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# TILLAGE PRACTICES AND NITROGEN APPLICATION INFLUENCED SOIL PHYSICAL PROPERTIES AND WHEAT PRODUCTION

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## ABSTRACT

Tillage practice and N management was hypothesized to play a significant role in crop production by influencing soil physical properties. Present field experiment was conducted to assess the effect of different tillage practices and nitrogen rates on soil physical properties and growth of wheat crop. Three tillage practices [conventional (four ploughing + one planking); reduced (two ploughing + one planking); and zero (no ploughing and no planking)] and four N rates [control; 75 kg N $ha^{-1}$**;** 150 kg N $ha^{-1}$; and 200 kg N $ha^{-1}$] were imposed in all possible combinations in a split plot randomized complete block design. Tillage practices significantly affected grain and straw yields with maximum yields were achieved in conventional tillage than reduced and zero tillage practices. Application of N also significantly affected grain and straw yields. Maximum grain yield was recorded when either 150or 200 kg N was applied $ha^{-1}$ under conventional tillage. Root growth was also influenced by tillage practices and it was increased with increasing tillage intensity. Nitrogen application significantly increased root length up to recommended rate. Maximum N in seed and straw was observed under conventional tillage and it increased with increasing N rates. Soil properties such as bulk density, total porosity and organic C were also significantly affected by different tillage practices with maximum values at conventional tillage practice. It is concluded that conventional tillage improved crop yield as compared to zero tillage and a rate of 150 kg N $ha^{-1}$ is suitable for optimum yield with the said tillage practice. The results might vary in long term experiments; therefore, further investigations are required to elaborate these findings.

**Keywords:** Nitrogen, soil property, tillage practices, wheat.

## INTRODUCTION

Nitrogen is one of the main nutrients required by higher plants in large quantities. Adequate supply of N enhanced root growth (Stone, 2001), utilization of carbohydrates and uptake of other nutrients (Nylce and Weil, 2002). Nitrogen applied in mineral form and through organic source, improved protein contents in

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grain (Iftikhar *et al.*, 1999). Whereas, response of applied N rates and its availability from soil may depend on soil tillage practice.

Tillage is the modification in soil structure by mechanical manipulation which results in changing the soil physical and chemical properties. The objectives of the tillage are to reduce soil erosion, loose soil for improved root growth, removal of weeds and mixing of crop residues into soil to increase soil fertility (Shamsuddin and Bhatti, 2001). Soil physical properties such as soil moisture, water infiltration rate, aeration, drainage, bulk density, water holding capacity and water stable aggregates are influenced by tillage practices. Conventional tillage involve primary and secondary tillage practices like to lift and invert the soil, loosening of soil to incorporate animal and plant residues in the plough layer, harrowing to remove the weeds and to break the clods for the preparation of suitable seedbed (Nylce and Weil, 2002).There are several benefits of conventional tillage; however, conventional tillage is not considered a sustainable approach.

The soil serves as a component of ecosystem and it may be degraded when certain changes occur in the response of land use and management. So to achieve better yield through sustainable agriculture, efforts must be made to conserve the natural resources. One of such efforts is conservation tillage. Conservation tillage reduces the soil disturbance and improves soil productivity. During recent years, conservation or reduced tillage is becoming popular as it reduces the erosion and supports water conservation as well along with its other benefits. Appropriate tillage practices are those which avoid the disturbance of soil properties and produce better crop yield on sustainable bases (Lal, 1993). In long term, conservation tillage practices result in high soil organic matter, low sedimentation and chemical runoff to the streams, more soil moisture and nutrient enriched soils in conservation tillage as more beneficial microbes are present in the soils to decompose organic matter, and less release of $CO_2$ in the atmosphere which ultimately results in high crop yield as compared to the conventional tillage (Singh and Malhi, 2006).

Tillage modifies the soil structure through mechanical manipulation so bulk density, soil strength and other physical properties of the soil are greatly affected (Ishaq *et al.*, 2003; Vogeler *et al.*, 2006). The bulk density of the soil does not affect the crop growth directly but creates the conditions which affect the crop yield. Such conditions include changes in soil strength due to compaction, and pore size distribution which resists root penetration and decrease in infiltration rate in dry conditions mostly (Pedrotti *et al.*, 2005; Vogeler, 2000). Keeping in view the above discussion, the present study was aimed to compare the conventional tillage with conservation tillage under the different levels of N affecting the physical properties of a calcareous soil in relation to wheat yield.

## MATERIALS AND METHODS

A field experiment was conducted at Research Area of Faculty of Agricultural Sciences and Technology, Bahaudin Zakarya University, Multan (Pakistan) during 2011-12 to evaluate the effects of different tillage practices and N rates on plant growth and physical properties of a calcareous soil.

Before sowing, composite samples of soil were randomly collected from experimental sites (separately from 0-15 cm and 15-30 cm depths) and analyzed for different physico-chemical properties. Soil texture was loam as measured by hydrometer method (Moodie *et al.,* 1959); $pH_S$ was 7.93; EC of saturated soil paste extract was 2.89 dS $m^{-1}$; organic C was 2.21 g $kg^{-1}$ soil; and $CaCO_3$ was 46 g $kg^{-1}$ soil.

After harvest of rice stubbles, experimental area was tilled for wheat (cv. Seher-2006). Wheat was sown in 7.8 m × 6.0 m plots with row-to-row distance of 0.3m. The recommended seed rates of 150 kg $ha^{-1}$ were sown. Three tillage practices [conventional (four ploughings + one planking); reduced (two ploughings + one planking); and Zero (no ploughing and no planking)] and four N rates [Control; 75 kg N $ha^{-1}$**;** 150 kg N $ha^{-1}$; and200 kg N $ha^{-1}$] were imposed in all possible combinations and triplicate treatments were arranged in a randomized complete block design (RCBD) under split plot layout. Tillage systems were kept in main plots and N rates were kept in sub-plots.

Rates of N, as mentioned above for various treatments, were applied in three equal splits, one each at: sowing, first irrigation and second irrigation. Phosphorus (100 $kgha^{-1}$) was applied as basal dose of triple super phosphate. Crop was irrigated with canal water and weeds were manually removed at different crop growth stages.

At tillering and booting, ten plants were selected randomly and uprooted carefully with the help of stainless steel core sampler. Soil was gently washed to separate roots. Root length was measured according to Tennant’s line intercept method (Tennant, 1975). Whole above ground plant material was harvested at physiological maturity. An area of 1 $m^2$ was randomly selected for the harvest. Sun dried bundles were threshed manually and yields were measured. Sub samples of grains and straw were digested in concentrated sulfuric acid, followed by distillation and titration to determine concentration of N in plant tissues (Jackson, 1962). After crop harvest, composite soil samples from each plot (separately for 0-15 cm and 15-30 cm depths) were collected to measure soil bulk density [by core method], soil porosity [by utilization the data of bulk density and particle density], soil aggregate stability [by wet sieving of different sized aggregate (Kemper and Rosenau, 1986)] and soil organic C [by oxidation with potassium dichromate (Nelson and Sommers, 1996)].

## RESULTS

### Root length and crop yield

Tillage practice, N rate and their interaction significantly ($P \leq 0.05$) affected root length of wheat crop (Table 1). Root length was maximum in conventional tillage when supplied with 200 kg N $ha^{-1}$. At booting stage, root length was non-significantly different between the treatments of 200 and 150 kg N ha$^{-1}$. This was also true at tillering stage except in reduced tillage practice. For various tillage practices; however, root length increased significantly with the application of N up to 150 kg N ha$^{-1}$. In general, root length was minimum in zero tillage and maximum in conventional tillage.

On average, increasing either of N rate or tillage activity significantly ($P \le 0.05$) increased grain and straw yields of wheat (Fig. 1). Moreover, interaction of N rate and tillage practice was also significant for grain and straw yields. The grain yield was highest in conventional tillage when applied with 200 kg N ha$^{-1}$ which was statistically non-significant to that achieved at 150 kg N ha$^{-1}$ with the same tillage practice producing a yield of 5.65 Mg ha$^{-1}$ and 5.47 Mg ha$^{-1}$, respectively. Straw yield was also maximum (8.41 Mg ha$^{-1}$) at 200 kg N ha$^{-1}$in conventional tillage. At various N rates, grain and straw yields were significantly greater in conventional tillage as compared with other applied tillage practices.

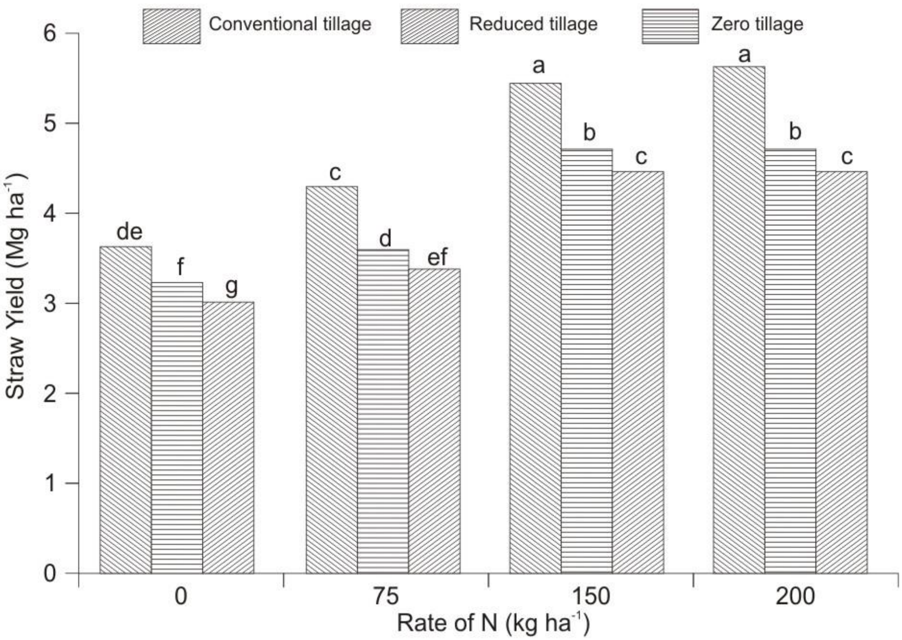
## Concentration of nitrogen in plant tissues

Tillage practice and N rate had significant ($P \le 0.05$) effects on N concentration in grains and straw of wheat plants (Table 3). Grain and straw N concentration was greater in conventional tillage as compared to reduced and zero tillage. However, much of the variation in N concentration was explained by N rates. Concentration of N in plant tissues increased with the incrementalN rates and ranged from 1.33% at control N rate to 1.46% at 200 kg N ha$^{-1}$.

## Soil physical properties

Only tillage practices significantly affected soil bulk density and soil porosity (Table 3). For the surface soil layer, bulk density and soil porosity were significantly lower in conventional tillage when compared to reduced and zero tillage practices. However, soil bulk density and soil porosity achieved in conventional tillage was similar to that achieved in reduced tillage. Nevertheless, bulk density and soil porosity of sub-surface soil layer in zero tillage was significantly greater that in conventional tillage.

Achieved results clearly indicated that tillage practice and N rates had non-significantly ($P \le 0.05$) affected water stable aggregates (data not shown). Similarly, the interaction effect of both the factors was also found to be non-significant. However, tillage practices and N rates ($P \le 0.05$) had significant effect on soil organic carbon. The mean maximum value (2.77 g kg$^{-1}$) was observed in conventional tillage followed by reduced tillage (2.65 g kg$^{-1}$) and no tillage (2.56 g kg$^{-1}$). Comparison of means indicated organic C was significantly more in conventional tillage as compared to zero tillage. However, it was statistically non-significant to reduced tillage. With respect to N rates, maximum mean organic C (2.79 kg kg$^{-1}$) was achieved at 150 kg N ha$^{-1}$ with about 13% increase over control treatment of N. However, organic matter was not significantly different at 150 kg N ha$^{-1}$ and 200 kg N ha$^{-1}$.



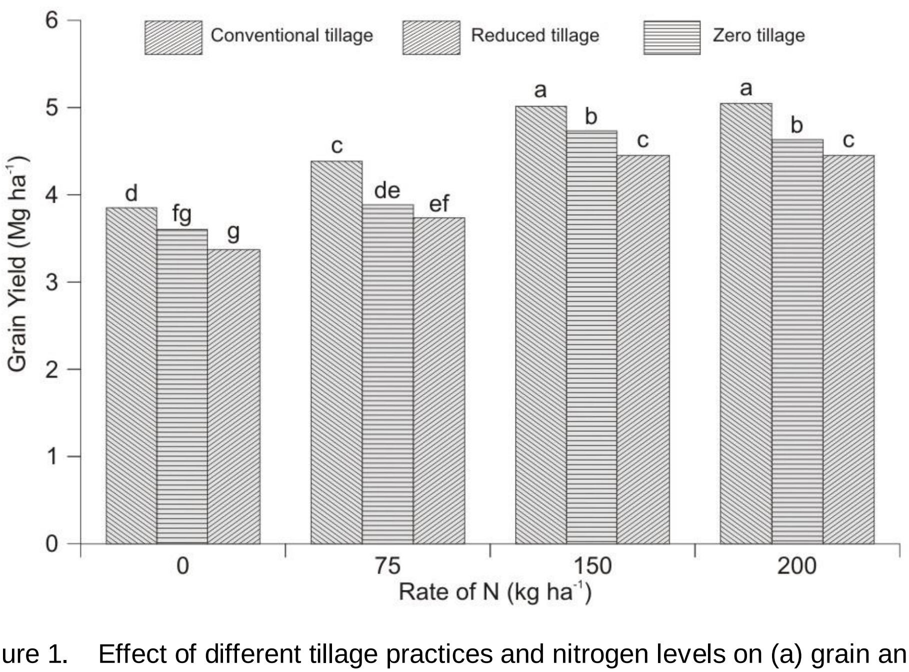




Figure 1. Effect of different tillage practices and nitrogen levels on (a) grain and (b) straw yields of wheat.

## DISCUSSION

Increase in root length underneath conventional tillage (Table 1) might be due to proper soil conditions which exploit more soil for better root growth. Parallel results were measured by Ishaq *et al.* (2003) that compaction condensed root density thus restraining the volume of the soil for less nutrient and water uptake.) Nitrogen application improved root density, root weight density and root length that contributed towards improved grain yield (Ibrahim *et al.* 2010; Rahman, 2000). Role of N in crop yield is well known (Bazitov *et al.*, 2000; Khan *et al.,* 2000; Patil and Intal, 2002; Hameed *et al.*, 2003). Increase in straw yield with increasing N fertilizer may be attributed towards better vegetative growth of the plants. Similar findings were observed by Allam (2003) and Al-Abdulsalam (1997). They also suggested that straw yield increased significantly under higher nitrogen rates. Nitrogen application results in increased N concentration in plant tissues (Ibrahim *et al.*, 2010). Nitrogen uptake also depends on tillage as poor soil conditions and minimum root growth (Ishaq *et al.*, 2001). Increase in grain and straw yield under conventional tillage as compared to reduced and zero tillage practices (Fig. 1) might be due to availability of proper soil conditions and proper crop establishment (Lopez, 2007; Khan *et al.*, 2011).

Table 1. Effect of different tillage practices and nitrogen levels on root length at different wheat growth stages

| Tillage system | Rates of N (kgha$^{-1}$) | | | | Means |
|---|---|---|---|---|---|
| | 0 | 75 | 150 | 200 | |
| **Root length at tillering stage (cm)** | | | | | |
| Conventional | 9.66 de | 10.61 c | 11.88 a | 11.90 a | 11.01 A |
| Reduced | 8.78 f | 9.77 d | 10.39 c | 10.97 b | 10.11 B |
| Zero | 8.54 f | 9.44 e | 10.47 c | 10.51 c | 9.74 C |
| Means | 8.99 C | 9.94 B | 10.91 A | 11.13 A | - |
| **Root length at booting stage (cm)** | | | | | |
| Conventional | 11.63 de | 12.83 c | 14.75 a | 14.86 a | 13.52 A |
| Reduced | 10.80 f | 11.78 d | 13.06 bc | 13.15 b | 12.19 B |
| Zero | 10.74 f | 11.39 e | 12.95 bc | 13.00 bc | 11.92 C |
| Means | 11.06 C | 12.00 B | 13.59 A | 13.67 A | - |

Values with similar letters are non-significantly ($P\leq0.05$) different.

Tillage intensity affected soil bulk density and soil porosity (Glab and Kulig, 2008). The tillage also relates with soil structure and soil compaction. Howeler *et al.* (1993) has reviewed tillage systems for tuber crops and concluded that tillage influences various physical properties of soil that may differentially affect different type of crops. While, bulk density and porosity often does not relate with application of fertilizers (Hossain *et al.,* 2004). In present study, tillage practices had no effect on aggregate stability. However, Filho *et al.* (2001) and Jia *et al.* (2012) have related water stable aggregates with tillage practices in long term studies. The contradictory result in current study might be owing to that organic C contents and soil aggregation increased significantly over a long period (Abid and Lal, 2008); however, only resulted in non-significant changes in present short term experiment (Table 3).

Table 2. Effect of different tillage practices and nitrogen levels on nitrogen concentration in grains and straw of wheat crop.

| Tillage System | Rates of N ($kgha^{-1}$) | | | | Means |
|---|---|---|---|---|---|
| | 0 | 75 | 150 | 200 | |
| **Grain N concentration (%)** | | | | | |
| Conventional | 1.38$^{NS}$ | 1.45 | 1.55 | 1.60 | 1.49 A |
| Reduced | 1.32 | 1.35 | 1.42 | 1.45 | 1.38 B |
| Zero | 1.30 | 1.34 | 1.40 | 1.42 | 1.36 C |
| Means | 1.33 D | 1.38 C | 1.45 B | 1.49 A | - |
| **Straw N concentration (%)** | | | | | |
| Conventional | 0.27$^{NS}$ | 0.34 | 0.44 | 0.46 | 0.38 A |
| Reduced | 0.24 | 0.30 | 0.36 | 0.37 | 0.32 B |
| Zero | 0.18 | 0.22 | 0.26 | 0.26 | 0.23 C |
| Means | 0.23 C | 0.29 B | 0.35 A | 0.36 A | - |

Values with similar letters are non-significantly ($P≤0.05$) different; $^{NS}$ Non-significant at $P≤0.05$.

Table 3. Effect of different tillage practices and nitrogen levels on soil bulk density, soil porosity and soil organic carbon.

| Tillage system | Rates of N ($kgha^{-1}$) | | | | Means |
|---|---|---|---|---|---|
| | 0 | 75 | 150 | 200 | |
| **Bulk density ($Mg\ m^{-3}$) of surface layer (0–15 cm depth)** | | | | | |
| Conventional | 1.47$^{NS}$ | 1.48 | 1.45 | 1.47 | 1.47 B |
| Reduced | 1.53 | 1.54 | 1.52 | 1.53 | 1.53 A |
| Zero | 1.56 | 1.55 | 1.53 | 1.55 | 1.55 A |
| Means | 1.52$^{NS}$ | 1.52 | 1.51 | 1.52 | |
| **Bulk density ($Mg\ m^{-3}$) of subsurface layer (15–30 cm depth)** | | | | | |
| Conventional | 1.54$^{NS}$ | 1.55 | 1.53 | 1.54 | 1.54 B |
| Reduced | 1.56 | 1.56 | 1.59 | 1.58 | 1.57 AB |
| Zero | 1.61 | 1.61 | 1.62 | 1.59 | 1.61 A |
| Means | 1.57$^{NS}$ | 1.57 | 1.58 | 1.57 | |
| **Porosity (%) of surface layer (0–15 cm depth)** | | | | | |
| Conventional | 44.28$^{NS}$ | 44.15 | 45.00 | 44.53 | 44.50 A |
| Reduced | 42.18 | 41.76 | 42.64 | 42.18 | 42.17 B |
| Zero | 41.01 | 41.26 | 41.89 | 41.38 | 41.38 B |
| Means | 42.47$^{NS}$ | 42.39 | 43.19 | 42.68 | |
| **Porosity (%) of subsurface layer (15–30 cm depth)** | | | | | |
| Conventional | 41.64 $^{NS}$ | 41.01 | 41.89 | 41.38 | 41.84 A |
| Reduced | 40.89 | 40.88 | 39.49 | 40.00 | 40.31 AB |
| Zero | 38.73 | 38.86 | 38.48 | 39.75 | 38.95 B |
| Means | 40.42$^{NS}$ | 40.25 | 39.95 | 40.38 | |
| **Organic carbon ($g\ kg^{-1}$) in surface layer (0–15 cm depth)** | | | | | |
| Conventional | 2.67$^{NS}$ | 2.67 | 2.88 | 2.89 | 2.77 A |
| Reduced | 2.43 | 2.61 | 2.78 | 2.73 | 2.65 AB |
| Zero | 2.28 | 2.55 | 2.71 | 2.73 | 2.56 B |
| Mean | 2.46 C | 2.61 B | 2.79 A | 2.78 A | |

Values with similar letters are non-significantly ($P≤0.05$) different; $^{NS}$ Non-significant at $P≤0.05$.

Similar to present study (Table 3), Whalen (2005) observed that total C concentration was greater in conventional tillage than zero tillage. However, Ishaq *et al.* (2002) reported a non-significant change in soil organic C under different tillage systems based on field trails on wheat and cotton from 1996 to 1998.This shows that effects of tillage practices on soil organic C depends on time.

## CONCLUSION

It is concluded that conventional tillage leads to better crop growth than the no-tillage system and 150 kg N $ha^{-1}$ is suitable for optimum wheat yield in such a tillage system. However, results might vary in long term experiments and further long term investigations are required to better understand the effects of tillage systems on soil quality.

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