Effect of Mulch on Soil Physical Properties and N, P, K Concentration in Maize (Zea mays) Shoots under Two Tillage Systems

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ABSTRACT

Tillage is an ancient practice to alleviate soil related problems and mulch also have its definite role in conserving soil physical health. A field experiment was conducted on sandy clay loam soil to evaluate the effect of mulch on soil physical properties and N, P, K concentration in maize shoots under two tillage systems. Deep and conventional tillage were used along with three levels of wheat straw as mulch i.e., control (M0), 7 (M1) and 14 (M2) Mg ha⁻¹. Recommended dose of N, P and K was applied. Mulch increased soil organic matter (1.32 g kg⁻¹) and soil moisture contents (17%), but decreased bulk density (1.35 Mg m⁻³) and soil strength (464 kPa) compared to control. Greater plant height (2.59 m) and grain yield (10.6 Mg ha⁻¹) were obtained from M₂ and biological yield (20.7 Mg ha⁻¹) from M₁ in combination with deep tillage. Tillage and mulch significantly affected the N and P concentration in maize shoots, while its effect on K concentration was appreciable. Interactive effect of mulch and tillage was statistically significant in case of N (1.423 g kg⁻¹) and P (0.156 g kg⁻¹) concentration but non significant in case of K (1.767 g kg⁻¹) concentration. It is concluded that wheat straw as mulch in conjunction with deep tillage improves soil physical health and crop quality.

Key Words: Deep tillage; Wheat straw mulch; Soil physical properties; N, P, K concentration in maize

INTRODUCTION

World population is increasing day by day, which is likely serious thread to food security. This can be overcome by enhancing production of major crops. Maize (Zea mays L.) is the third most important cereal crop in the world after wheat and rice with respect to area and productivity. In Pakistan, it was grown on area of 1017 thousand hectares with annual production of 3088 thousand tones (GOP, 2007-08). Developing countries like Pakistan, India, Iran are facing great challenges to meet input resources i.e., fertilizer, irrigation, good quality seed and energy crisis in order to sustain their production. There is need to adopt such practices and combination of organic and inorganic sources to decrease the cost of production.

The practice of spreading plant residue or any other material like straw on the soil surface to reduce water evaporation losses is called mulching. Appropriate tillage and mulch practices are used to conserve soil moisture and increase the yield of crops. Crop residues at the soil surface act as shade; serve as a vapor barrier against moisture losses from the soil, causing slow surface runoff. Rathore et al. (1998) reported that more water conserves in the soil profile during the early growth period with straw mulch than without it. Subsequent uptake of conserved soil moisture moderated plant water status, soil temperature and soil mechanical resistance, leading to better root growth and higher grain yields. Applications of crop residue mulches increase soil organic carbon contents (Havlin et al., 1990; Paustin et al., 1997; Duiker & Lal, 1999; Saroa & Lal, 2003).

Tillage systems are site-specific and depend on crop, soil type and the climate (Rasmussen, 1999). Tillage also affect nitrate-N concentration, water contents, aeration and available C (Rice & Smith, 1982; McKenny et al., 1993; Khurshid et al., 2006), which in turn, can impact N loss through denitrification and N₂O emissions (Rice & Smith, 1982; Fan et al., 1997). Conservation tillage methods are considered most effective under low rainfall conditions, typically 200-400 mm of annual rainfall (Unger et al., 1991). No-tillage with standing stubble conserves soil organic matter and water, generally increases crop production (Zentner & Lindwall, 1978; Phillips et al., 1980). Tillage practices that maintain crop residue on the soil surface have shown higher maize yield in numerous studies (e.g., Lal, 1974, 1978 & 1995; Unger, 1986; Wicks et al., 1994).

Keeping this in view, the present investigation was planned to determine the effect of different tillage systems in combination with mulch application on soil physical properties and N, P, K concentration in maize shoots.

MATERIALS AND METHODS

An experiment was conducted on sandy clay loam soil from 15 July, 2005 to 15 October, 2005 at Research Area of Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan. Physical and chemical characteristics of original soil were determined (Table I). A soil composite was taken from 0-0.15 m depth. Weedeicides were used to control weeds. Recommended levels of N (0.15 Mg ha⁻¹), P (0.15 Mg ha⁻¹) and K (0.05 Mg ha⁻¹) were applied by Urea, DAP and SOP respectively. Full dozes of P and K were applied at the time of sowing, while N was applied in splits. One third of recommended nitrogen was applied at seedbed preparation, after one month of germination and at tassling stage in three splits. Weedicides were used to control weeds.

A composite soil sample was taken (0-0.15 m depth) before sowing. Soil sample was air-dried, ground, passed through 2 mm sieve and preserved in plastic bottles for analysis. Samples were analyzed for pH by pH meter (McLean, 1982), electrical conductivity of soil extract by Rhoades (1982) method, soil texture by Bouyoucos hydrometer method (Moodie et al., 2001), soil moisture by gravimetric method (Jalota et al., 1998), soil bulk density measured by core method (Blake & Hartge, 1986), soil strength by cone penetrometer, soil organic carbon by Walkley and Black (1934) method, Total N by Bourem and Mulvancy (1982) and Buresh et al. (1982), Available P by spectrophotometer (Olsen & Sommers, 1982), Available K by flame photometer (Richards, 1954).

Plant height was recorded at 45 and 70 days after sowing and at crop harvest. Biological yield (oven dried) and grain yield (at 15% moisture) were taken at harvesting manually. Total N was determined by Sulfuric-salicylic acid digestion method (Buresh et al., 1982), Total P by spectrophotometer (Chapman & Pratt, 1961) and Total K by flame photometer (Chapman & Pratt, 1961). The data was analyzed by randomized complete block design with split plot arrangement and means were compared by least significant difference test (Steel & Torrie, 1980).

RESULTS AND DISCUSSION

Soil moisture contents. Soil mulching significantly affected soil moisture contents at harvest, while tillage affected non-significantly (Table II). Higher soil moisture contents were observed in case of deep tillage (16.1%) and minimum in conventional tillage (15.2%). These results are similar to Bonari et al. (1994) and Bhatt et al. (2004) that soil moisture contents are substantially higher with chisel plowing than shallow, disk or deep plowing of maize field. Mulch levels also significantly affected the soil moisture contents, the maximum soil moisture contents were observed in M2 (17.0%), followed by M1 (15.8%) and minimum in M0 (14.0%) (Table II). The interactive effect of tillage and mulch was significant (Table III), the higher moisture contents were observed in conventional tillage with M0 (17.8%) and minimum in deep tillage with M2 (13.4%). Liu et al. (2002) and Khurshid et al. (2006) stated the same results that mulching improves the ecological environment of the soil and increases soil water contents. Soil bulk density. Tillage had significant effect on bulk density (BD) of soil (Table II). Higher BD was observed in case of conventional tillage (1.40 Mg m⁻³) and minimum in deep tillage (1.37 Mg m⁻³). Diaz-Zorita (2000) and Khurshid et al. (2006) reported that bulk density significantly decreased by enhancing tillage practices. Mulching also reduced soil BD (Table II). Higher BD was observed in M0 (1.41 Mg m⁻³), followed by M1 (1.39 Mg m⁻³) and minimum in M2 (1.35 Mg m⁻³). However, the interactive effect of mulch and tillage was non significant (Table III). Mulching increased soil moisture, organic matter contents leading to suitable environment for root penetration. Ghuman et al. (2001) and concluded that mulching decreases bulk density of the surface soil. Soil strength. Tillage and mulch had significant effect on soil strength (Table II). Maximum soil strength was observed in conventional tillage (663 kPa) and minimum in deep tillage (539 kPa). Soil strength was manipulated of surface soil and increased soil pore-spaces leading to minimum soil strength. Lamprilánés et al. (2003) found larger soil strength in no-tillage than in sub-soiling and minimum-tillage. Akinci et al. (2004) described the same results that Sub-soiling has significant effect on the soil strength. Mulching significantly affected soil strength, the maximum soil strength was observed in M0 (715 kPa), followed by M1 (579 kPa) and minimum in M2 (464 kPa). The interactive effect of tillage and mulch levels was significant (Table II), maximum soil strength was observed in conventional tillage with M0 (831 kPa) and minimum in deep tillage with M2 (450 kPa). Gajri et al. (1994) reported that both soil strength and bulk density decreased by increasing mulch levels.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand (%)</td>
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<tr>
<td>Silt (%)</td>
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</tr>
<tr>
<td>Clay (%)</td>
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<td>Textural Class</td>
<td>Sandy Clay Loam</td>
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<tr>
<td>pH</td>
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</tr>
<tr>
<td>Electrical Conductivity (dS m⁻¹)</td>
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</tr>
<tr>
<td>Bulk Density (Mg m⁻³)</td>
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</tr>
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<td>Organic carbon contents (%)</td>
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<td>Total N (%)</td>
<td>0.023</td>
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<tr>
<td>Available P (ppm)</td>
<td>6.029</td>
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<tr>
<td>Available K (ppm)</td>
<td>108</td>
</tr>
</tbody>
</table>

Table I. Physical and Chemical Properties of Original Soil
Soil organic matter contents. Tillage systems affected significantly at 0-15 cm and 15-30 cm depth. The mean maximum soil organic matter contents were observed in deep tillage (1.06 g kg\(^{-1}\)) and minimum in conventional tillage (0.9 g kg\(^{-1}\)) at 0-15 cm depth. Similarly, mean maximum soil organic matter contents were observed in deep tillage (0.63 g kg\(^{-1}\)) and minimum in conventional tillage (0.54 g kg\(^{-1}\)) at 15-30 cm depth. The deep tillage had 15.21 and 12.94% more SOM contents as compared to conventional tillage at 0-15 and 15-30 cm depths. Khurshid et al. (2006) found maximum organic matter contents in minimum tillage as compared to conventional tillage. The effects of mulch levels were also significant at both soil depths (Table II). Mean maximum value was observed in M\(_2\) (1.32 g kg\(^{-1}\)), followed by M\(_1\) (0.98 g kg\(^{-1}\)) and minimum in M\(_0\) (0.65 g kg\(^{-1}\)) at 0-15 cm depth. Similarly, mean maximum value was observed in M\(_2\) (0.82 g kg\(^{-1}\)), followed by M\(_1\) (0.53 g kg\(^{-1}\)) and minimum in M\(_0\) (0.40 g kg\(^{-1}\)) at 15-30 cm depth. The SOM increased due decomposition of applied mulch. Lal et al. (1980) and Khurshid et al. (2006) concluded that organic matter was significantly higher when more mulch was applied. The interactive effect of tillage and mulch was also significant (Table III), the mean maximum value of organic matter contents was observed in M\(_2\) (1.36 g kg\(^{-1}\)) and minimum in M\(_0\) (0.53 g kg\(^{-1}\)) in combination with conventional tillage at 0-15 cm depth. Similarly, maximum value of organic matter contents was observed in deep tillage with M\(_2\) (0.93 g kg\(^{-1}\)) and minimum in conventional tillage with M\(_0\) (0.40 g kg\(^{-1}\)) at 15-30 cm depth.

Plant height. Tillage system had significantly affected plant height (Table IV). Maximum plant height was observed in deep tillage (1.846 m) followed by conventional tillage (1.696 m) at 45 days after sowing. Similar trend regarding the plant height was found after 70 days and at harvest. Bonari et al. (1994), Albuquerque et al. (2001) and

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Soil Moisture contents (%)</th>
<th>Soil bulk density (Mg m(^{-3}))</th>
<th>Soil Strength (kPa)</th>
<th>Soil Organic Matter Contents (g kg(^{-1}))</th>
</tr>
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<tbody>
<tr>
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<tr>
<td>Tillage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep tillage</td>
<td>16.1NS</td>
<td>1.37NS</td>
<td>539B</td>
<td>1.065A</td>
</tr>
<tr>
<td>Conventional tillage</td>
<td>15.2NS</td>
<td>1.40NS</td>
<td>633A</td>
<td>0.903B</td>
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<td>Mulch</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>@ 0 Mg ha(^{-1}) (M(_0))</td>
<td>14.0C</td>
<td>1.41A</td>
<td>715A</td>
<td>0.650C</td>
</tr>
<tr>
<td>@ 7 Mg ha(^{-1}) (M(_1))</td>
<td>15.8B</td>
<td>1.39AB</td>
<td>579B</td>
<td>0.980B</td>
</tr>
<tr>
<td>@ 14 Mg ha(^{-1}) (M(_2))</td>
<td>17.0A</td>
<td>1.35B</td>
<td>464C</td>
<td>1.323A</td>
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<tr>
<th>Treatments</th>
<th>Soil Moisture contents (%)</th>
<th>Soil bulk density (Mg m(^{-3}))</th>
<th>Soil Strength (kPa)</th>
<th>Soil Organic Matter Contents (g kg(^{-1}))</th>
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<tr>
<td>Deep tillage</td>
<td>Mulch @ 0 Mg ha(^{-1}) (M(_0))</td>
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<td>1.39NS</td>
<td>598B</td>
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<td></td>
<td>Mulch @ 7 Mg ha(^{-1}) (M(_1))</td>
<td>15.7b</td>
<td>1.37NS</td>
<td>569d</td>
</tr>
<tr>
<td></td>
<td>Mulch @ 14 Mg ha(^{-1}) (M(_2))</td>
<td>17.8a</td>
<td>1.35NS</td>
<td>450f</td>
</tr>
<tr>
<td>Conventional tillage</td>
<td>Mulch @ 0 Mg ha(^{-1}) (M(_0))</td>
<td>13.4d</td>
<td>1.43NS</td>
<td>831a</td>
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<tr>
<td></td>
<td>Mulch @ 7 Mg ha(^{-1}) (M(_1))</td>
<td>15.9b</td>
<td>1.41NS</td>
<td>590c</td>
</tr>
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<td>Mulch @ 14 Mg ha(^{-1}) (M(_2))</td>
<td>16.3b</td>
<td>1.36NS</td>
<td>477e</td>
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<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant Height (m)</th>
<th>Biological Yield (Mg ha(^{-1}))</th>
<th>Grain Yield (Mg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 45 Days</td>
<td>After 70 Days</td>
<td>At Harvest</td>
</tr>
<tr>
<td>Tillage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep tillage</td>
<td>1.846A</td>
<td>2.474A</td>
<td>2.494A</td>
</tr>
<tr>
<td>Conventional tillage</td>
<td>1.696B</td>
<td>2.444B</td>
<td>2.464B</td>
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<td>Mulch</td>
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<td>@ 0 Mg ha(^{-1}) (M(_0))</td>
<td>1.723NS</td>
<td>2.398B</td>
<td>2.418B</td>
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<td>@ 7 Mg ha(^{-1}) (M(_1))</td>
<td>0.803NS</td>
<td>2.452B</td>
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<td>@ 14 Mg ha(^{-1}) (M(_2))</td>
<td>0.785NS</td>
<td>2.528A</td>
<td>2.548A</td>
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<tr>
<th>Treatments</th>
<th>Plant Height (m)</th>
<th>Biological Yield (Mg ha(^{-1}))</th>
<th>Grain Yield (Mg ha(^{-1}))</th>
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<tbody>
<tr>
<td></td>
<td>After 45 Days</td>
<td>After 70 Days</td>
<td>At Harvest</td>
</tr>
<tr>
<td>Deep tillage</td>
<td>Mulch @ 0 Mg ha(^{-1}) (M(_0))</td>
<td>1.793NS</td>
<td>2.410NS</td>
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<td>Mulch @ 7 Mg ha(^{-1}) (M(_1))</td>
<td>0.903NS</td>
<td>2.440NS</td>
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<td>Mulch @ 14 Mg ha(^{-1}) (M(_2))</td>
<td>0.840NS</td>
<td>2.575NS</td>
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<tr>
<td>Conventional tillage</td>
<td>Mulch @ 0 Mg ha(^{-1}) (M(_0))</td>
<td>1.653NS</td>
<td>2.387NS</td>
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<td>Mulch @ 7 Mg ha(^{-1}) (M(_1))</td>
<td>0.703NS</td>
<td>2.463NS</td>
</tr>
<tr>
<td></td>
<td>Mulch @ 14 Mg ha(^{-1}) (M(_2))</td>
<td>0.730NS</td>
<td>2.483NS</td>
</tr>
</tbody>
</table>
Khurshid et al. (2006) observed the same results that plant height increases by increasing tillage intensity. This is due to deep tillage that develops suitable environment for root penetration. Mulch affected non-significantly plant height at 45 days, while significantly at 70 days after sowing, where as maximum plant height was obtained in M2 (2.53 m), followed by M1 (2.45 m) and minimum in M0 (2.40 m), as shown in Table IV. Interactive effect of mulch and tillage was non significant (Table V). Similar trend in plant height was observed at harvest. Wicks et al. (1994) and Khurshid et al. (2006) pointed out that maize grew taller under greater mulch levels, because of availability of more soil moisture contents for plant growth.

**Biological yield.** Tillage increased biological yield significantly and maximum biological yield was observed in deep tillage (20.4 Mg ha\(^{-1}\)) and minimum in conventional tillage (17.5 Mg ha\(^{-1}\)) (Table IV). These results were similar to Diaz-Zorita (2000) that maize production increases with increasing tillage intensity. The biological yield was increased significantly by increasing mulch levels (Table IV), maximum biological yield was observed in M2 (19.8 Mg ha\(^{-1}\)), followed by M1 (18.7 Mg ha\(^{-1}\)) and minimum in M0 (18.2 Mg ha\(^{-1}\)). The interactive effect of tillage and mulch on biological yield was significant (Table V). The maximum biological yield was observed in deep-tillage with M1 (20.7 Mg ha\(^{-1}\)) and minimum in conventional tillage with M0 (15.8 Mg ha\(^{-1}\)).

**Grain yield.** Tillage systems affected grain yield non-significantly while mulch effected significantly (Table IV). Although tillage effect was non-significant, higher grain production was observed in deep tillage (9.9 Mg ha\(^{-1}\)) and minimum in conventional tillage (9.1 Mg ha\(^{-1}\)). Bhatt et al. (2004) observed higher grain yield in minimum tilled plots as compared to conventionally tilled plots. Bonari et al. (1994) stated that grain yield is significantly higher with chisel plowing than shallow, disk or deep plowing.

Mulch significantly increased grain yield. Maximum grain yield was observed in M2 (10.5 Mg ha\(^{-1}\), followed by M1 (9.4 Mg ha\(^{-1}\) and minimum in M0 (8.6 Mg ha\(^{-1}\)) (Table IV). The interactive effect of tillage and mulch was differed significantly (Table V). Maximum grain yield was observed in deep tillage with M2 (10.65 Mg ha\(^{-1}\)). Tolk et al. (1999) and Liu et al. (2002) concluded that mulch increases soil moisture and nutrients availability to plant roots, in turn, leading to higher grain yield.

**Nitrogen concentration in maize shoots.** The data regarding the effect of tillage and mulch on nitrogen concentration (g kg\(^{-1}\)) in shoots at 45 and 70 days after sowing and at maturity indicated that tillage systems affected N significantly at 45 days and at 70 days after sowing. The mean maximum N conc. was observed in M1 (10.5 g kg\(^{-1}\)) and minimum in M0 (8.6 g kg\(^{-1}\)) (Table IV). The interactive effect of tillage and mulch was differed significantly (Table V). Maximum grain yield was observed in deep tillage with M2 (10.65 Mg ha\(^{-1}\)). Tolk et al. (1999) and Liu et al. (2002) concluded that mulch increases soil moisture and nutrients availability to plant roots, in turn, leading to higher grain yield.

**Table VI. Effect of Tillage and Mulch on N, P, K Concentration at Maize Shoots**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>N (g kg(^{-1}))</th>
<th>P (g kg(^{-1}))</th>
<th>K (g kg(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 45 Days</td>
<td>After 70 Days</td>
<td>At Harvest</td>
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<tr>
<td>Tillage</td>
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</tr>
<tr>
<td>Deep tillage</td>
<td>1.124B</td>
<td>1.357B</td>
<td>1.149</td>
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<td>Conventional tillage</td>
<td>1.267A</td>
<td>1.440A</td>
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<tr>
<td>Mulch</td>
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<tr>
<td>@ 0 Mg ha(^{-1}) (M0)</td>
<td>0.939B</td>
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<tr>
<td>@ 7 Mg ha(^{-1}) (M1)</td>
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</tr>
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<td>@ 14 Mg ha(^{-1}) (M2)</td>
<td>1.337A</td>
<td>1.503A</td>
<td>1.290A</td>
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</table>

Means followed by different letters are significantly different at 5% level of probability.

**Table VII. Effect of interaction of Tillage and Mulch on N, P, K Concentration at Maize Shoots**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>N (g kg(^{-1}))</th>
<th>P (g kg(^{-1}))</th>
<th>K (g kg(^{-1}))</th>
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<tbody>
<tr>
<td></td>
<td>After 45 Days</td>
<td>After 70 Days</td>
<td>At Harvest</td>
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<tr>
<td>Deep tillage</td>
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<tr>
<td>Mulch @ 0 Mg ha(^{-1}) (M1)</td>
<td>1.45c</td>
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<td>0.8633e</td>
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<td>0.970f</td>
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<td>@ 7 Mg ha(^{-1}) (M0)</td>
<td>1.477a</td>
<td>1.610a</td>
<td>1.423a</td>
</tr>
<tr>
<td>@ 14 Mg ha(^{-1}) (M0)</td>
<td>1.310b</td>
<td>1.420b</td>
<td>1.250c</td>
</tr>
</tbody>
</table>

Means followed by different letters are significantly different at 5% level of probability.
kg$^{-1}$) at 70 days and deep tillage with M$_0$ (0.970 g kg$^{-1}$) at harvesting.

**Phosphorous concentration in maize shoots.** The data regarding the effect of tillage and mulch on phosphorous concentration (g kg$^{-1}$) in shoots revealed that tillage and mulch had statistically significant effect on phosphorous concentration in maize shoots (Table VI). Tillage systems affected non-significantly at 45 days and significantly at 70 days and at harvest. The maximum phosphorous concentration in shoots of maize was observed in deep tillage (0.169 g kg$^{-1}$) and minimum in conventional tillage (0.159 g kg$^{-1}$) at 70 days and at harvest. Maximum phosphorous concentration was observed in conventional tillage (0.128 g kg$^{-1}$) and minimum in deep tillage (0.117 g kg$^{-1}$). Mulch levels affected significantly at all three levels of observation. Maximum P concentration in shoot of maize was observed in M$_1$ (0.204 g kg$^{-1}$), followed by M$_2$ (0.185 g kg$^{-1}$) and minimum in M$_0$ (0.174 g kg$^{-1}$) at 45 days. The similar results were found at harvest. But at 70 days, mean maximum P concentration in shoot was observed in M$_1$ (0.155 g kg$^{-1}$), followed by M$_2$ (0.187 g kg$^{-1}$) and minimum in M$_0$ (0.151 g kg$^{-1}$). These findings are in agreement with Acharya and Sharma (1994) that mulched treatments show significantly greater total uptake of nitrogen, phosphorus and potassium than corresponding unmulched ones. The interactive effect of tillage and mulch affected significantly at 45 days and at harvest (Table VII). Maximum P concentration was observed in deep tillage with M$_1$ (0.226 g Kg$^{-1}$) at 45 days, deep tillage with M$_2$ (0.196 g kg$^{-1}$) at 70 days and conventional tillage with M$_1$ (0.16 g kg$^{-1}$) at harvest. Similarly, minimum P concentration was observed in conventional tillage with Mo (0.165 g kg$^{-1}$) at 45 days, conventional tillage with M$_1$ (0.148 g kg$^{-1}$) at 70 days and deep tillage with M$_0$ (0.09 g kg$^{-1}$) at harvest.

**Potassium concentration in maize shoots.** The data regarding the effect of tillage and mulch on potassium concentration (g kg$^{-1}$) in maize shoots at 45 and 70 days after sowing and at maturity are presented in Table VI. Tillage systems affected non-significantly at all three observations. Maximum K concentration was observed in conventional tillage (1.98 g kg$^{-1}$) at 45 and minimum in deep tillage (1.84 g kg$^{-1}$) at 70 days after sowing. But at harvest, maximum K concentration was recorded in deep tillage (1.68 g kg$^{-1}$) and minimum in conventional tillage (1.60 g kg$^{-1}$). Iqbal et al. (2005) reported that tillage methods significantly increased K content in shoots only, while their effect on N and P content in shoot was non-significant. Mulch levels affected non-significantly, maximum K concentration in maize shoots was observed in M$_1$ (2.00 g kg$^{-1}$) and minimum in M$_0$ (1.842 g kg$^{-1}$) at 45 days. The similar trend was observed at harvest. But at 70 day after sowing, maximum K concentration in maize shoots was observed in M$_2$ (1.89 g kg$^{-1}$) and minimum in M$_0$ (1.74 g kg$^{-1}$). The interactive effect of mulch and tillage was found non-significant on K concentration in maize shoots (Table VII). Acharya and Sharma (1994) also reported that mulched showed significantly greater total uptake of nitrogen, phosphorus and potassium than un-mulched ones.

**CONCLUSION**

Mulch and tillage significantly affected the soil physical properties and growth of maize as it increased soil moisture contents, organic matter contents, plant height, grain yield and decreased bulk density and soil strength. Soil moisture and organic matter contents were maximum, while soil strength was minimum in deep tillage. Interaction between tillage and mulch levels significantly affect soil physical properties and growth of maize, while non-significant for bulk density and plant height. Tillage significantly affected the N and P concentration in maize shoots, while effect on K concentration was non-significant. Mulch significantly increased N and P concentration in maize shoots and its effect on K concentration was non-significant. Interactive effect of mulch and tillage was statistically significant in case of N and P concentration but non-significant in case of K concentration.

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