Research Article

Wheat Yield and Post-Harvest Fertility Status of Calcareous Soil Using Shallow and Deep Tillage and Integrated Nutrient Management (INM)

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Abstract | The study was conducted in Research Farm of the University of Agriculture, Peshawar during wheat crop season 2015-16 to test different nutrient inputs for their effect on wheat yield and soil fertility status under different tillage practices. Randomized Complete Block Split Plot Design with three replications was used for the study where nutrient inputs were allotted to sub-plots whilst tillage practices were studied in main plots. Nutrient input consisted of Farmer's fertilizer practice (FP; $N:P_2O_5:K_2O$=60:45:00 kg ha^{-1}), Recommended dose (RD; $N:P_2O_5:K_2O$=120:90:60 kg ha^{-1}), Farmyard manure (FYM) alone at the rate of 5, 10, 15 and 20 t ha^{-1} and the integration of 5, 10 and 15 t ha^{-1} FYM with 75, 50 and 25% of the RD, respectively. Tillage practice included shallow tillage (ST; 0-20 cm) and deep tillage (DT; 0-40 cm). The FYM alone resulted in increased soil NPK, organic matter (OM) and the electrical conductivity (EC) but failed to improve the yield significantly. However, the RD, along with improving these parameters, also increased the yield significantly over the FP. Amongst all treatments, the 5 t ha^{-1} FYM and 75% NPK of the RD ($INM_{5:75}$) stood superior with respect to yield as well as soil fertility status. However, efficacy was negative under deep tillage compared to shallow tillage for all treatments since yield as well as harvest Index (HI), mineral nutrients and OM content in soil were significantly lower and pH and EC higher under deep tillage. Results suggested that, unless otherwise necessary, deep tillage in alkaline calcareous soil should be avoided, preventing lime resurfacing from depth and keeping the applied amendments concentrated in surface layer.

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Introduction

The forecasted 10 billion population of the world by 2050 (Lampe, 2000) sets forth the massive challenge of food and feed production, Pakistan is no exception. Besides production constraints, only one fourth (22.07 m ha) of its total area (79.61 m ha) is under cultivation (Agricultural Statistics, 2013-14). Constraints like salinity, water logging, irrigation water deficit, erosion, low organic matter and nutrient status and degraded physico-chemical properties are most common on agricultural soils. One solution for food security issue is to intensify the cultivation on normal productive soils which, currently, is under practice on 33% (7.30 m ha) cultivated land. But due to constraints like low nutrient and organic matter status, non-judicious fertilizer use, water shortage (Guan et al., 2015) and lack of suitable and potential plant genotypes, the challenge of food security and soil fertility remediation still remains unmet.

Different conservation, water management and tillage practices are being advised under specific circumstances to compensate water resource shortage. Tillage practices alter soil properties, expedite crop growth and development and are considered the most effective farm activity for developing a desired soil structure. Minimum tillage is effective in saving more precipitation for crop production (Habtegebrial et al., 2007), preserves soil biota (Nakamoto et al., 2006), reduces N leaching, soil bulk density and penetration resistance (Gangwar et al., 2006; Guan et al., 2015), pH and CO_2 emission (Wang and Dalal, 2006), erosion (Lopez and Bellido, 2001) and increase water use efficiency under rain-fed conditions (Guan et al., 2015). Both conventional and deep tillage can improve soil aeration and porosity, conserve nutrients and moisture for plants, microbes release nutrients from soil micro flora pool for crops and thus ultimately 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 the soil and that NO_3-N leaching could be decreased 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.

Recovery of soil organic matter and mineral nutrient recycling is critical to rehabilitation schemes (Banning et al., 2008). Application of organic soil amendments, with and without mineral fertilizers improve fertility and physical parameters of the soil (Barzegar et al., 2002; Jadoon et al., 2003; Hati et al., 2006; Dolan et al., 2006; Ahmad et al., 2014; Ahmad and Khan, 2014). In developing countries including Pakistan where animal rearing is an integral component of agricultural system, farm yard manure is one of the most important and easily accessible organic manure, supplementing about 1.5 million tons of soil nutrients (Bari, 2003). Its integration with inorganic fertilizers not only has positive interaction with chemical fertilizers to increase their efficiency but also reduce environmental hazards. Integrated approaches increase crop yields as well as sustain the agricultural productivity, preserve soil moisture, improve plant growth and recover soil health.

The aforementioned benefits of nutrient cycling and tillage management are non-controversial; however, there are negligible information on nutrient management and tillage practices effect on yield potential, chemical properties and NPK status of a low fertility alkaline calcareous soil. The information sought in this study will surely add new findings to the existing knowledge of soil fertility management of similar soil conditions.

Materials and Methods

The experiment was conducted on a low fertility alkaline calcareous cultivated soil in New Developmental Farms (NDF) of the University of Agriculture, Peshawar, Pakistan, during Winter 2015-16. Experimental field has been characterized in Table 1.

Table 1: *Physico- chemical properties of the study site before sowing.*

Property	Unit	value
Sand	%	30
Silt	%	56.4
Clay	%	13.6
Textural class	-	Silt loam
pH (1:5)	-	7.8
Electrical conductivity(EC)	$dS\ m^{-1}$	0.52
Lime	%	16
Organic matter content	%	0.72
AWHC	%	14
Bulk density	$g\ cm^{-3}$	1.24
Mineral Nitrogen	$mg\ kg^{-1}$	14
AB-DTPA extractable P	$mg\ kg^{-1}$	2.2
AB-DTPA extractable K	$mg\ kg^{-1}$	62

AB-DTPA extractrable P and K: *Soil mineral P and K extracted in 1N Ammonium bicarbonate diethylene triamine penta acetic acid solution;* **AWHC:** *Available water holding capacity*

Randomized complete block design with split plot arrangement was used for field layout. The sub-plot factor was the assessment of efficacy and optimization of nutrients from different sources including Farmer's Practice ($N:P_2O_5:K_2O$, 60:45:00 kg ha^{-1}) denoted as FP, Recommended NPK dose ($N:P_2O_5:K_2O$, 120:90:60 kg ha^{-1}), farmyard manure (FYM) alone at the rate of 5, 10, 15 and 20 t ha^{-1} ($FYM_{5,10,15,20}$) and its first three dose integration with 75, 50 and 25% of the RD ($INM_{5:75,\ 10:50,\ 15:25}$), respectively. Plot size was 5 × 3 m^2. The main plot factor was tillage practices i.e. shallow (cultivator 0-20 cm) and deep (moldboard plough 0-40 cm) tillage.

$$\text{Biological yeild } (kg\ ha^{-1}) = \frac{\text{Biological yeild in four center rows } (kg)}{\text{Row} - \text{row distance } (m) \times \text{Row length } (m) \times \text{No. of rows}} \times 10000\ (m^2 ha^{-1}) \ldots\ldots (1)$$

$$\text{Grain yield } (kg\ ha^{-1}) = \frac{\text{Grain yeild in four center rows } (kg)}{\text{Row} - \text{row distance } (m) \times \text{Row length } (m) \times \text{No. of rows}} \times 10000\ (m^2 ha^{-1}) \ldots\ldots (2)$$

$$CaCO_3\ (\%) = \frac{(\text{ml of HCl x N of HCl}) - (\text{ml of NaOHxN of NaOH}) \text{x } 0.05 \text{ x } 100}{\text{Weight of Soil sample (g)}} \ldots\ldots (5)$$

Plots were sown with spring wheat (*Triticum aestivum* L.) uniformly (120 kg ha^{-1}) on November 15, 2015 using *CV* Siran 2010, accommodating 10 rows (5 m long) with row-row distance of 30 cm. Nutrients were incorporated at the time of sowing. The sources of NPK were urea, diammonium phosphate (DAP) and sulphate of potash (SOP), respectively whilst FYM (Characterized in Table 2) was obtained from the University Dairy farm. Nitrogen was applied in two splits one at sowing time and other at the 45th day after sowing along with second irrigation whilst other fertilizers were applied and mixed with soil at the time of sowing. The crop was harvested on May 5, 2016.

Table 2: *Moisture holding capacity, NPK status and C:N ratio of the FYM.*

Parameter	Unit	FYM
Total N	%	0.9
Total P	%	0.2
Total K	%	0.6
Organic C	%	21.1
C/N ratio	-	23.4
Moisture holding capacity	%	47%

Normal recommended cultural practices were followed throughout the growing season. After threshing, 1000 grains plot^{-1} were counted and weighed with electronic balance. Biological yield (above ground plant material including heads and grain) was recorded by harvesting 4 central rows in each treatment plot, dried and weighed and then weight was converted into kg ha^{-1} using Equation 1.

The crop (above ground plant material including heads and grain) harvested from four central rows for biological yield was sun dried, threshed, cleaned and grain weight recorded. Grain weight was converted into kg ha^{-1} using Equation 2.

Harvest index was calculated with the following formula: (Equation 3)

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}} \ldots\ldots (3)$$

Where;
Economic yield is the total grain yield in kg ha^{-1}

Post-harvest soil samples from 0-20 cm depth were collected for assessing soil fertility assessment. Soil pH was determined in 1:5 soil water suspension duly mixed with a rotary shaker for 30 minutes and read with pH meter (Mclean, 1982). Electrical conductivity ($EC_{1:5}$) was read with the EC meter using the same 1:5 soil water suspension (Rhoades, 1982).

Soil organic matter content was determined following the Walkley and Black procedure as described in Nelson and Sommers (1996). (Equation 4)

$$\%\ OM = \frac{(B - S) \text{ x N x } 0.69}{\text{Wt.of soil}} \ldots\ldots (4)$$

Lime content in soil sample was determined by acid neutralization (Method 23 c, USDA HB 60) as described by Richard (1954). Five (5) gram soil was transferred to 150 ml flask and mixed with 0.5 N 50 ml HCl. The suspension was boiled in fume hood for five minutes then cooled and filtered through whatman No. 40 filter paper and titrated with 0.25 N NaOH using phenalpthaline as indicator till pink color is obtained. (Equation 5)

For mineral N, the soil sample (10g) was extracted with KCL 1N 50ml solution (Mulvaney, 1996) and the extract was distilled through Kjeldhal procedure as A 20 ml aliquot was the distilled in the presence of 20 ml of 40% NaOH solution and the condensed ammonia was collected into 5.0 ml boric acid indicator solution till its volume reached 75ml and titrated against HCl of 0.05 N. The N content was calculated using Equation 6.

$$N(\%) = \frac{(\text{HCl used for sample} - \text{HCl used for blank}) \times 0.014 \times N \times \text{dilution} \times 100}{\text{Wt. of sample (g)}} \quad ..(6)$$

Table 3: *Crop nutrition from different sources and tillage practice effect on wheat yield parameters.*

Treatments	1000 grain weight (g)	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index
Control	40.6 cd	5886 c	2680 de	0.46
NPK rec.	43.2 ab	7354 b	3498 c	0.48
5 t FYM	39.9 d	5445 c	2518 e	0.47
10 t FYM	40.4 cd	6117 c	2817 de	0.47
15 t FYM	41.3 c	6080 c	2834 d	0.48
20 t FYM	42.3 b	6187 c	2815 de	0.47
5 t FYM + 75% NPK rec.	43.4 a	8482 a	4127 a	0.49
10 t FYM + 50% NPK rec.	43.2 ab	8284 a	4015 ab	0.49
15 t FYM + 25% NPK rec.	42.8 ab	7729 ab	3728 bc	0.49
$LSD_{(p<0.05)}$	0.97	900	305	ns
Shallow tillage (0-20 cm)	42.32	6729	3273	0.49
Deep tillage (0-40 cm)	41.44	6951	3179	0.46
T.Test $_{(probability)}$	0.196 (ns)	0.70 (ns)	0.75 (ns)	0.045
F x T	ns	ns	ns	ns

Control (F. Pract. 60-45 NP kg ha^{-1}), NPK rec. (120:90:60 kg ha^{-1}), Means followed by same letters are not significantly different at the p < 0.05.

Extractable P and K and micro-nutrients in soil samples were determined by the method as described by Soltanpour and Schawab (1977). A 10 g air dried soil sample was extracted with 20 mL of 1N AB-DTPA solution with the help of rotary shaker for 30 minutes leaving the flasks open to let the CO_2 escape. The solution was filtered with whatman No 42 filter paer. Phosphorus content in soil extract was measured on Spectro-photometer at wavelength of 880 nm and K content was measured on flam photometer.

Statistical analysis

The collected data were analysed by analysis of variance (ANOVA) procedure for randomized complete block split-plot design using Statistix 8.1 analytical software (Statistix, Tallahassee P.O. Box 12185, 32317 FL). Regression where necessary was carried out and r^2 values were determined. Significantly different treatments were compared using LSD test of significance at p<0.05 (Steel and Torri, 1980).

Results and Discussion

Results revealed that the recommended dose (*RD)* significantly (p<0.01) increased the 1000 grain weight (*GW,* 6 and 4%), biological yield (*BY,* 5 and 25%) and grain yield (*GY,* 5 and 30.5%) over the FP and FYM, respectively (Table 3) indicating the soil deficiency with respect to these major nutrients. Recommended NPK application to a poor and intensively cultivated soil actively supplement the plant nutrition and enhance the crop yield (Nadeem et al., 2016). But the net utilization of inorganic N from NPK fluctuates from 55-65% only (Mercik and Stepien, 2012) leaving the crop as N starved. Further increasing the NPK beyond the recommended level may increase production cost as well as will disturb the plant physiological functions through dilution of the rest of the nutrients. Results (Table 3) from sole FYM at low doses ($FYM_{5,\ 10}$) on yield parameters were negative whilst FYM_{15} on GW and $FYM_{10,15,20}$ on *BY* and *GY* were non-significant. However, the effect of FYM_{20} on *GW* was significant (4% higher) over the FP and was statistically similar to the RD (Figure 1) indicating that FYM at low doses was non-potent to provide the required nutrients in desirable quantities. However, the significant (4%) higher GW with FYM_{20} over the FP clarified that FYM is needed in large quantities on such low fertility soils.

No doubt, there might be some immobilization of the available nutrients by the FYM and the start of FYM mineralization to release the nutrients is very slow at the initial stages of crop growth (Balemi, 2012) but the

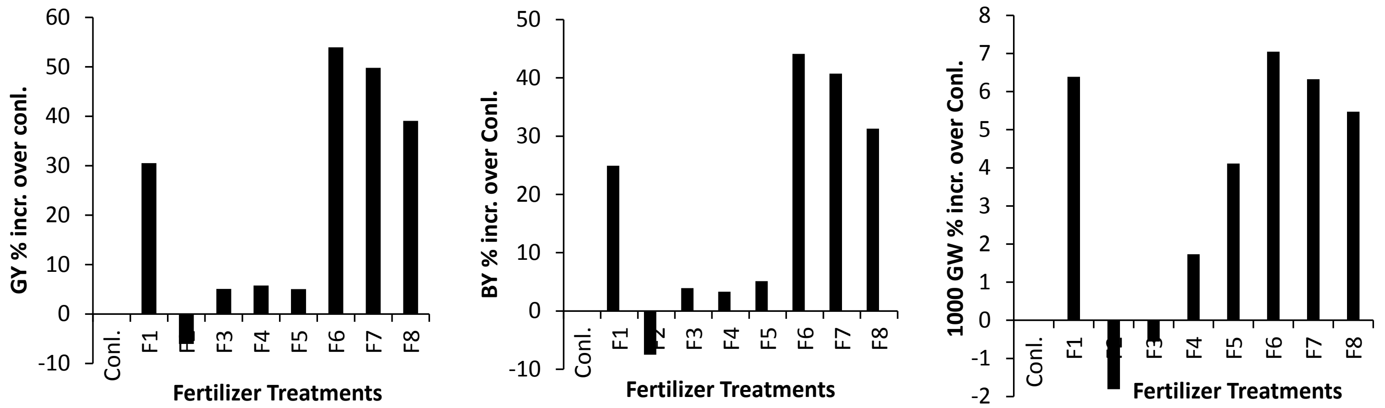

Figure 1: *Percent variation in grain yield (GY) biological yield (BY) and 1000 grain weight with fertilizer treatments over control. F1:NPK , F2: 5 t FYM, F3: 10 t FYM, F4: 15 t FYM, F5: 20 t FYM, F6: 5 t FYM + 75% NPK , F7: 10 t FYM + 50% NPK, F8: 15 t FYM + 25% NPK.*

nutrients requirement is also small at the initial growth stages and large quantities of FYM applications somehow fulfil the plant minimal nutrient requirements to withstand the stress. Masood et al. (2014) also reported improved soil properties, nutrient uptake and higher plant biomass as a result of large quantities of FYM applications. However, keeping in view the rest of the yield parameters e.g. BY and GY which were still statistically equivalent to the FP, the sole FYM at large quantities can also not be recommended for successful and potential crop production.

Results (Table 3) revealed the maximum yield and yield parameters with the integrated application of 5 t ha^{-1} FYM and 75% of the recommended NPK ($INM_{5:75}$) with 7, 44 and 54% increase in 1000 grain weight (*GW),*biological yield *(BY)* and grain yield (*GY)*, respectively, over the farmer's practices (FP, Figure 1). The integrated application of 10 t ha^{-1} FYM with 50% of the recommended NPK ($INM_{10:50}$) dropped the increase to 6, 41 and 50% and the integrated application of 15 t ha^{-1} FYM with 25% of the recommended NPK ($INM_{15:25}$) further dropped the edge to 5.5, 31 and 39%, respectively, over the farmer's practice (FP). These significant improvements might be due to improved soil aeration, availability of essential nutrients in sufficient quantities and high moisture content (Turk and Tawaha, 2003). Research workers (Chaudry et al., 2007; Uddin et al., 2008; Hammad et al., 2011; Nadeem et al., 2016) are agreed that growth and yield of crop plants was further improved when the RD was supplemented with micronutrients. Application of organic fertilizers not only add micronutrients into the soil but also increase biological activities beneath the soil surface, increase water and nutrient holding capacity of the soil resulting in less soil moisture/nutrient losses and more bio-availability (Defra, 2002; Weil and Magdoff., 2004). Results from the study conducted by Khan et al. (2016) on eroded soil with significantly degraded physical properties in District Swabi revealed 75% of the recommended NPK combined with 10 t ha^{-1} FYM, as a potential treatment for increased wheat GW, BY, GY and straw yield (SY) over the control and other treatments. The management and incorporation of soil organic carbon into agricultural soils links to soil fertility, erosion prevention, nutrient retention and above and below-ground biodiversity (Johnston et al., 2009; Tsiafouli et al., 2015). Results further revealed that $INM_{5:75}$ was closely followed in significance by the $INM_{10:50}$. However, further decreasing the NPK application below 50% of the recommended dose and increasing the FYM application over the 10 t ha^{-1} did not prove fruitful with regard to these yield related parameters.

Results (Table 3) further revealed that GW and GY were 2 and 3%, however to a non-significant extent, and HI was significantly lower in the deep tillage (DT) than shallow tillage (ST). This is an indication of reduction in the effectiveness of soil amendments tilled deeply soon after their application as being mixed with larger volume of soil (0-40 cm) compared to the shallow tilled (0-20 cm) field. In other words, when the applied nutrients are mixed with 0-20 cm depth with a routine tillage practice, they remain concentrated in a relatively smaller volume of soil (0-20 cm) than deep tillage (0-40 cm) and, therefore, remain in easily accessible locations for the plants roots that get established there. This result in a relatively higher plant growth and yield attributes in the shallow tillage

Table 4: *Nutrition and tillage practice on the chemical properties of soil.*

Treatments	$pH_{(1:5)}$	$EC_{(1:5)}$	Soil OM	Lime content (%)
		d Sm^{-1}	%	
Control	7.88 abc	0.75 b	0.53 c	15.0
NPK rec.	7.80 abcd	0.89 a	0.88 b	14.9
5 t FYM	7.91 a	0.88 a	0.87 b	14.3
10 t FYM	7.88 abc	0.84 a	1.1 ab	14.9
15 t FYM	7.89 ab	0.87 a	1.08 ab	14.4
20 t FYM	7.91 a	0.87 a	1.17 a	14.1
5 t FYM + 75% NPK rec.	7.72 d	0.86 a	1.24 a	15.2
10 t FYM + 50% NPK rec.	7.77 bcd	0.89 a	1.19 a	14.0
15 t FYM + 25% NPK rec.	7.75 cd	0.87 a	1.18 a	14.3
$LSD_{(p<0.05)}$	0.134	0.056	0.28	ns
Shallow tillage (0-20 cm)	7.75 b	0.78 b	1.13	13.5
Deep tillage (0-40 cm)	7.92 a	0.93 a	0.92	15.6
T. Test (probability)	0.002	0.000	0.08 (ns)	0.000
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), Means followed by same letters are not significantly different at the $p < 0.05$.

than deep tillage of the intensively cultivated initially low fertility soil. Another phenomenon un-avoidable in this whole processes is the disturbance of the surface soil environment through resurfacing of the illuviated lime and soluble salts. Our results closely match with Neugschwandtner et al. (2014) who reported more uniform mixing of soil P and K in the shallow mould-board plough than deep conservation tillage and higher Calcium carbonate with depth. Resurfacing of such deeply accumulated lime could be beneficial while working with acid soils (Bezdicek et al., 2003) but detrimental as this study indicated when the soils are already alkaline calcareous. However, the 3% higher BY in deeply tilled soil might be due to improved physical conditions therein and the availability of more space and water resulting in more nutrient uptake. Results further indicated that there was no interaction between fertilizer treatments and tillage practices to affect GW, BY, GY and HI indicating that these two factors possessed significant ability to individually affect plant growth and yield parameters.

Results revealed that soil amendment from organic and inorganic sources significantly affected soil pH ($p<0.05$), $EC_{1:5}$ ($p<0.01$) and OM ($p<0.01$) whilst lime content remained statistically unaffected. The pH values observed at $FYM_{5,20}$ (7.91), $FYM_{10,15}$ (7.89) and FP (7.88) were statistically similar (Table 4). Whereas at $INM_{5:75}$ soil pH (7.72) significantly lower than FYM applied at any rate and the FP whilst it was statistically at par with $INM_{10:50}$ (7.77), $INM_{15:25}$ (7.75) and the RD (7.8) (Table 4). However, the $INM_{10:50, 15:25}$ were also statistically at par with FP and the FYM_{10}. These results clearly indicated that sole application of FYM has been significantly ($p<0.05$) increasing soil pH over the RD (upto 2.9%) whilst its mixed application along with inorganic NPK fertilizer has been decreasing it (upto 2.1%). Sole inorganic NPK application also possesses decreasing effect on soil pH, although, to a non-significant extent, up to 1.06%. It means FYM applied could have pH increasing characteristics under acid conditions (Ashiono et. al., 2005). In soil, manure in its humic form absorbs or binds H^+ ions resulting in a decrease in its concentration in soil solution (Munybarenzi, 2014) and therefore, increases soil pH (Joanna et al., 2014). Previous studies reported N fertilizers for decreased soil pH (Samuel et. al., 2011; Mercik and Stepien, 2012; Joanna et al., 2014) due to the addition of H+ into the soil (Munybarenzi, 2014). Lowering of pH by the INM might, therefore, be attributed to the NPK component of the treatment releasing H^+ ions by its nitrogenous part and its acidic single super phosphate (SSP)-fertilizer component and, in addition, through FYM mineralization and release of different organic acids (Okwuagwu et al., 2003). Ahmad et al. (2013) reported the lowest soil pH for treatment receiving organic sources with 50% of recommended NPK fertilizers.

It was further noted that soil amendments irrespective of its type and quantity, significantly ($p<0.05$) increased soil EC (by 16-19%) over the FP whilst they amongst themselves, despite a range of difference from 1 to 6%, were statistically at par (Table 4). The maximum increase (19%) in soil $EC_{1:5}$ over the FP was noted with RD and $INM_{10:50}$. These results indicated that RD increased soil EC by 1-6% more over the FYM and by 0-3% in INM. Lower EC in FYM treated soil than NPK despite its ability to increase Ca^{+2} and Mg^{+2} (Munybarenzi, 2014) could be ascribed to improved soil physical conditions with FYM which may favour more salts leaching than the NPK treated soils. The EC compensation effect of the INM is attributed to improved soil physical conditions by the organic component and soil acidification from N fertilizer resulting in the replacement of Ca^{+2} and Mg^{+2} on clay particles by Al^{+3} and H^{+1} and allowing them to leach down (Motta et al., 2002).

Results (Table 4) further revealed that tillage practices effect on soil pH, and $EC_{1:5}$ was highly significant ($p<0.01$) whereas the application of soil amendments were more effective in shallow tillage with regards to decrease in soil pH and EC than deep tillage and the deep tillage soil remained significantly higher in pH (by 2.19%) and EC (by 19%) than shallow tillage soil. Keeping these facts in mind, frequent deep tillage and without any visible or emerging need is neither feasible nor fruitful. The non-significant interaction of soil amendments and tillage practices with regard to soil pH and EC indicate that these two factors were mutually synergistic to affect soil pH and EC than in shared performance.

Results further revealed that RD increased OM by 66% over the FP (Tables 4) that could be credited its higher BY contributing to one third to one fourth of its portion below ground in form of root and stubbles. However, with FYM_5, increase in SOM over the FP was 63% which was comparable to RD. The 63% increase in OM with the lowest rate of FYM (5 t ha^{-1}) indicated its capacity to increase the soil OM. This fact was further affirmed by by the increases in soil OM (106, 103 and 120%) with increasing FYM applications (10, 15 and 20 t ha^{-1}, respectively). These results closely match the previous work (Mercik and Stepien, 2012; Ahmad et al., 2013). These results further clarified that soil OM increased with FYM_5 and FYM_{10} were quite wide but the difference between OM content in FYM_{10} and FYM_{15} and FYM_{15} and FYM_{20} treated plots were relatively narrow. These results, therefore, clarified that large increase in soil OM is possible with initial soil OM content and conversely the effectiveness of soil amendments decreases when the soil OM content increases in a given season. This may, however, not be true in longer period of time. The $INM_{5:75,\,10:50,\,15:25}$ recorded 132, 123 and 122% increase in OM over the FP, respectively. These results showed that the shared application of FYM and mineral fertilizers has had an asset over the sole NPK and the sole FYM. These results, further, clarified that the larger rates of FYM (20 t ha^{-1}) are almost two times more effective than the recommended NPK with regard to increase soil OM, however, their shared application could further improve this effectiveness to increase soil OM by 132% compared to FYM_{20}. This property of the INM could be attributed to the larger BY with the INM compared to FYM_{20}. Ahmad et al. (2013) after the application of shared organic and inorganic fertilizer to maize crop revealed the maximum post-harvest soil OM on a low fertility soil.

These results further indicated that soil OM in shallow tillage was different near to a significant level ($p=0.08$) than deep tillage soil, the difference, being 18% amongst these two. This, lower OM content in deep tillage soil is clearly due to the dilution of soil OM with large volume of soil in deep tillage than shallow tillage soil with which the same quantity of soil amendments were treated. Applications of 20 t ha^{-1} FYM integrated with NPK has been reported for 0.82% OM in the 0-20 cm and 0.6% OM in the 20-40 cm soil with an average amount of 0.71% in the 0-40 cm soil (Ahmad and Khan, 2014). This reported data support the dilution effect of the same quantity of soil amendment as well as the existing higher soil OM content of the surface soil when mixed with 0-40 cm soil through deep tillage compared to its incorporation with 0-20 cm soil through shallow tillage. These results, therefore, unveil the fact that unless required necessarily and for a particular purpose, deep tillage casts a damper effect on soil chemical properties under alkaline calcareous condition and in which case soil amendment quantity has to be increased.

A non-significant reduction in lime content ranging from 0.6 to 6.8% was noted with fertilizer amendments over the FP (Table 4). Decrease in the lime content with RD was the minimum (0.6%). With sole application of FYM, decrease in lime content ranged from 1% at medium rate (10 t ha^{-1}) to 6% at

Table 5: *Nutrition and tillage practices effect on mineral NPK in soil.*

Treatments	Mineral N mg kg^{-1}	AB-DTPA ext. P (mg kg^{-1})	AB-DTPA ext. K (mg kg^{-1})
Control	10.30 de	1.29 d	67.58 bc
NPK rec.	13.5 bcd	2.00 bc	73.17 b
5 t FYM	9.54 e	1.41 d	65.4 c
10 t FYM	11.65 cde	1.69 cd	72.37 b
15 t FYM	12.84 cde	2.05 bc	80.1 a
20 t FYM	13.73 bc	2.18 b	81 a
5 t FYM + 75% NPK rec.	17.26 a	2.85 a	81.67 a
10 t FYM + 50% NPK rec.	17.79 a	2.93 a	82.60 a
15 t FYM + 25% NPK rec.	16.67 ab	2.93 a	80.64 a
$LSD_{(p<0.05)}$	3.38	0.48	6.26
Shallow tillage (0-20 cm)	14.60	2.19	77.29
Deep tillage (0-40 cm)	12.80	2.10	74.83
T. Test $_{(p<0.05)}$	0.226 (ns)	0.78 (ns)	0.45 (ns)
F x T	ns	Ns	ns

Mineral N: N present in the inorganic forms as NO_3 and NH_4. Control (F. Pract. 60-45 NP kg ha^{-1}), NPK rec. (120:90:60 kg ha^{-1}), ext. (extractable), Means followed by same letters are not significantly different at the $p < 0.05$.

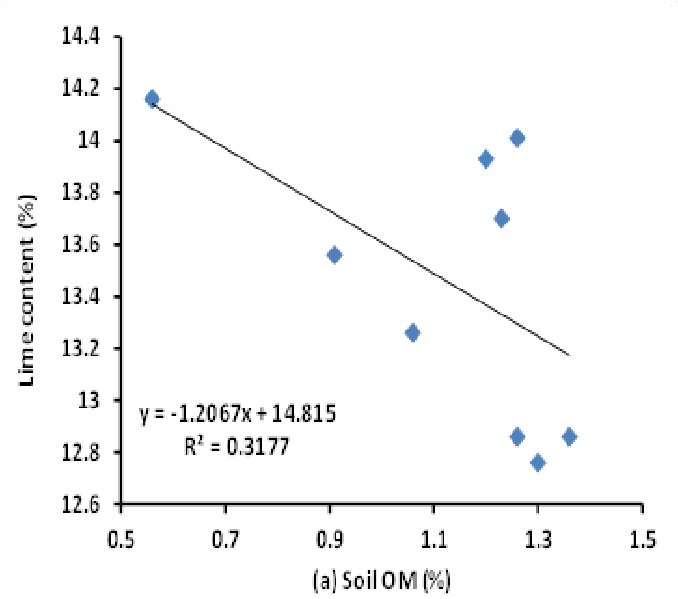

Figure 2: *Correlation between soil OM and lime content under the shallow tillage.*

higher rate (20 t ha^{-1}). The maximum reduction in lime content was noted with $INM_{10:50}$ whilst at either extremity of the shared application, reduction in lime content decreased. However, despite 0.6 to 6.8% reduction in lime, the trend remained non-significant and inconsistent. But, one indication was observed from the data (Table 4) that higher doses of FYM either as sole or combined with NPK showed maximum reduction in lime (upto 6.8%). These results are understandable as with the application of soil amendments, its OM content (Ahmad and Khan, 2014) and physical conditions (Ahmad et al., 2014) might have improved resulting in leaching of the existing lime content in soil. Upon these findings, SOM was correlated with soil lime content in the shallow tillage (r^2=-0.32) (Figure 2).

Results (Table 4) further revealed that lime in the deep tillage was significantly higher (by 15%) over the shallow tillage soil. This is clearly attributed to resurfacing of the leached and accumulated soil lime content and to the soil OM content and physical properties in deep tillage than the shallow tillage soil. There was no interaction between fertilizer amendments and the tillage practice to affect lime.

Applicating 20 t ha^{-1} FYM alone or in combination with inorganic fertilizers ($INM_{5:75,\ 10:50,\ 15:75}$) resulted in significant increase in soil mineral N ($p<0.05$), P ($p<0.01$) and K ($p<0.01$) over the FP (Table 5). The FYM_5 decreased the soil mineral N by 7% whilst the FYM_{10}, FYM_{15} and FYM_{20} increased it by 13, 25 and 33%, respectively, over the FP. The RD increased the mineral N by 31% over the FP (Table 5). The $INM_{5:75}$, $INM_{10:50}$ and $INM_{15:25}$ registered 68, 73 and 62% higher mineral N, respectively. However, despites 31 and 28% higher mineral N over the RD and FYM_{20}, the $INM_{15:25}$ remained statistically at par with these treatments (Table 5). With regard to AB-DTPA extractable P, the $FYM_{5,\ 10}$ were statistically similar to the FP while the RD was significantly (56%) than the FP. These results revealed the maximum increase in AB-DTPA extractable P with INM (128% with $INM_{10:50}$, 127% with $INM_{15:25}$ and 121% with $INM_{5:75}$) over the FP. However, all the INM treatments were statistically similar to each other and were significantly higher than the non-INM treatments.

The AB-DTPA extractable K did not improve with the $FYM_{5, 10}$ and the RD over the FP (Table 5). However, increase due to RD and the FYM_{10} were 8 and 7% higher, respectively, over the FP. The $FYM_{15, 20}$ significantly improved the AB-DTPA extractable K content with an increase of 19 and 20%, respectively, over the FP and remained statistically at par with INM treatments. The FYM_5 decreased the K by 3% over the FP suggesting the immobilization of K (Table 5). The maximum increase in AB-DTPA extractable K content was noted with $INM_{5:75, 10:50, 15:25}$ with 21, 22 and 19% increase over the FP. These results showed that the INM had a significant effect to increase in AB-DTPA extractable K content by 14% over the RD and are, therefore, superior amongst the treatments.

Data analysis further revealed that difference in mineral N, AB-DTPA extractable P and K contents in shallow tillage and deep tillage were non-significant. A non-significant interaction between the fertilizer amendments and tillage practice to affect the soil mineral N and AB-DTPA extractable P and K in soil was noted.

The NPK status of the initially poor but intensively cultivated soil can significantly be increased through application of soil amendments, irrespective of source and types (Sharif et al., 2004). However, these results indicated that the shared application of the inorganic fertilizers and FYM at intermediate rates were superior to their individual applications at recommended rates throughout the experiment. Patel et al. (2000) reported similar findings and stated that unless integrated with synthetic fertilizers, the sole use of FYM may not supply nutrient as per crop demand, especially in the year of application. The $INM_{5:75}$ and $INM_{10:50}$ were more successful in building-up of the soil available post-harvest NPK status. This could be credited to the efficiency of FYM manure in improving the fertilizer recovery (Gedam et al., 2008). Joanna et al. (2014) reported 56 mg kg^{-1} P in the N treated plot without FYM and 71 mg kg^{-1} P in the N treated plot applied with FYM. Literature revealed that sole NPK application at recommended rates may lose N upto 35% as Mercik and Stepien (2012) reported only 55-65% recovery of the applied N whilst the rest is lost through various pathways. Besides the increased recovery of the applied inorganic NPK by plants (Gedam et al., 2008) through improved soil physic-chemical properties (Tirol-Padre et al., 2007) the combined applied FYM also supply macro and micro nutrients through its own mineralization (Negassa et al., 2001; Tirol-Padre et al., 2007). Our results revealed that $FYM_{5,10,15}$ could not significantly increase available NPK content in soil over the FP and RD and that rather the lower rates of FYM (5 t ha^{-1}) decreased the mineral N content by 7% and K content by 3% over the FP that might be attributed to the lower NPK load in FYM and the resultant immobilization of the soil available nutrients. The increased N content up to 25% by FYM_{15} and 33% by FYM_{20} are apparently equal to the N content increased by RD (31%), however, due to their lower net increase in production and the problem of their availability in large quantities throughout the area put forward their grave disadvantage. Therefore, as stated above, the shared application at the lower to medium rates of FYM (5 and 10 t ha^{-1}) with 75 and 50% of the recommended NPK, respectively, is a solution for soil fertility and crop productivity problems of such poor but intensively cultivated soils.

The effect of tillage practice was apparently similar on soil NPK status, however, the higher mineral NPK content (by 12% N, 4% P and 3% K) in the shallow tillage than deep tillage soil might be associated with higher concentration of NPK in surface soil (Joanna et al., 2014). Individual analysis of the treatments effect in the shallow and deep tilled soils, revealed that the contribution of RD to soil mineral N was lower, however to a non-significant extent, than the FYM_{20} in the shallow tillage soil. But in the deep tillage soil the contribution of the RD to soil mineral N was higher, however to a non-significant extent, to FYM_{20}. Thus the initial administration of the applied N into deep soil portions through deep tillage and the subsequent escape through leaching from the shallow surface and accumulation there are the sole reasons. In case of P, both the RD and FYM_{20} contributed significantly higher in the shallow tillage soil over the FP whilst in the deep tillage soil, their effect was statistically similar to the FP. Joanna et al. (2014) reported the average content of available phosphorus was 59 mg P·kg^{-1} for the soil sampled from 0-15 cm and was 53 mg P kg^{-1} in the soil sampled 15-30 cm deep. In case of K content, the supremacy of $FYM_{5,10}$ as well as the RD was visible in shallow tillage soil, although to a non-significant extent, with 3, 13 and 14% increase whilst in the deep tillage soil the increase was -9, 1 and 3%, respectively. Motta et al. (2002) reported non-significant tillage effect on soil extractable K content at the same depth. Similar was the case for either the $FYM_{15,20}$ or their shared application with NPK at variable rates that lost their respective edge by 5-8% compared to the shallow tillage soil despite they maintained their superimacy with significantly higher AB-DTPA extractable K content over the FP.

Conclusions

Research concluded that 15 and 20 t ha^{-1} farmyard manure ($FYM_{15,20}$) were comparable to recommended dose (RD) but both lagged behind the integrated nutrient management (INM) with respect to yield and restoration of soil properties. Superior performance of the integrated application of 5 t ha^{-1} FYM and 75% of the recommended NPK ($INM_{5:75}$) compared to rest of the INM practices confirmed its potential to come up with the current crop nutritional demand in a low fertility alkaline calcareous soil. However, tillage depth was non effective in alkaline calcareous soils.

Author's Contribution

Imran Khan: Conducted the field experiment.
Zahir Shah: Planned the experiments and supervised the filed layout.
Wiqar Ahmad: Conducted the statistical analysis and manuscript write up.
Farmanullah Khan: Helped in data collection and laboratory analysis.
Muhammad Sharif: Helped in data collection, tabulation and calculations.

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