% was observed in control treatment. The mean soil moisture values of the three treatments were statistically similar but were different from that of control. The mean increase of 14.11% was observed in treatment, where mulch was applied @ of 12 Mg ha^{-1} as compared to control.

DISCUSSION

In this study, effect of tillage and mulch on soil physical properties and growth of maize was investigated.

Result showed a significant response in the growth parameters of crop and physical properties of soil. Integrated use of tillage and mulch was beneficial in improving the growth and yield of maize.

In the present study, tillage methods significantly affected the soil physical properties as increase in soil moisture contents and decrease in bulk density of soil was noted. The soil moisture contents (18.51%) were maximum in conventional tillage and bulk density (1.38 Mg m^{-3}) was minimum in case of deep tillage as compared to minimum tillage. Organic matter contents (0.875%) were found maximum in minimum tillage. These results are in

agreement with those of Materechera and Mloza (1997), who concluded that a distinct hard and compact layer had developed below the ridges (_25 cm depth) in both CT and MT. Soil on ridges of CT had consistently lower penetration resistance than did MT. Bulk density and penetration resistance of soil on the ridges were less under CT than under MT. These results are also in agreement with those of Gordon *et al.* (1993), who concluded that ridged plots contained a greater amount of water in the soil profile at emergence and during mid-silking than chisel-ploughed plots or mouldboard-ploughed plots.

The maximum value of plant height (214.94 cm), number of grains per cob (659.5) and 1000-grain weight (410.71 g) was observed in case of conventional tillage, while maximum total dry matter (32.13 Mg ha^{-1}) and grain yield (5.57 Mg ha^{-1}) was noted in case of deep tillage as compared to minimum tillage. These results are in agreement with those of Diaz-Zorita (2000), who concluded that shoot dry matter (hence plant height) was significantly higher in the tilled treatment than those under no-tillage. These results are also in agreement with those of Bonari (1994), who concluded that grain yield was significantly higher with chisel plowing than shallow, disk or deep plowing. Similar results were shown by Albuquerque *et al*. (2001), who concluded that plant height, number of green leaves, weight and numbers of grains per ear were reduced with no tillage as compared with conventional tillage.

Mulch significantly affected the soil physical properties and growth of maize. The soil moisture contents (18.43%), organic matter contents (0.887%), plant height (217.67 cm), total dry matter (27.18 Mg ha^{-1}), number of cobs per plant 1.06, number of grains per cob 610.55, and 1000-grain weight (398.68 g) of maize were maximum when mulch was applied @12 Mg ha^{-1}, while maximum values of grain yield (5.77 Mg ha^{-1}) and soil bulk density (1.539 Mg m^{-3}) were obtained when mulch was applied @ 8 Mg ha^{-1} and in control. These results are in agreement with those of Wicks *et al.* (1994), who concluded that early maize growth was retarded by increasing mulch levels due to reduced soil temp., but after tasselling maize grew taller under greater mulch levels because of increased soil moisture. They also reported that stover DM and total DM (hence plant height) increased with increasing mulch levels. These results are also in accordance with Liu *et al*. (2002), who concluded that transplanting spring maize with plastic film mulching improved the ecological environment of the soil, increased soil temperature and soil water contents, promoted the growth and maturation of maize and increased crop yield.

Interaction between tillage methods and mulch levels were statistically significant for soil physical properties and growth of maize as in case of soil moisture content, organic matter content, plant height, total dry matter, 1000-grain weight and plant height, while these results were non-significant for number of cobs per plant and number of grains per cob.

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