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IMPROVING WHEAT PRODUCTIVITY AND SOIL PHYSICAL PROPERTIES OF WATER ERODED AGRICULTURAL LAND THROUGH INTEGRATED PLANT NUTRITION

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ABSTRACT

Improving soil fertility and crop productivity through integrated nutrient sources is a globally accepted practice. The reported study was conducted during 2014-15 for field investigations in the improvement of eroded soil's physical characteristics and wheat crop productivity using integrated nutrient management techniques. The treatments contained combinations of NPK (% of the recommended dose 120:90:60 kg N: P_2O_5:K_2O ha^{-1}): FYM (t ha^{-1}). Poultry manure (PM, (t ha^{-1}) as; 0:0:0, 100%:0:0, 0:20:0, 25%:15:0, 50%:10:0, 75%:5:0, 0:0:10, 25%:0:7.5, 50%:0:5, 75%:0:2.5, 0:5:2.5, 25%:5:2.5, 50%:5:2.5 and 75%:5:2.5. Results revealed that 50%:5:2.5 combination of nutrient sources significantly ($P \leq 0.05$) improved spike m^{-2} (by 34%), grains spike^{-1} (by 38%) and grain yield (by 90%) over the control treatment. Regarding soil physical properties, 0:20:0 combination reduced soil bulk density and improved available water, organic matter content and saturation water percentage at 0-15 cm soil depth. Positive correlation of soil organic matter was observed with available water (ṙ= 0.92) and saturation percentage (ṙ= 0.93) while it showed negative correlation with soil bulk density (ṙ= -0.96). It was concluded that chemical fertilizer's showed improvement in physical properties of eroded soil, however, the resultant production was significantly lagging behind to that achieved with integrated nutrient management. Under the current experimental conditions, 50%:5:2.5 combination of nutrient sources application restituted the physical properties of eroded soil and showed asset over rest of the integrated plant nutrients management (IPNM) and their applications.

Keywords: available water, bulk density, organic and inorganic fertilizers, saturation percentage

INTRODUCTION

World's population has rapidly increased in the previous few decades and according to the latest reports it will reach to 9 billion by the year 2050 (UN, 2008). To feed the ever increasing population, growers are shifting to carry out agriculture activities on slopping and marginal lands also and that with unsuitable

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cultivation methods (Ali *et al*., 2007). These practices reward on site effects such as loss of soil particles, plant nutrients, change in soil structure, reduce available soil moisture and soil organic matter contents, all these factors are devastating soil productivity (Khan *et al*., 2004). Soil losses from sloppy field depend upon slope length and types, soil property, rainfall and soil management factor (Khan *et al*., 2001). Soil losses from 2-104 ț ħa^{-1} yr^{-1} in northern areas of Pakistan are reported (Khan *et al*., 2001). In district Swabi the soil loss from silty clay loam texture, with 50% slope has been calculated as 356 t ha^{-1} yr^{-1} without ground cover and taking no conservation measures (Allen, 1991). Bhatti and Zahid (1998) reported that grain yield of wheat crop got decreased by 20% in severely eroded land as compared to slightly eroded soil.

Under these circumstances, the soil physical, chemical and biological properties of water eroded land needs to be enhanced through joint use of mineral and organic nutrient sources to enhance crop yield on sustainable basis (Khan *et al*., 2007). Improving degraded soil quality depends on the improvement of its physicochemical and biological parameters (Ahmad *et al*., 2014). Initially the poor farming community uses livestock by product as fuel and the crop nutrients demand is meet from the recommended NPK fertilizer which provides specific nutrients to crop and improvement in soil physical parameters is negligible (Banning *et al*., 2008). Application of NPK fertilizers maintains yield potential, however, application of crop nutrients other than NPK fertilizers is needed for degraded soil to enhance soil environment and crop production (Mussgnug *et al*., 2006). Development of soil yield parameters and physical properties mainly rests upon the enhancement of soil organic matter content and replenishment of nutrient reserves (Ahmad *et al*., 2014). In an experiment Ahmad *et al*. (2017) reported 5 and 7% increase in total soil porosity and available water content and 4% decrease in bulk density of the moderately degraded Alfisols after four seasons applications of FYM (20 t ha^{-1}), 50% lower than the recommended N and of the same as the recommended P and K doses. This study was conducted on water eroded agricultural soil (34.72° N, 72.11° E) at Swabi district of the Khyber Pakhtunkhwa Province of Pakistan in 2014-2015 with the objective to provide a more realistic and feasible blend of the organic and inorganic nutrient sources for restoring the physical qualities and yield of the soils affected by water erosion.

MATERIALS AND METHODS

Experimental plot was selected on water eroded agricultural land (34.72° N, 72.11° E) in Swabi district of the Khyber Pakhtunkhwa province of Pakistan during 2014-2015. The mean annual rainfall varies from 450 to 750 mm. Mean temperature of the crop growth season was 18.85±3^{o}C during winter of 2014-15. However, maximum mean temperature was 25.7±3^{o}C and minimum temperature was 9.2±3^{o}C, with a relative humidity of 57.6% (Pakistan Metrological Department, Risalpur). The experimental soil was fine, mixed, hyperthermic, Typic on Haplustalfs (Pirsabak Soil Series). A composite soil sample was taken from 0-15 cm depth, before sowing and was analyzed for the determination of soil physical properties (Table 1).

Table 1. Physical properties of the composite soil under study before crop sowing

Properties	**Units**	**Concentration**
Sand	%	31.6
Silt	%	55.4
Clay	%	13
Textural class	-	Silt loam
Organic matter contents	%	0.69
Saturation percentage	%	33.28
AWHC	%	13.43
Bulk density	(g cm^{-3})	1.42

AWHC (available water holding capacity)

The experimental trial was carried out in a Randomized Complete Block Design (ŔĊƁƊ) replicated three times in treatment plot of 3 m x 5 m. The treatments contained combinations of NPK (% of the recommended dose (120:90:60 kg $N:P_2O_5:K_2O$ ḥa^{-1}) (Shehzadi *et al*., 2017): FYM (t ha^{-1}): Poultry manure (PM t ha^{-1}) as: 0:0:0, 100%:0:0, 0:20:0, 25%:15:0, 50%:10:0, 75%:5:0, 0:0:10, 25%:0:7.5, 50%:0:5, 75%:0:2.5, 0:5:2.5, 25%:5:2.5, 50%:5:2.5 and 75%:5:2.5. All the organic fertilizer doses were applied to respective plots 15 days before sowing. Wheat variety Aas was sown on 27 November 2014 and seed rate of 120 kg ha^{-1} was used. Urea, DAP and SOP were used as sources for NPK, respectively. Nitrogen was applied in two splits, half at sowing whilst the other half at tillering stage. All Ṗ and Ķ doses were applied at the time of sowing. All other agronomic practices were uniformly adopted. Soil samples from each experimental plot after wheat crop harvest were collected at 0-15 cm depth. Soil physical properties such as texture (Tagar and Bhatti, 1996), bulk density (Blake and Hartage, 1984), saturation percentage (Gardner, 1986) and available water holding capacity (Raza *et al*., 2003) from soil samples of each experimental plot were determined.

Data were collected on number of spikes m^{-2} and grains per spike at physiological maturity. Spike m^{-2} was calculated in each treatment by counting tillers in one meter row which were randomly selected at three different locations then changed into square meter. Grains per spike data was determined by selecting randomly ten spikes from each treatment and grains were counted in each spike, whereas grain yield was determined after threshing of each treatments plot, grains were cleaned weighted and then the data were converted into kg ha^{-1} by following formula:

$$\text{Grain yield}(\text{kg ha}^{-1}) = \frac{\text{Grain yield in four central rows}}{\text{Row} - \text{row distance x Row length x } \textit{number} \text{ of rows}} \text{x10000}$$

The data were subjected to analysis of variance (ANOVẠ) using Statistics 8.1 software. Mean values were compared using LSD (least significant difference) test at the $P \leq 5\%$ (Steel *et al*., 1997). Correlation of soil physical characteristics and organic matter content was determined using MS Excel.

RESULTS AND DISCUSSION

Spikes m^{-2}

Combined application of organic and inorganic nutrient sources significantly improved spikes m^{-2} of wheat crop (Table 2). Statistically maximum spikes m^{-2} (270) were produced with the use of 50%:5:2.5 combination of NPK: FYM: PM as compared to control (201). Increase over the control (34%) in spikes m^{-2} was recorded with the combined use of organic and inorganic fertilizers of 50%:5:2.5 combination of NPK: FYM: PM (Figure 1). These findings were in close confirmation of the results of Bhatti (2006), who reported that joint use of organic and inorganic nutrient sources significantly improved spike m^{-2} as compared to application of either organic or inorganic fertilizers alone. In an earlier study Idrees *et al*. (2002) investigated and informed that organic fertilizers slowly release nutrients through the process of mineralization throughout the growing season.

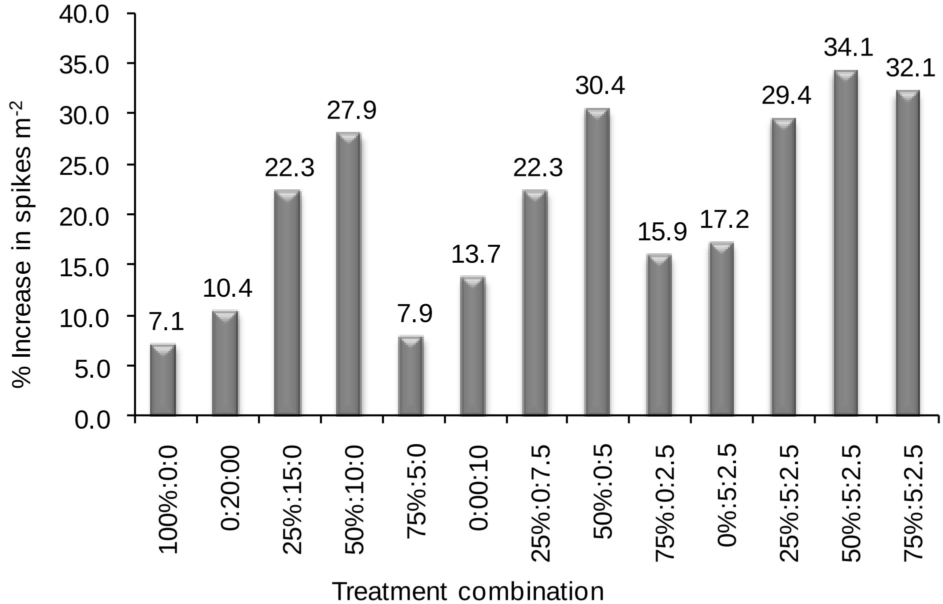

Figure 1. Percent (%) increase in spike m^{-2} over control due to organic and inorganic fertilizer application treatments

Grains spike^{-1}

Integrated use of organic and inorganic sources of nutrients had significantly enhanced grains spike^{-1} (Table 2). Statistically more grains spike^{-1} (63) were obtained with application of 50%:5:2.5 combination of NPK: FYM: PM, while fewer grains spike^{-1} (46) were obtained from control plot. Integrated use of organic and inorganic nutrient sources @ ratio of 50%:5:2.5 of NPK: FYM: PM improved grains spike^{-1} by 38% over control (Figure 2). Continued availability of crop nutrients from organic and inorganic nutrient sources might have improved grains spike^{-1}. Arif *et al*. (2006) reported that joint application of organic and mineral sources of crop nutrients enhances grains spike^{-1} which was associated to the slow release of plant nutrients from decomposition of organic manure maintaining continuous availability of plant nutrients during the crop growth period.

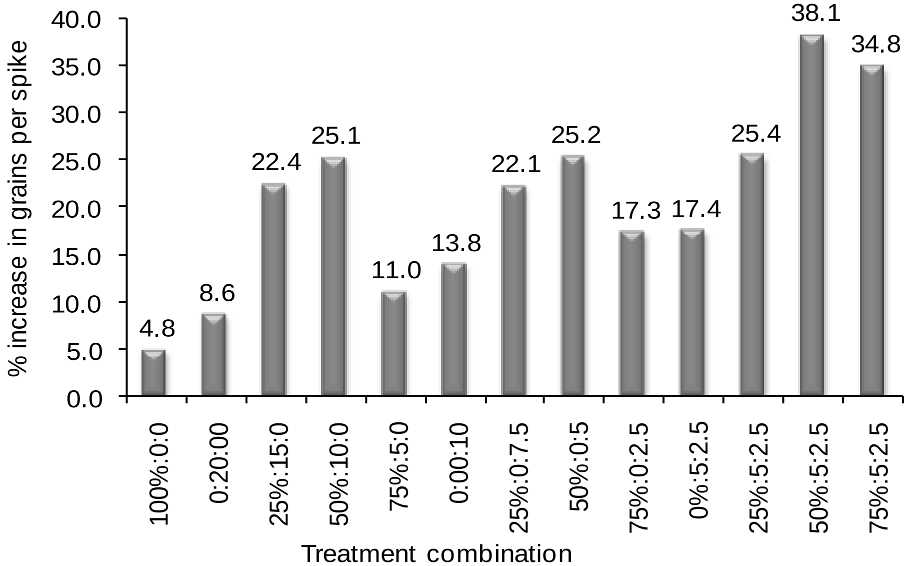

Figure 2. Percent (%) increase in grain spike^{-1} over control due to organic and inorganic fertilizer treatments

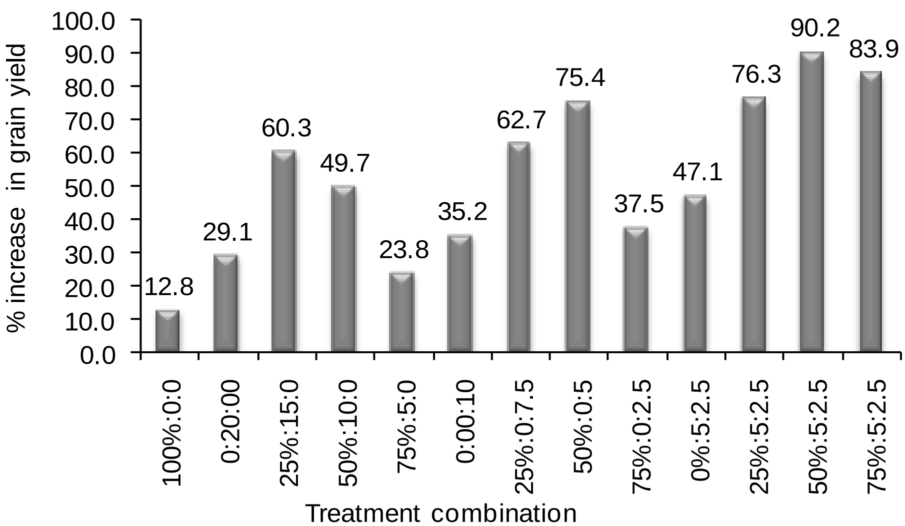

Figure 3. Percent (%) increase in grain yield over control due to organic and inorganic fertilizer treatments

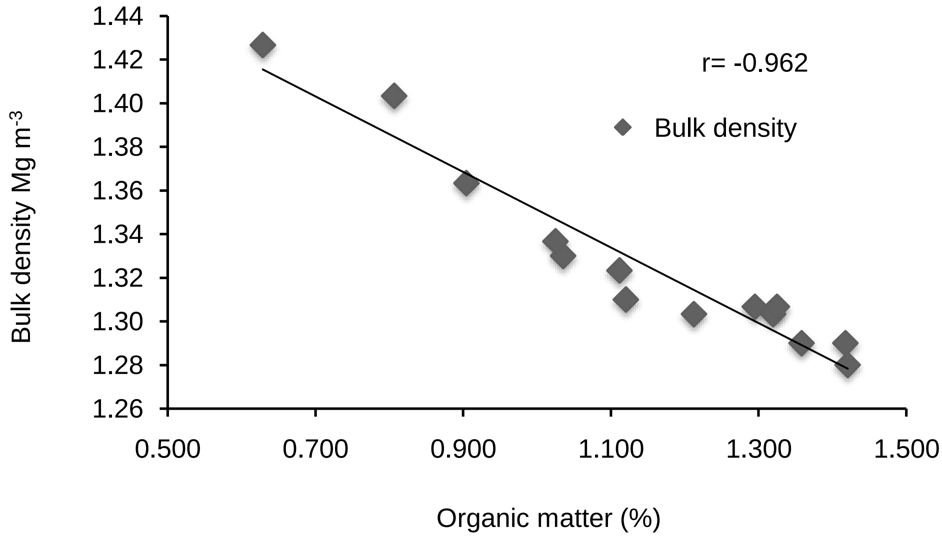

Figure 4. Relationship between soil organic matter and bulk density

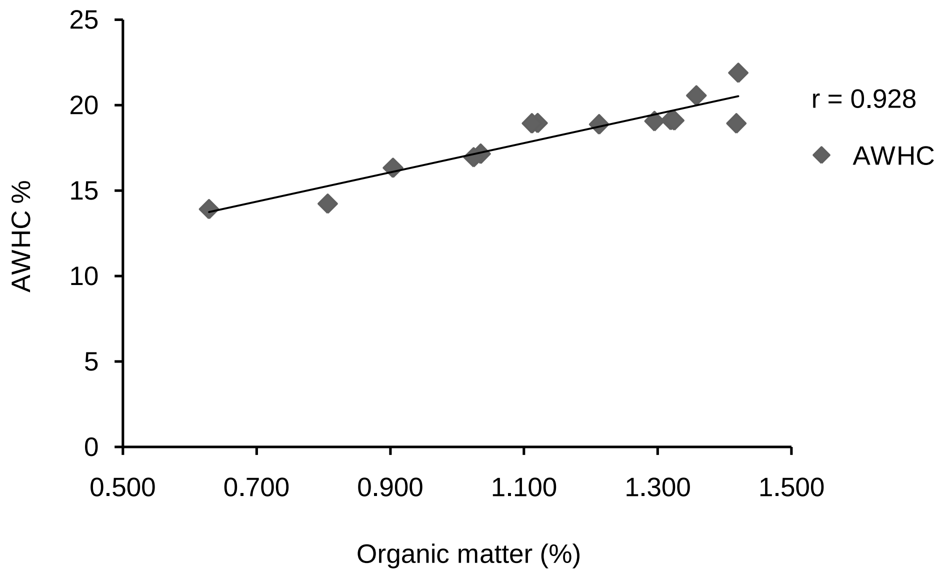

Figure 5. Relationship between soil organic matter and percent available water

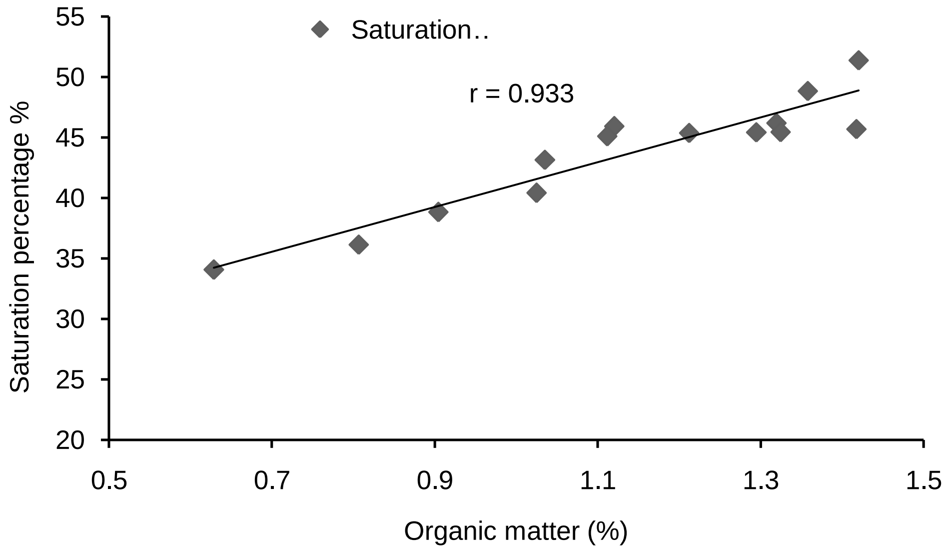

Figure 6. Relationship between soil organic matter and saturation percentage

Grain yield

Integrated application of organic and inorganic nutrient sources increased grain yield (Table 2). Statistically higher grain yield (4206 kg ḥa^{-1}) was produced with the integrated application of 50%:5:2.5 combination of NPK: FYM: PM as compared with minimum grain yield (2211 kg ha^{-1}) in control plot. The joint use of organic and mineral nutrient sources of 50%:5:2.5 combination of NPK: FYM: PM increased the grain yield by 90% over the control (Figure 3). The results obtained are in line with Pooran *et al*. (2002), who reported that significantly higher grain yield was obtained from the plots that were more fertile with proper water availability and better crop management practices. The application of organic manure might have improved soil nutrient holding capacity and boosted nutrients availability. Application of inorganic fertilizer has improved crop yield and growth rate (Rani *et al*., 2001), whilst the decomposing organic manures might have served for nutrients availability at the later growth stages of the crop resulting in higher grain yield from the treatment plots.

Soil bulk density

Joint use of organic and inorganic nutrient sources had significantly improved soil bulk density (Table 3). Statistically lower soil bulk density (1.28 g cm^{-3}) was recorded with the application of 0:20:0 combination, followed by 25%:15:0 combination of NPK: FYM: PM while higher soil bulk density (1.43 g cm^{-3}) was observed in control plots. The results are in accordance with Shirani *et al*. (2002), who investigated that application of organic manure alone or its combination with inorganic fertilizers had significantly improved ṣoil bulk density, enhanced soil porosity and soil condition due to the dilution of soil body with the application of organic matter. Parallel results were also obtained by Tejada *et al*. (2009) and Ahmad *et al*. (2017).

Table 2. Effect of integrated plant nutrients on spikes m^{-2}, grains pike^{-1} and grain yield of wheat crop

Treatments (NPK: FYM:PM)	**Spike (m^{-2})**	**Grains ($spike^{-1}$)**	**Grain yield (kg ha^{-1})**
0:0:0	201.7 f	45.6 e	2211 g
100%:0:0	216.0 ef	47.8 de	2493 fg
0:20:0	222.6 def	49.5 cde	2855 defg
25%:15:0	246.6 abcd	55.8 abcd	3544 abcd
50%:10:0	258.0 abc	57.1 abc	3311 bcde
75%:5:0	217.6 ef	50.6 cde	2738 efg
0:0:10	229.4 de	51.9 cde	2991 cdef
25%:0:7.5	246.6 abcd	55.7 abcd	3597 abc
50%:0:5	262.9 a	57.1 abc	3878 ab
75%:0:2.5	233.8 cde	53.5 bcde	3042 cdef
0:5:2.5	236.3 bcde	53.5 bcde	3253 bcde
25%:5:2.5	261.0 ab	57.2 abc	3900 ab
50%:5:2.5	270.5 a	63.0 a	4206 a
75%:5:2.5	266.4 a	61.5 ab	4066 a
LSD $_{(P \leq 0.05)}$	26.55	9.19	739

NPK (% of the Recommended dose (120:90:60 Kg $N:P_2O_5:K_2O$ ḥa^{-1}): FYM (t ha^{-1}): Poultry manure (PM t ha^{-1})

Table 3. Effect of integrated plant nutrient management on soil bulk density, saturation percentage and available water holding capacity (AWHC)

Treatments (NPK:FYM:PM)	**Bulk density (g cm^{-3})**	**AWHC (%)**	**Saturation (%)**	**Soil organic matter (%)**
0:0:0	1.43 a	13.9 g	34.1 g	0.63d
100%:0:0	1.40 ab	14.2 f	36.2 fg	0.81cd
0:20:0	1.28 d	21.9 a	51.4 a	1.42a
25%:15:0	1.29 d	20.6 b	48.8 ab	1.36a
50%:10:0	1.31 cd	19.0 c	45.9 bc	1.12abc
75%:5:0	1.33 cd	17.1 d	43.2 cd	1.04abcd
0:0:10	1.29 d	18.9 c	45.7c	1.42a
25%:0:7.5	1.30 d	18.9 c	45.4 c	1.21abc
50%:0:5	1.34 cd	17.0 d	40.4 de	1.02abcd
75%:0:2.5	1.36 bc	16.3 e	38.8 ef	0.90bcd
0:5:2.5	1.32 cd	18.9 c	45.1 c	1.11abc
25%:5:2.5	1.31 cd	19.1 c	45.4 c	1.29ab
50%:5:2.5	1.30 d	19.1 c	46.2 bc	1.32ab
75%:5:2.5	1.31 cd	19.1 c	45.4 c	1.32ab
LSD $_{(P \leq 0.05)}$	0.06	0.29	3.08	0.44

Available water

Joint use of organic and inorganic nutrient sources had significantly enhanced ṣoil available water holding capacity (Table.3). Application of 0%:20:0

combination of NPK: FYM: PM resulted in statistically higher soil available water (22%), followed by application of 25%:15:0 combination of NPK: FYM: PM. Application of 50%:5:2.5 combination of NPK: FYM: PM had improved soil available water as compared to control plot. Addition of organic matter showed improvement in soil porosity and aggregation, which might have increased soil water holding capacity. These results are in different with Ahmad *et al*. (2014, 2017), who reported that addition of organic matter either alone or in combination with inorganic fertilizers improve soil water holding capacity possibly due to its efficient water absorbing ability. The hydrophobic and colloidal nature of organic manure might be the probable reason of improved water holding capacity of soil (Mbah and Mbagwu, 2006).

Saturation percentage

Application of organic manures had significantly improved soil saturation percentage (Table 3). Statistically highest saturation percentage (51%) was observed with application of 0%:20:0 combination of NPK: FYM: PM, followed by the application of 25%:15:0 combination of NPK: FYM: PM. Addition of 50%:5:2.5 combination of NPK: FYM: PM resulted in statistically higher percent saturation as compared to control plot (34%). Application of organic manure had improved soil bulk density and enhanced soil porosity. The findings are in accordance with Khan *et al*. (2007) who described that addition of organic matter had improved soil bulk density and porosity. Haynes and Naidu (1998), have reported similar results.

Soil organic matter

Soil organic matter contents were significantly improved with application of organic manure alone or in combination with inorganic fertilizer over control treatment (Table.3). The plot which were treated with 0:20:0, 0:0:10 combination of NPK: FYM: PM resulted in statistically high organic matter content 1.42% and 1.36%, respectively, followed by the use of 50%:5:2.5 mixture of NPK: FYM: PM. The control treatment had low organic matter (0.63%). The results are supported by the finding of Blair *et al*. (2006) who concluded that use of organic manure alone or in combination with chemical fertilizer improved physical properties and organic matter content of soil. The probable reason may be due to increases in microbial activity which decomposes organic manure and increase organic matter content of soil (Marschner, 2011).

Correlation of organic matter with soil properties

Negative correlation of soil organic matter with bulk density (r= -0.96, Figure 4) while positive correlation with soil percent available water (Figure 5), and saturation was found (Figure 6). Organic amendments improved soil bulk density, total pores, percent saturation and available water (Wiqar, 2009).

CONCLUSION

From this investigation, it can be concluded that combined application of organic and synthetic fertilizers significantly improved crop yield and soil physical properties over the recommended levels of NPK fertilizers alone which counsel that the application of mineral fertilizers alone cannot improve the physical environment and yield potential of water-eroded soil. Therefore, integrated sources of plant nutrients application should be carried out for sustainable farming on such water eroded land. The current study found 50%:5:2.5 combination of NPK: FYM: PM as the best combination of nutrient sources for restoring soil physical properties and yield of the soil affected by water erosion.

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