Research Article

# Integrated Nutrient and Tillage Management Improve Organic Matter, Micronutrient Content and Physical Properties of Alkaline Calcareous Soil Cultivated with Wheat

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**Abstract** | This study assessed the effect of shallow tillage (ST, cultivator 0-20cm) and deep tillage (DT, mold-board plough 0-40cm) and different organic and inorganic fertilizers application to wheat crop on organic matter, micro-nutrient status and physical properties of soil at the NDF Farm, the University of Agriculture, Peshawar during 2015-16. The study was planned in RCB split plot design with fertilizers; control (Farmer's practices, FP, 60-45 N-$P_2O_5$ kg $ha^{-1}$), NPK recommended dose (RD, 120:90:60 N:$P_2O_5$:$K_2O$ kg $ha^{-1}$), 5, 10, 15 and 20 t FYM alone ($FYM_{5,10,15,20}$) and 5, 10 and 15 t $ha^{-1}$ FYM in combination with 75, 50 and 25% of the recommended NPK ($INM_{5:75, 10:50, 15:25}$) in sub plot (5 * 3 $m^2$) and tillage practices (TP) in main plots. Tillage practices effect on micronutrient status was significant, however, variations in physical properties were negligible. The Zn, Cu, Fe and Mn contents were 23, 11, 38 and 33% higher in ST than DT soil, respectively. Significantly higher OM in ST than DT soil is supporting these results where in their respective regression showed $r^2$ values of 0.4, 0.22, 0.22 and 0.24 in ST and 0.24, 0.12, 0.55 and 0.33 in DT soil. The $INM_{5:75,10:50, 15:25}$ recorded significantly higher Zn (60-83%), Cu (49-55%) and Fe (55-72%) over the farmers practice and only second after sole FYM 20 t $ha^{-1}$ whilst the maximum Mn (115-145%) were observed in these treatments. The $FYM_{5,10,15,20}$ reduced the BD significantly ($p<0.01$) by 7-12% and increased the porosity by 9-14%, saturation water by 9-20% and available water by 19-29%. However the $INM_{5:75,10:50, 15:25}$, closely followed the $FYM_{5,10,15,20}$ with reduction in BD by 9-11% and increased in porosity by 11-13%, saturation water by 14-17% and available water by 25-30%. All interactions remained non-significant. These results concluded that integrated nutrient management improved the soil OM, micro-nutrients content and physical properties of soil. The deep tillage in poorly fertile soils negatively affect micro-nutrients status. Positive influence of DT on physical properties and micronutrients status as well, seems to have been superseded by high OM content in ST soil due to amendments incorporation with relatively small volume of soil than DT

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## Introduction

In arid to semi-arid subtropical areas, nutrient removal through crop plants, erosion and leaching combined with the unsustainable nutrient management practices on the already low fertility arable soil are resulting the negative nutrient balance in soils. Moreover, increasing the food and fiber requirements of the teeming population compel farmers to bring partially arable and marginal land under cultivation.

This brings the already scarce water resources further under pressure to the water requirements for sustainable crop production. Along with lower soil fertility, water stress is another major bottleneck for obtaining potential yield especially in the arid and semi-arid climate. However, agricultural scientists are trying for the management of both these constraints according to crop and soil requirements to obtain high yield on sustainable basis. According to some worker (Banning et al., 2008), recovery of soil organic matter content and nutritional status of the soil is critical for soil restoration and successful crop production. Fertilization amendments usually alter soil chemical attributes and nutrient status depending upon the nature, type and amount of fertilizer used. Nutrient application from a variety of sources in integrated form have been reported for improved physical properties (Barzegar et al., 2002; Hati et al., 2006; Ahmad et al., 2014) andsoil organic matter (Dolan et al., 2006; Ahmad and Khan, 2014). These not only supply essential nutrients but also increase the inorganic fertilizer use efficiency and hamper their losses as environmental hazards. Integrated approaches restore soil fertility (Ahmad and Khan, 2014) and reduces soil erosion through implementation of appropriate conservation principles (Ahmad et al., 1998).

Tillage practices affect nutrient dynamics mainly through altering soil properties and incorporation of crop residues and mineral fertilizers which in turn expedite crop growth and development by providing fair soil tilth for root growth and maximum uptake of nutrients. Tillage is considered the most effective farm activity for developing a desired soil structure. Soil tillage is influencing soil chemical characteristics, carbon sequestration and nutrient distribution (West and Post, 2002; López-Fando and Pardo, 2009; Houx et al., 2011). Minimum tillage also improve emergence, grain N and reduce moisture in wheat grain (Wiatrak et al., 2006). Both conventional and deep tillage can improve soil aeration and porosity, conserved nutrients and moisture for plants, microbes released nutrients from soil micro flora pool for crops and thus ultimetry increase crop yield (Wang and Dalal, 2006). On the other hand, no significant effect of tillage practices on gross and net N transformation rates was observed by Gomez-Rey et al. (2012) and suggested that tillage practices had a limited effect on N transformation rates in this soil and that $NO_3$-N leaching could decrease under conservation tillage. Rahman et al. (2008) reported that physical properties of soil, pH, micro nutrients and C: N ratio was significantly higher in deep tilled plots compared to conventional or no tilled plots. Several studies have reported that integrated water and nutrient management is a sound option for soil productivity improvement (Sanchez and Jama, 2002). Keeping in view the importance and long term sustainability and the confirmed benefits of the integrated nutrient and tillage management, this study was carried out on wheat crop during 2015-16 to assess the effect of integrated nutrient and tillage management on soil organic matter, micronutrient status and physical properties under alkaline calcareous conditions. The information sought in this study is lacking and the findings will surely add a new drop to the existing ocean of knowledge.

**Table 1:** *Physico- chemical properties of the soil under study.*

| Properties | Units | Concentration |
|---|---|---|
| Sand | % | 30 |
| Silt | % | 56.4 |
| Clay | % | 13.6 |
| Textural class | - | Silt loam |
| pH (1:5) | - | 7.8 |
| Electrical conductivity(EC) | d $Sm^{-1}$ | 0.52 |
| Lime | % | 16 |
| Organic matter content | % | 0.72 |
| AW H C | % | 14 |
| Bulk density | g $cm^{-3}$ | 1.24 |
| Mineral Nitrogen | mg $kg^{-1}$ | 14 |
| AB-DTPA extractable P | mg $kg^{-1}$ | 2.2 |
| AB-DTPAextractable K | mg $kg^{-1}$ | 62 |

## Materials and Methods

This study assessed the effect of shallow (cultivator 0-20cm) and deep (moldboard plough 0-40 cm) on the performance of different organic and inorganic fertilizers in restoration of soil micro-nutrient status and soil physical properties of low fertility intensively cultivated soil in New developmental farms of the University of Agriculture Peshawar during 2015-16. Characteristics of the study site are given in Table 1. The study was conducted in RCB split plot design in which the fertilizer treatments; control (Farmer's practices (FP) 60-45 N-$P_2O_5$ kg $ha^{-1}$), NPK recommended (RD) (120:90:60 N:$P_2O_5$:$K_2O$ kg $ha^{-1}$), 5, 10, 15 and 20 t FYM alone ($FYM_{5,10,15,20}$) and 5, 10 and 15 t $ha^{-1}$ FYM in combination with 75, 50 and 25% of the recommended NPK ($INM_{5:75,\ 10:50,\ 15:25}$) were applied in sub plot (5 * 3 $m^2$) whilst tillage practices were to main plots.

Plots were sown with wheat (*Triticum aestivum* L.) variety (Ata Habib) accommodating 10 rows, each row was 5m long with row-row distance of 30 cm. calculated amounts of farmyard manure for each treatment were applied one month before sowing and respective tillage practices were carried out in the designated plots, whereas inorganic nutrient were incorporated at the time of sowing. The sources of NPK were urea, DAP and SOP, respectively whilst FYM (Table 2) was obtained from the University Dairy farm. Nitrogen was applied in two splits, one at sowing time and other at tillering stage. The recommended wheat variety was sown at the rate of 120 kg $ha^{-1}$ at optimum soil moisture conditions. Sowing was done on November 15, 2015 and harvested on May 5, 2016. Normal recommended cultural practices were followed throughout the growing session.

**Table 2:** *Nutrient status of the farm yard manure used in the experiment.*

| Parameter | Unit | FYM |
|---|---|---|
| Nitrogen | % | 0.6 |
| Phosphorous | % | 0.21 |
| Potassium | % | 0.3 |
| Zn | % | 0.06 |
| Cu | % | 0.02 |
| Fe | % | 0.09 |
| Mn | % | 0.05 |

Post-harvest soil samples were collected from each plot and analysed after proper preparation. Depth of the samples was 0-20cm after the harvesting of crop plants. Micron-nutrients in soil sample were determined by the method as described by Soltanpour and Schawab (1977). In brief; a 10 g soil sample was added with 20 ml AB-DTPA solution and shacked through reciprocating shaker for 15 minutes while keeping the flasks open to let $CO_2$ evolve in the air. The solution was extracted with whatman number 42 filter paper and extracts were directly read for Zn, Cu, Fe and Mn with Atomic Absorption Spectro-photometer Perkin Elmer Model 2380, USA, using the respective cathode lamp for each element. Soil organic matter content was determined with Nelson and Sommers (1996) procedures. In brief, 1 g soil's (S) organic matter was oxidized with excess (10 mL) of 1 N $K_2Cr_2O_7$ in the presence of $H_2SO_4$ (20 mL). A 200 mL distilled water was added and titrated against 0.5 N $FeSO_4.7H_2O$ solution in the presence of ortro-phenopthroline indicator. A blank (B) was run and the organic matter was calculated as; % OM = (S-B) *0.69/wt of the sample. Soil pH and EC were determined in 1:5 soil: water suspension by pH meter (Mclean, 1982) and EC meter (Rhoades, 1982), respectively. Relevant procedures for soil texture (Koehler et al., 1984), lime content (US Salinity Lab Staff, 1954), mineral N (Mulvany, 1996), Total N (Bremner and Mulvaney, 1982), extractable P and K (Soltanpour and Schawab, 1977) in soil sample andtotal P, K and micronutrients in FYM (Kue, 1996) were adopted. Phosphorus content in soil extracts was measured by Spectro-photometer using wavelength of 880 nm and K content was measured using flam photometer.

Soil bulk density was determined through Black and Hartge (1984) procedure using 100 $cm^3$ steel core for in situ sampling, drying in oven and using the formula:($\rho_b$) = Ms/Vt where Ms = Mass of dry soil, Vt = total volume. Soil total porosity (%) was determined through calculation using the procedures of Danielson and Sutherland (1986); Porosity = (100 − $\rho_b$/$\rho_p$) x 100. *where* $\rho_b$= bulk density, $\rho_p$= partical density (2.65 Mg $m^{-3}$). Soil percent saturation water was determined using core samples and allowing them to absorb water through capillary rise for 24 hours. After complete saturation, saturated samples were weighed, then oven dried and weighed again. Saturated water percentage was calculated by the given formula (Gardner, 1986);

$$Saturation\ water\ percentage\ (sPw) = \frac{Sw - Dw \times 100}{Dw}$$

Where;
Sw: Saturated weight of the core sample; Dw: Oven dry weight of core sample.

Pressure membrane apparatus was used to determine the extractable water at 0.3 and 15 bar pressure (Raza et al., 2003). Available water holding capacity was thus calculated as;

$$AWHC\ (\%) = \frac{\omega_{fc} - \omega_{pwp} \times 100}{Dry\ weight\ of\ soil}$$

$\omega_{fc}$: Water content at 0.3 bar (field capacity); $\omega_{pwp}$: Water content at 15 bar (permanent wilting point).

The collected data on different soil properties and crop yield will be analysed statistically using RCBD split-plot with three replications using MS Excel and statistical package MStat C (Gomez and Gomez, 1984).

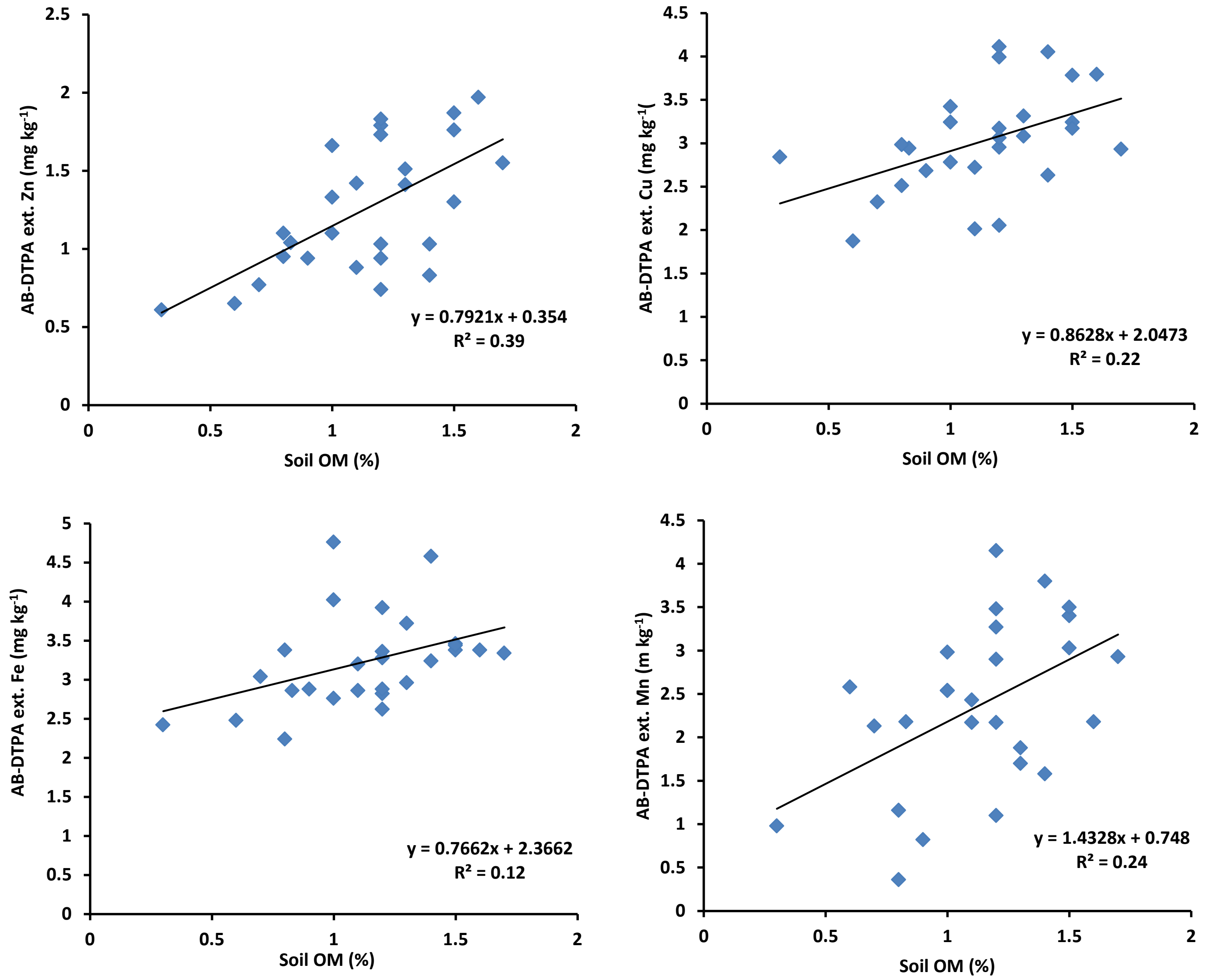


**Figure 1:** *AB-DTPA extractable Zn, Cu, Fe and Mn correlation with soil OM in shallow (0-20 cm) tilled soil.*

Significantly different treatments were compared using LSD test of significance at p<0.05 according to Steel and Torri (1980).

## Results and Discussion

Extractable Zn in soil was significant amongst the fertilizer treatments ($p<0.01$) and tillage practices ($p<0.05$) extractable . Amongst the treatments, the sole 20 t ha$^{-1}$ FYM was the maximum in extractable Zn with securing 100% increase over the farmers practice. However, the sole application of 15 t ha$^{-1}$ FYM its shared application at variable rates (5, 10 and 15 t ha$^{-1}$) with mineral NPK (75, 50 and 25% of the recommended dose, respectively) secured significantly higher with 63, 60, 83 and 80% more extractable Zn over the farmers practice and thus remained statistically similar with the maximum value (Table 3). The role of the recommended NPK and the sole FYM 5 t ha$^{-1}$ with 17 and 36% increase in extractable Zn was statistically similar to the farmers practice. The sole 10 t ha$^{-1}$ FYM secured 50% increase in extractable Zn and remained significantly higher over the farmers practice but significantly lower over the sole FYM 20 t ha$^{-1}$ or the shared applications of FYM and mineral fertilizers at variable rates.

The extractable Zn in the deeply tilled soil was 23% lower than the extractable Zn values in the shallow tilled soil (Table 3). These results are confirmed well by regressing the extractable Zn over the soil OM in the respective depths where the extractable Zn showed a significant dependence ($R^2$ = 0.4) over the soil OM values in the shallow (Figure 1) and deeply tilled ($R^2$ = 0.24, Figure 2) soil. Both in the shallow (Figure 3) and deep (Figure 4) tilled soils, as the soil OM level increases, so is the content of extractable Zn. There was no interaction between fertilizer treatments and tillage practices to affect extractable Zn in soil.

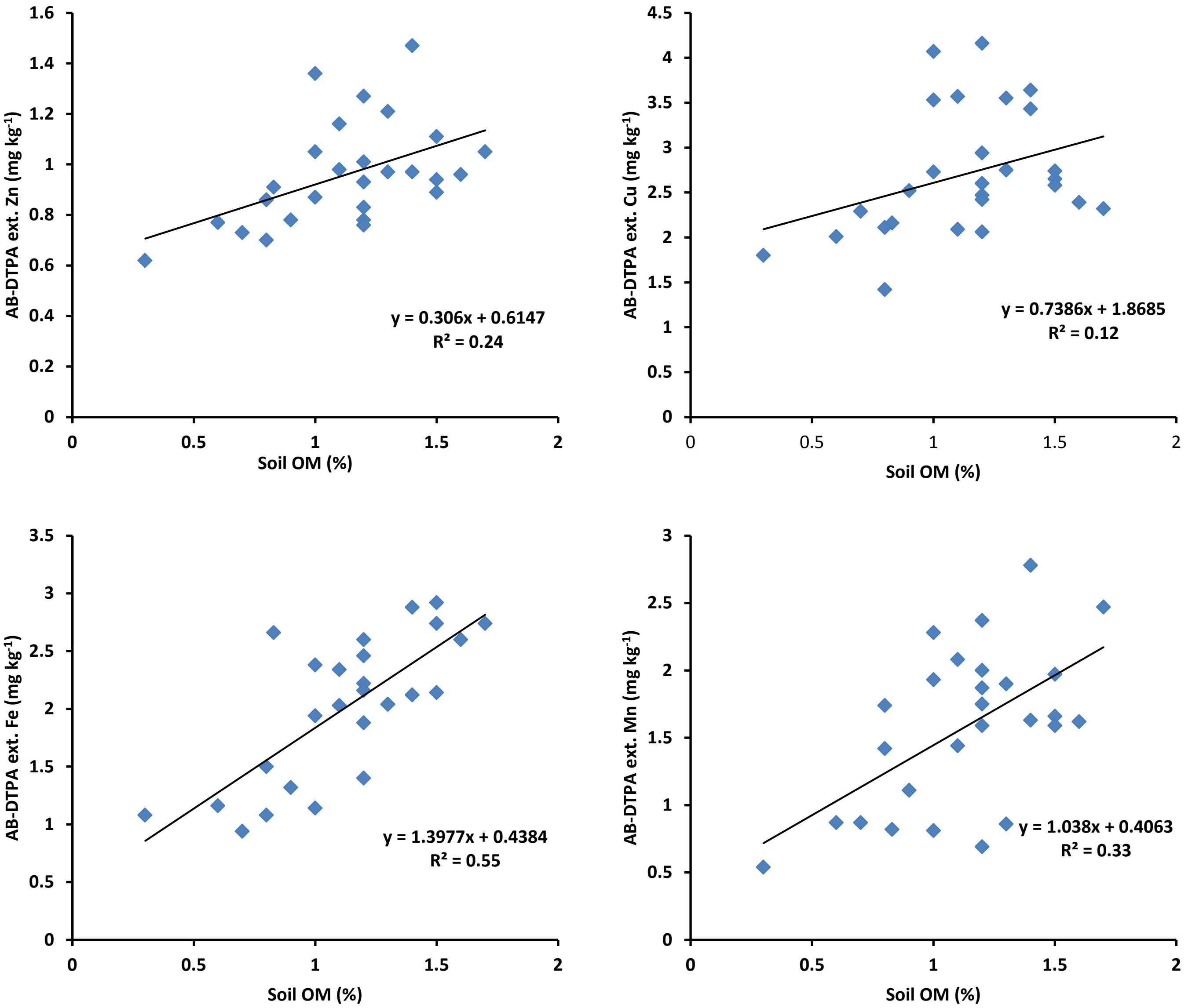


**Figure 2:** *AB-DTPA extractable Zn, Cu, Fe and Mn correlation with soil OM in deep (20-40 cm) tilled soil.*

**Table 3:** *Effect of fertilizer treatments and tillage practices on micro-nutrients in soil.*

| Treatments | Zn | Cu | Fe | Mn |
|---|---|---|---|---|
| | (mg kg$^{-1}$) | | | |
| Control | 0.71 e | 2.08 c | 1.81 c | 1.13 c |
| NPK rec. | 0.84 de | 2.36 c | 2.25 cd | 1.45 cd |
| 5 t FYM | 0.97 cde | 2.63 bc | 2.36 cd | 1.44 cd |
| 10 t FYM | 1.08 bcd | 2.94 ab | 2.5 bc | 1.74 bcd |
| 15 t FYM | 1.17 abc | 2.92 ab | 2.63 abc | 1.92 bc |
| 20 t FYM | 1.43 a | 3.35 a | 3.10 a | 2.22 ab |
| 5 t FYM + 75% NPK rec. | 1.15 abc | 3.17 ab | 2.81 abc | 2.42 ab |
| 10 t FYM + 50% NPK rec. | 1.31 ab | 3.22 a | 3.06 ab | 2.76 a |
| 15 t FYM + 25% NPK rec. | 1.29 ab | 3.10 ab | 3.11 a | 2.7 a |
| LSD $_{(p<0.05)}$ value | 0.29 | 0.55 | 0.6 | 0.74 |
| Shallow Tillage (0-20 cm) | 1.25 a | 3.02 | 3.23 | 2.368148 |
| Deep Tillage (0-40 cm) | 0.96 b | 2.70 | 2.02 | 1.58 |
| T.Test$_{(0.05)}$ Prob. | 0.03 | 0.15 (ns) | 0.000 | 0.02 |
| F x T | ns | ns | ns | ns |

*Control (F. Pract. 60-45 NP kg ha$^{-1}$), NPK rec. (120:90:60 kg ha$^{-1}$), OM (Organic matter), incr. (increase over control), Means followed by same letters are not significantly different.*

Based on combined data over tillage practices, soil extractable Cu was highly significant (p<0.01) whilst based on combined data over treatments, tillage practices were non-significant in extractable Cu content. Amongst the treatments, the sole 20 t ha$^{-1}$ FYM and the shared 10 t ha$^{-1}$ FYM and inorganic 50% NPK were the maximum and significantly higher in extractable Cu with 61 and 55% increase over the

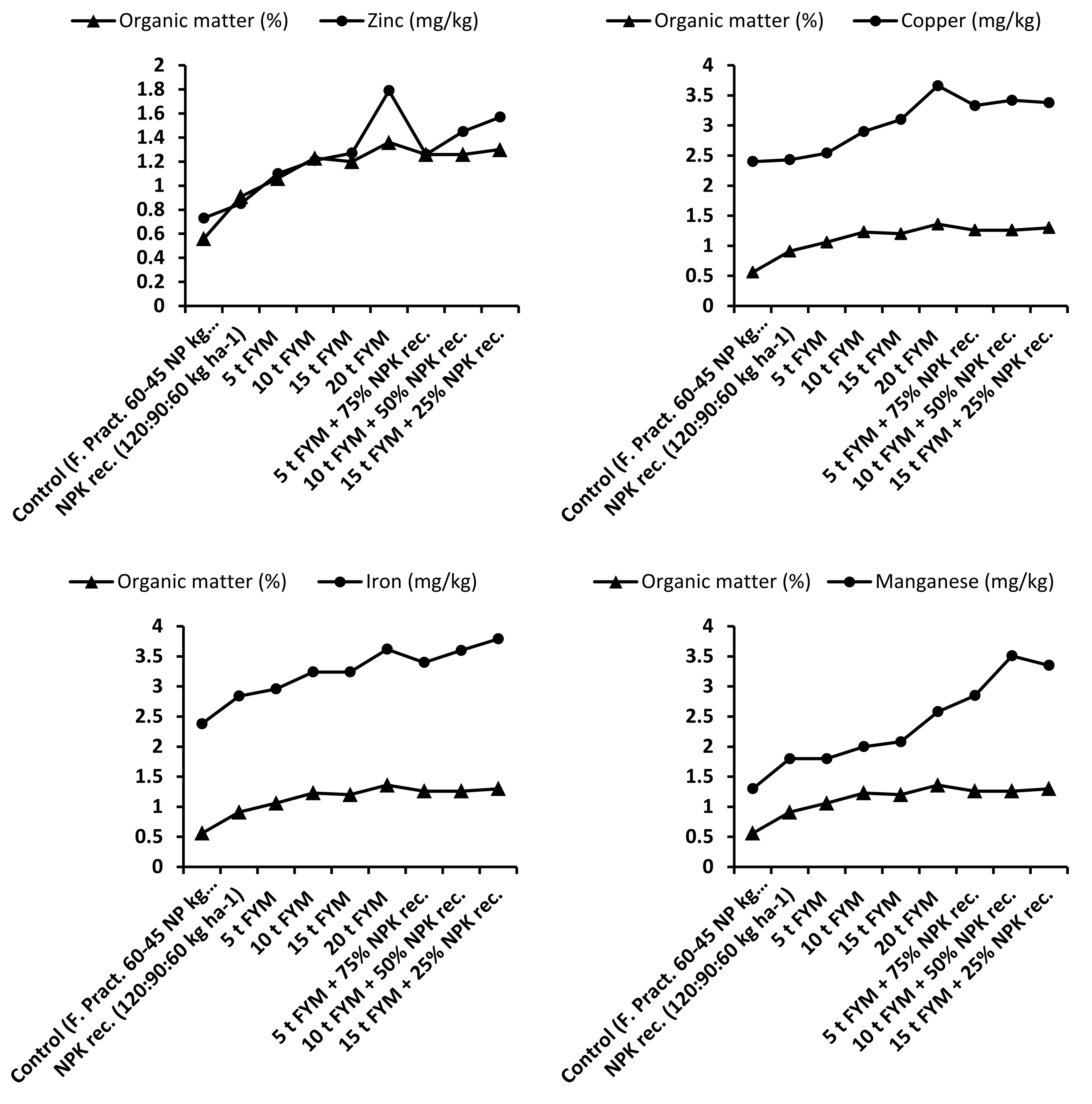


**Figure 3:** *Graph showing trend in micronutrient content with respect to variation in soil organic matter in shallow (0-20 cm) tilled soil.*

farmers practice and 47 and 41% increase over the recommend NPK dose and 32 and 28% increase over the sole 5 t ha$^{-1}$ FYM dose (Table 3). Overall contribution of the sole 15 and 20 t ha$^{-1}$ FYM and its hared application with inorganic NPK at various rates were found significant over the farmers practice and the recommended NPK dose both non-significant among themselves.

It was also observed that extractable Cu in the deeply tilled soil was 11% lower than the extractable Cu values in the shallow tilled soil (Table 3). when correlated with the soil OM content at their respective depth, $R^2$ values were 0.22 and 0.12 for the shallow and deep tilled soils, respectively (Figure 1 and 2). Trend line in both in the shallow (Figure 3) and deep (Figure 4) tilled soils showed increase in soil extractable Cu with the increase in soil OM level. There was no interaction between fertilizer treatments and tillage practices to affect extractable Cu in soil.

Based on combined data over tillage practices, soil extractable Fe was highly significant ($p<0.01$) and based on combined data over treatments, tillage practices

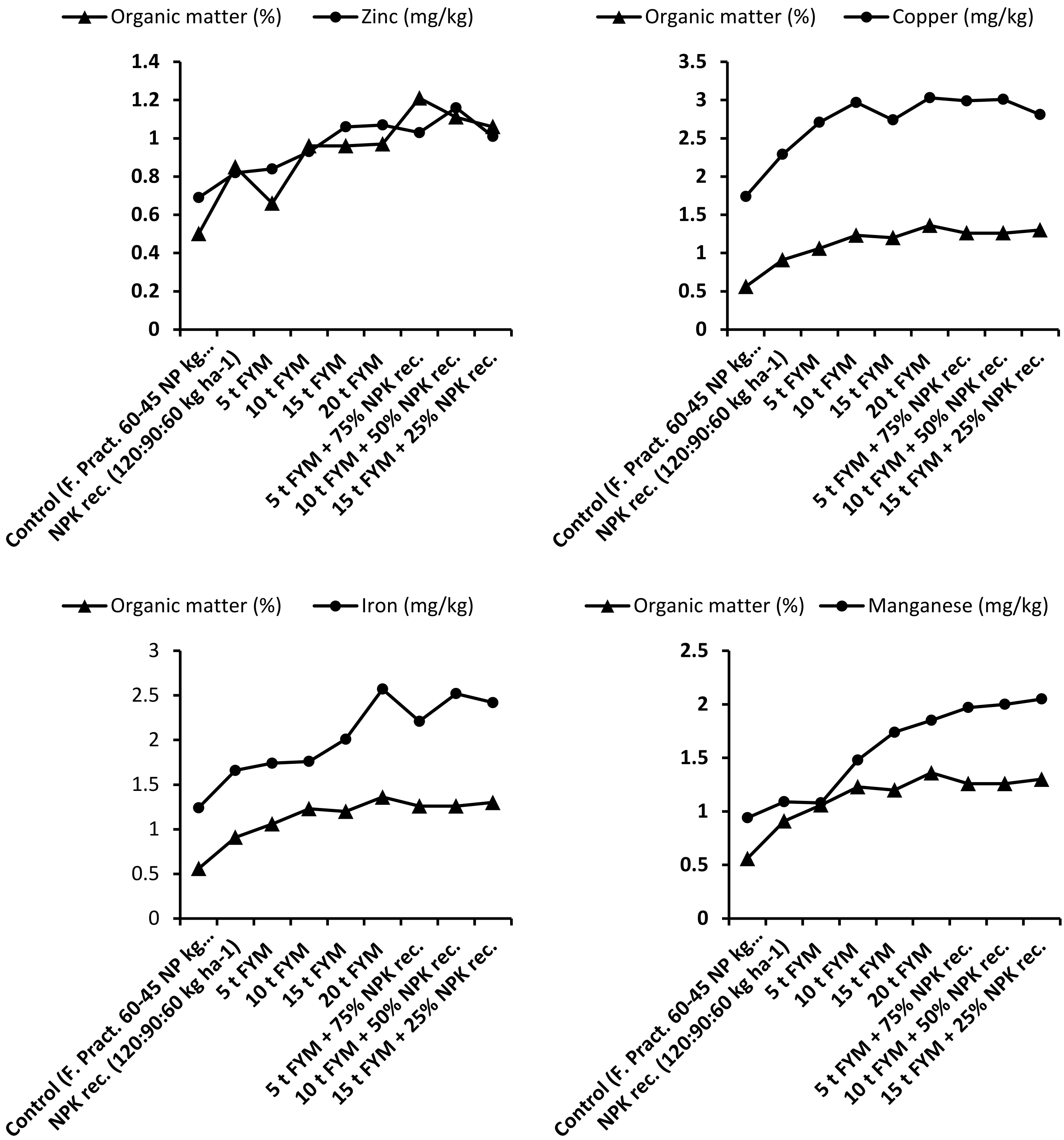


**Figure 4:** *Graph showing trend in micronutrient content with respect to variation in soilorganic matter in deep (20-40 cm) tilled soil.*

were highly significant ($p<0.01$) inextractable Fe content. Amongst the treatments, the sole 20 t ha$^{-1}$ FYM and the shared 15 t ha$^{-1}$ FYM and inorganic 25% NPK were the maximum and significantly higher in extractable Fe with 71 and 72% increase over the farmers practice. Both these treatments were also significantly higher over the recommended NPK dose and the sole 5 and 10 t ha$^{-1}$ FYM doses (Table 3). Despite their increase by 24, 30 and 38% over the Farmers practice, the recommended NPK and sole 5 and 10 t ha$^{-1}$ FYM were statistically similar to the farmers practice. Similarly, the sole 15 and 20 t ha$^{-1}$ FYM and its share application with inorganic NPK at variable rates were statistically similar in extractable Fe.

The extractable Fe in the deeply tilled soil was 38% lower than the extractable Fe values in the shallow tilled soil. when correlated with the soil OM content at their respective depth, $R^2$ value for shallow tilled soil was 0.22 and for deep tilled soil it was 0.55 (Figure 1 and 2). Both the shallow (Figure 3) and deep (Figure 4) tilled soils showed similar trend in soil extractable Fe with respective soil OM levels. There was no interaction between fertilizer treatments and tillage practices to affect extractable Fe in soil.

Based on combined data over tillage practices, soil extractable Mn was highly significant ($p<0.01$) and based on combined data over treatments, tillage practices were also significant ($p<0.05$) in extractable Mn content. Amongst the treatments, the sole 20 t ha$^{-1}$ FYM and the shared 5, 10 and 15 t ha$^{-1}$ FYM with their respective inorganic NPK ratio doses were the maximum and significantly higher in extractable Mn with a huge 97, 115, 145 and 140% increase over the farmers practice. All these four treatments were also significantly higher over the recommended NPK dose and the sole 5 and 10 t ha$^{-1}$ FYM doses (Table 3). Despite their increase by 29, 28 and 55% over the Farmers practice, the recommended NPK and sole 5 and 10 t ha$^{-1}$ FYM were statistically similar to the farmers practice. Similarly, the sole 15 and 20 t ha$^{-1}$ FYM and its shared application with inorganic NPK at variable rates were statistically similar in extractable Mn.

The extractable Mn in the deeply tilled soil was 33% lower than the extractable Mn values in the shallow tilled soil. When correlated with the soil OM content at their respective depth, $R^2$ value for shallow tilled soil was 0.24 and for deep tilled soil it was 0.33 (Figure 1 and 2). Both the shallow (Figure 3) and deep (Figure 4) tilled soils showed similar trend in soil extractable Mn with respective soil OM levels. There was no interaction between fertilizer treatments and tillage practices to affect extractable Mn in soil.

Based on combined data analysis over the shallow and deep tillage, results revealed a highly significant ($p<0.01$) reduction in bulk density (BD) as a result of fertilizer treatments whilst results based on combined data over fertilizer treatments, effect of tillage practices on soil bulk density was non-significant. The maximum bulk density was noted in the farmers practice (1.45 g cm$^{-3}$) followed by the recommended NPK(1.4 g cm$^{-3}$) that registered a significant 4% decrease in BD. Application of sole and shared FYM at any rate further decreased the BD with 7, 10, 11 and 12% decrease with sole 5, 10, 15 and 20 t ha$^{-1}$ FYM and 9, 11 and 11% decrease with shared 5, 10 and 15 t ha$^{-1}$ FYM with their respective NPK ratios (Table 4). The FYM at the rate of 10 t ha$^{-1}$ and greater amount and all the shared FYM and NPK treatments were statistically similar. The tillage effect on BD was almost similar (0.2% lower in deep than shallow tilled soil) (Table 4). When correlated with the soil OM content at their respective depth, $r^2$ value for shallow tilled soil was 0.43 and for deep tilled soil it was 0.33 (Figure 5 and 6). There was no interaction between fertilizer treatments and tillage practices to affect bulk density in soil.

**Table 4:** *Fertilizer treatments and tillage effect on soil physical properties.*

| Treatments | B.D | Porosity | Sat. | AWHC |
|---|---|---|---|---|
| | (g cm$^{-3}$) | % | | |
| Control | 1.45 a | 45.1 d | 27.8 d | 17.7 d |
| NPK rec. | 1.4 b | 47.1 c | 29.2 cd | 19.8 c |
| 5 t FYM | 1.35 c | 49.1 b | 30.3 c | 21.0 bc |
| 10 t FYM | 1.31 cd | 50.4 ab | 32.0 ab | 22.5 a |
| 15 t FYM | 1.3 d | 50.9 a | 32.4 ab | 22.4 a |
| 20 t FYM | 1.29 d | 51.4 a | 33.3 a | 22.8 a |
| 5 t FYM + 75% NPK rec. | 1.32 cd | 50.1 ab | 31.9 b | 22.1 ab |
| 10 t FYM + 50% NPK rec. | 1.3 d | 51.1 a | 32.6 ab | 22.7 a |
| 15 t FYM + 25% NPK rec. | 1.3 d | 51.1 a | 32.6 ab | 22.9 a |
| LSD $_{(p<0.05)}$ | 0.04 | 1.52 | 1.4 | 1.25 |
| Shallow Tillage (0-20 cm) | 1.34 | 49.6 | 31.9 | 22.1 |
| Deep Tillage (0-40 cm) | 1.33 | 49.7 | 30.7 | 20.9 |
| T.Test | 0.94 (ns) | 0.94 (ns) | 0.18 (ns) | 0.18 (ns) |
| F x T | ns | ns | ns | ns |

*Control (F. Pract. 60-45 NP kg ha$^{-1}$), NPK rec. (120:90:60 kg ha$^{-1}$), OM (Organic matter), incr. (increase over control), Means followed by same letters are not significantly different.*

Based on combined data over the tillage practices, the treatments effect on soil total porosity was highly significant ($p<0.01$) whilst based on combined data over fertilizer treatments, effect of tillage practices on soil total porosity was non-significant. The maximum total porosity was recorded in the 20 t ha$^{-1}$ FYM (51.4%) followed by both the shared 10 and 15 t ha$^{-1}$ FYM with their respective NPK ratios (51.1%). The difference between the sole 20 t ha$^{-1}$ FYM and the farmers practices was 14% whilst that of the shared 10 and 15 t ha$^{-1}$ FYM was 13% each. The sole 5, 10 and 15 t ha$^{-1}$ FYM recorded 9, 12 and 13% increase in total porosity over the farmer's practices whilst the recommended NPK was 4% higher in total porosity over the farmers practices (Table 4). It can be seen from Table 4 that all the treatments receiving FYM either as sole or shared were significantly higher in total porosity

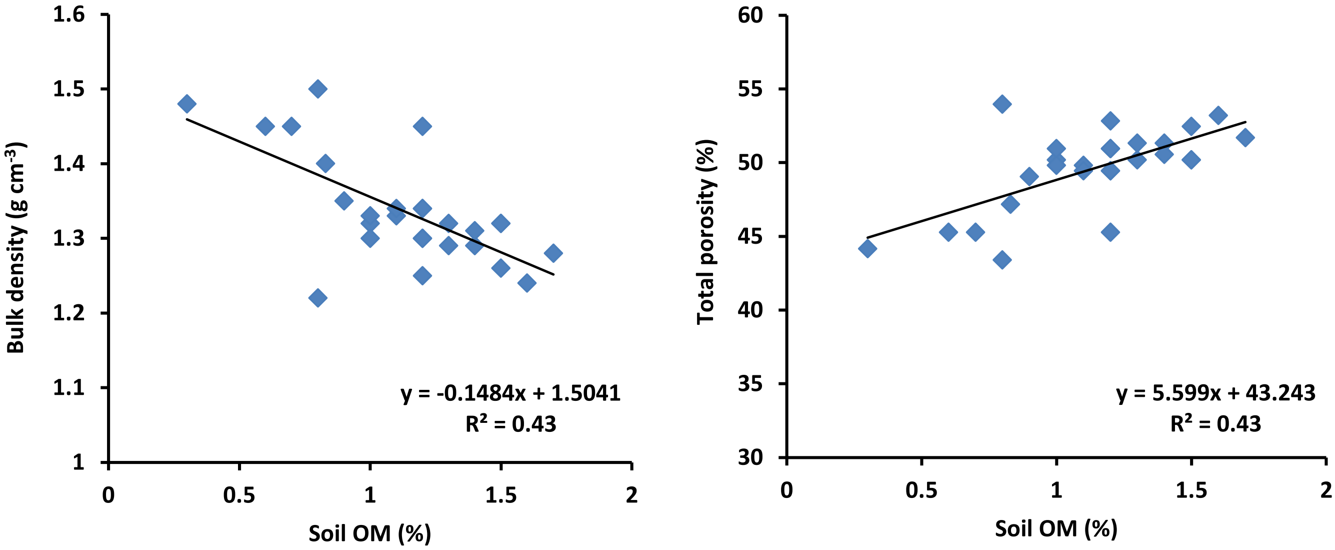


**Figure 5:** *Bulk density and total porosity correlation with soil OM in shallow (0-20 cm ) tilled soil.*

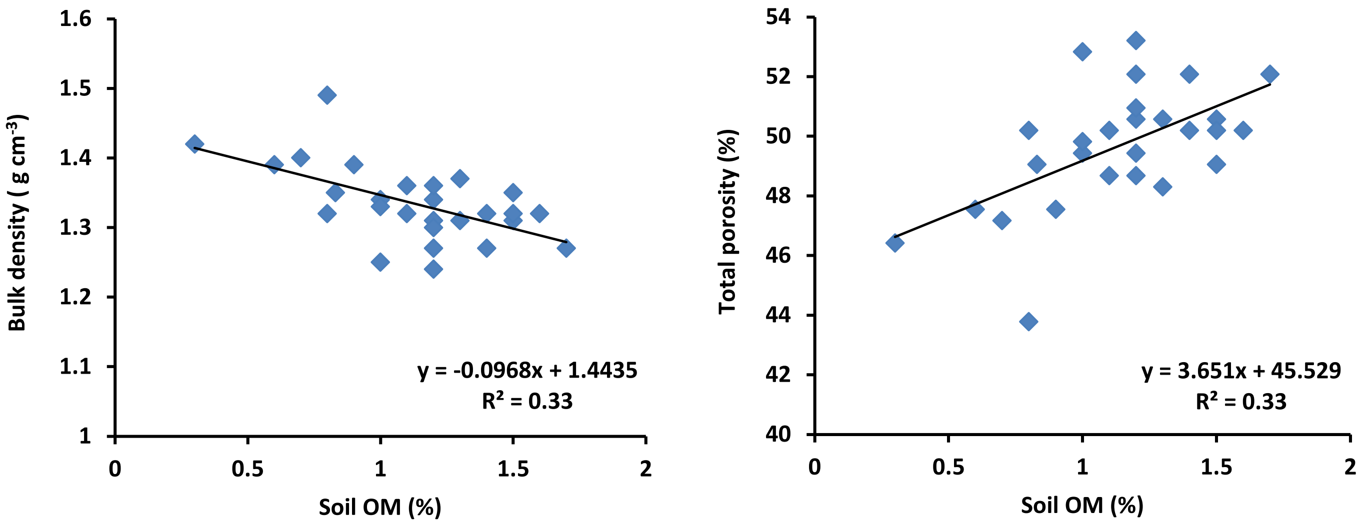


**Figure 6:** *Bulk density and total porosity correlation with soil OM in deep (20-40 cm ) tilled soil.*

than farmer's practices and recommended NPK dose whilst the recommended NPK was also significantly higher than the farmer's practice.

The shallow tillage was only 0.2% higher in total porosity than deep tilled soil (Table 4). Soil porosity was well correlated with the soil OM content at their respective depth, showing $r^2$ value for shallow tilled soil as 0.43 and for deep tilled soil it was 0.33 (Figure 5 and 6). Results further indicated that there was no interaction between fertilizer treatments and tillage practices to affect extractable Mn in soil.

Combined data over the tillage practices indicated the treatments effect on soil saturation water percentage as highly significant ($p<0.01$) whilst results based on combined data over fertilizer treatments indicated that the effect of tillage practices on soil saturation water percentage was non-significant. The maximum saturation water percentage (33.3) registered by the sole 20 t $ha^{-1}$ FYM was 20% higher over the farmer's practice and 15% higher over the recommended NPK dose. The saturation water percentage in sole 10 and 15 t $ha^{-1}$ FYM and shared 10 and 15 t $ha^{-1}$ FYM with their respective NPK ratios were 15, 16, 17 and 17% higher over the farmer's practices and were statistically similar with the maximum value. However, the sole and shared 5 t $ha^{-1}$ FYM were both significantly lower than the maximum value (Table 4) and were also significantly different among themselves. However, the shared FYM 5 t $ha^{-1}$ was significantly higher over the farmers practice and the recommended NPK whilst the sole 5 t $ha^{-1}$ FYM was significantly higher over the farmers practice and was statistically similar with the recommended NPK dose.

The shallow tillage was 4% higher in saturation percentage than deep tilled soil, however, this difference

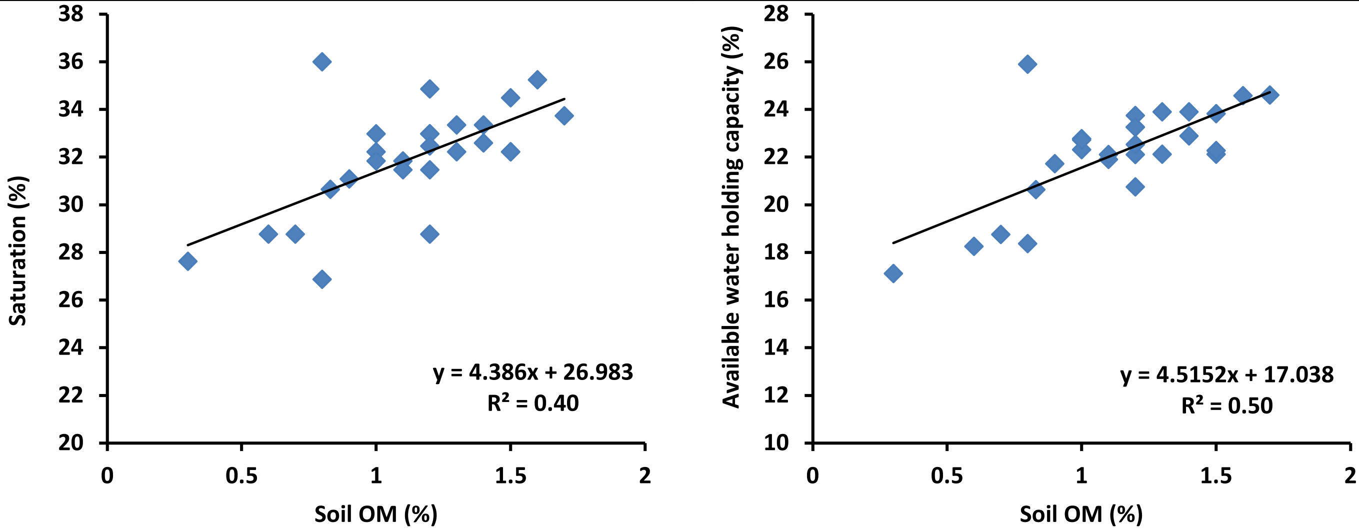


**Figure 7:** *Saturation percentage and AWHC correlation with soil OM in shallow (0-20 cm ) tilled soil.*

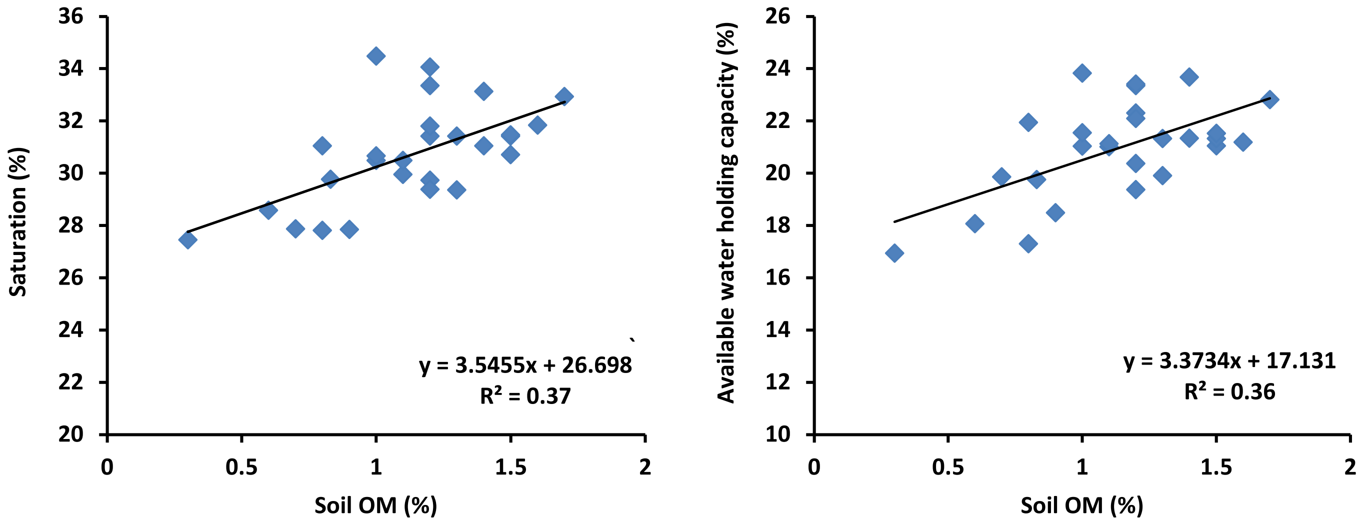


**Figure 8:** *Saturation percentage and AWHC correlation with soil OM in deep (20-40 cm ) tilled soil.*

was statistically non-significant (Table 4). Soil saturation water percentage was also well correlated with the soil OM content at their respective depth, showing $R^2$ value for shallow tilled soil as 0.40 and for deep tilled soil it was 0.37 (Figure 7 and 8). There was no interaction between fertilizer treatments and tillage practices to affect saturation water percentage in soil.

Combined data over the tillage practices revealed highly significant treatments effect on soil available water holding capacity (AWHC) whilst results based on combined data over fertilizer treatments indicated non-significant tillage practices effect. The maximum AWHC (22.9%) was recorded in the shared 15 t $ha^{-1}$ FYM with its respective NPK ratio dose and this was 30% higher over the farmer's practice and 18% higher over the recommended NPK dose (Table 4). The AWHC in sole 10, 15 and 20 t $ha^{-1}$ FYM and shared 5, 10 and 15 t $ha^{-1}$ FYM with their respective NPK ratios were 28, 27, 29% and 25, 28 and 30% higher over the farmers practices and were statistically similar with the maximum among themselves.

The shallow tillage was 5% higher in AWHC than deep tilled soil, however, this difference was statistically non-significant (Table 4). Soil AWHC was also well correlated with the soil OM content at their respective depth, showing $R^2$ value for shallow tilled soil as 0.50 and for deep tilled soil it was 0.36 (Figure 7 and 8). There was no interaction between fertilizer treatments and tillage practices to affect AWHC in soil.

Research workers are agreed upon the fact that growth and yield of the crop plants further improve when the recommended NPK fertilizer are supplemented with micronutrients during soil application(Chaudry et al., 2007; Uddin et al., 2008; Hammad et. al., 2011; Nadeem et al., 2016). Our results indicated the increase in soil micro-nutrient content with sole and shared FYM amendments which could be held as responsible factors for significant increase in crop production parameters (Data not shown in this paper) over the sole NPK treated soil at the recommended rates. These results indicated the significant ability of the FYM, being one of the major sources of soil OM in similar arid and semi-arid warm climates, to add and release through decomposition the various micro-nutrient in soil. Ahmad and Khan (2014) reported after mixed application of farmyard manure and mineral fertilizer for four seasons the highest increase in micro-nutrient concentration both in the surface and sub-surface soils. Inorganic fertilizers supply specific nutrients for which they are meant and manufactured whilst the FYM is said to have all the 16 essential nutrient element, though in variable quantity based on the quality of the FYM and its source. Researchers like Timsina and Connor (2001), Dawe et al. (2003) and Pratt (2008) also confirmed the FYM a source of micro-nutrients in agricultural soils that are slowly and gradually added to the soil nutrient pool upon FYM mineralization. Increase in micronutrients in the RD over the FP, irrespective of its significance level may be ascribed to higher below ground biological mass due to comparatively higher crop growth and the resultant higher OM content. Results regarding the higher micronutrients content in the ST than DT soil holds good for the dilution effect of the DT upon the applied soil amendments with a large volume of soil whilst in the ST, similar soil amendments remain concentrated in a relatively smaller volume of soil. Ahmad and Khan (2014) reported decreased concentration for Fe, Zn, Mn and Cu with depth by 14, 23, 18 and 7.7 % in sub-surface soil over the surface soil, respectively.

Fertilizers amendments, irrespective of its source, increase soil nutritional status (Pratt, 2008) as well as bring about changes in bio-physico-chemical characteristics of the soil (Motavalli et al., 2003). Results of the current study confirmed the results of Motavalli et al. (2003), Pratt (2008) and Ahmad et al. (2014) and revealed a significant reduction in bulk density and increase in soil porosity as a result of soil amendments application. Significant reduction in bulk density and increase in total porosity in the recommended NPK dose over the farmers practices is supported by Ahmad et al. (2014) and may be credited to higher below ground biomass production due to increased plant growth and resultant higher OM content compared to the farmers practice. The decrease in bulk density and a resultant increase in soil total porosity as a result of organic manure accumulation might be credited to a dilution effect that this organic material is causing for the denser mineral fraction of the soil (Haynes and Naidu, 1998). Soil OM acts as chelating agent for soil particles and hold soil particles together in a favourable manner. Thus soil aggregation is enhanced with increase in soil OM content resulting in lowering of BD and increasing soil porosity. Research indicated that soil aggregates formed as a result of soil OM addition in the form of FYM are mostly granular, possessing more pore space than any other soil aggregation. Such pore space distribution reduce weight per unit volume of soil and thus reduces bulk density and increase soil porosity. These results confirm the results of Ahmad et al. (2014) who also reported soil bulk density reduction and total porosity enhancement with sole mineral fertilizer addition ascribed the same to higher root density and biological yield that increased organic matter in the soil. Soil OM enhancement in the form of FYM results in the increase in number of the di (e.g. $Ca^{+2}$ and $Mg^{+2}$) and tri-valent cation (e.g. $Al^{+3}$) which are also aggregating agents and results in soil aggregation and therefore, reduce soil BD and increase total porosity. These results are confirmed by negative correlation ($r^2$=-0.43) between soil OM and BD and positive correlation ($r^2$=0.43) between OM and total porosity in shallow tilled soil and approximately similar correlation was observed in deeply tilled soil. Higher below ground root biomass as a result of increased plant growth might have higher root exudations of different kinds e.g. proteins and glomalins. These exudates, along with being attractive for rhizosphere microbes, act as cementing agents for soil particles resulting in soil aggregation and pore space distribution (Auburn, 1998). Results revealed that the maximum reduction in bulk density and increase in porosity was caused by the sole FYM applied at the maximum dose and this was closely followed by the shared application of FYM and mineral fertilizers on 50% basis of their maximum doses or the FYM at 75% and NPK at 25% of their maximum doses. These results supported by the findings of Hati et al. (2006), Khan et al. (2007) and Ahmad et al. (2014) who reported improved physical properties with the integrated use of FYM and chemical fertilizers. As against the results reported by Khan et al. (2003) showing increasing soil bulk density and decreasing porosity with depth without employing any tillage operations, results in this study indicated that tillage effect on BD and total porosity was positive, however, to a non-significant extent, and bulk density in the DT soil was 0.2% lower than the ST soil. Amin et al. (2014) also reported that DT practices performed better than ST practices (tine cultivator) and significantly decreased soil bulk density and penetration resistance. Siddiq (2013) also reported lower bulk density for deep tillage than conventional tillage. The non-significant improvement in bulk density and total porosity in DT than ST soil in our study might be credited to the higher OM content in ST than DT soil that counteracted the ST inferiority over the DT operations. When correlated with the soil OM content at their respective depth, $r^2$ value for ST soil was 0.43 and for DT soil it was 0.33 indicating higher correlation of the soil bulk density and soil OM in ST than DT soil.

Results further revealed significant increase in soil saturation and available water holding capacity (AWHC) as a result of amendments and these results are supported by Ahmad et al. (2014). Pore space in soil acts as a storehouse for water. With increasing soil porosity as mentioned above as a result of increasing soil OM or root actions hold good for the increasing soil saturation and available water content. Further analysis revealed the lowering of saturation and AWHC by 4 and 5%, respectively, with DT compared to ST, however, to a non-significant extent, might be ascribed to higher OM content in ST than DT soil. Secondly, in the ST soil, plant roots actions and effects might be considerably greater than the deeply sampled soil as a result of DT. These result are supported by Siddiq (2013) showing non-significant differences between tillage treatments but higher moisture depletion under DT compared to conventional and minimum tillage. Results further revealed that mostly the effect (Hayness and Naidu, 1998) of the sole and shared FYM decreased in the DT soil due to dilution of the amendments with larger soil volume whilst that of recommended NPK effects are either maintained (as in case of available water holding capacity) or slightly modified negatively (e.g bulk density and saturation) and this trend goes positive for DT despite of higher OM content in the ST soil.

## Conclusions

These results concluded that integrated nutrient management improved the soil OM, micro-nutrients content and physical properties of soil. The deep tillage in poorly fertile alkaline calcareous soils negatively affect micro-nutrients status. Positive influence of deep tillage on physical properties and micronutrients status as well, seems to have been superseded by high OM content in shallow tillage soil due to amendments incorporation with relatively small volume of soil than deep tillage soil.

## Author's Contribution

Imran Khan and Zahir Shah planned and Installed the experiment and conducted field work. Zahir Shah supervised the field work and data collection. Wiqar Ahmad helped in manuscript write up and discussion on the results. Farmanullah Khan helped in data collection, calculation, laboratory analysis, data entry in the computer. Muhammad Sharif helped in statistical analysis and interpretation.

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