Research Article

Nutrient Application from Integrated Sources Improve Crop Yield and Soil Properties of Water Eroded Land

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Abstract | Crop nutrition from integrated sources is advocated for higher productivity and soil fertility. The current research was designed to the exact ratio of nutrients from organic and inorganic sources for water eroded lands during 2007-08. The combination of nutrient sources tested were; control, NPK_{50} (50% NPK), NPK_{75} (75% NPK), NPK_{100} (100% NPK), FYM_{10} (10 t ha^{-1} FYM), $NPK_{50}+FYM_{10}$, $NPK_{75}+FYM_{10}$, $NPK_{100}+FYM_{10}$, FYM_{20} (20 t ha^{-1} FYM), $NPK_{50}+FYM_{20}$, $NPK_{75}+FYM_{20}$, $NPK_{100}+FYM_{20}$. Results revealed that $NPK_{75}FYM_{20}$, significantly ($p<0.05$) improved the yield. As regards soil properties, $NPK_{20}FYM_{20}$ reduced bulk density, increased WHC, saturation percentage, organic matter content, plant available N, P and K significantly ($p<0.05$) both at 0-15 and 15-30 cm depths. Effect of fertilizer sources either alone or in integrated form was non-significant on Cu, Zn, Fe and Mn concentration. Economic analysis showed that $NPK_{75}FYM_{20}$ rewarded the maximum net income of Rs. 43108 ha^{-1}, indicating its superiority for profitable wheat yield under rain-fed conditions. It can be concluded from these results that the application of plant nutrients from a variety of natural and manufactured fertilizer sources improve crop yield as well as augment the fertility of soils suffering from water erosion hazards.

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Introduction

Population increase and changes in dietary habits are important factors affecting food requirements of a nation. In the past few decades, population increase and the resultant increased food requirements compelled Pakistani growers for bringing marginal and sloping lands under cultivation with their inaccurate cultivation techniques (Ali et al., 2007). This practice, no doubt, rewards in the short run but is devastating for precious resources in the long run. The whole fertile surface soil is washed away as runoff after the occurrence of a few rainstorms leading to permanent degradation of soil. Crop productivity on such degraded soil goes uneconomical and restricted with respect to crop choice. Soil losses from a field are dependent upon many factors like type and amount of rainfall, soil characteristics, field slope type and length and soil cover and management factors. Due to these factors, researchers in northern Pakistan have reported soil loss from 2 – 104 t ha^{-1} $year^{-1}$ (Ahmad, 1990; Khan and Bhatti, 2000; Khan et al., 2001) with resultant soil physico-chemical deterioration including reduced soil organic matter (SOM) and nutrient concentration, reduced infiltration rate and water holding capacity, and exposure of clayey subsoil. Bhatti et al. (1997) reported loss of 48, 24 and 18 kg ha^{-1} soil P, N and organic matter, respectively, under water eroded conditions indicating heavy loss of valuable nutrients every year. Bhatti et al. (1998) further reported severe

Smith & Franklin

deficiency of available P and K (2.68 and 48 mg kg^{-1}, respectively) under eroded field conditions and the field was also low in organic matter (1.2 to 6.6 g kg^{-1}).

Cultivation of eroded lands need improved management techniques and conservation practices and the incorporation of nutrient from varied sources. Few of these nutrient sources have been counted by Khan et al. (2007) are farmyard manure, compost, humic acid, synthetic fertilizers and their combinations. Under such circumstances, livestock raring is very important way for the provision of farmyard manure required for intensive and sustainable crop husbandry (Reddy et al., 2003). In past, utilization of livestock by-products by the resource poor farming community for household energy purposes created its availability problems for field applications and the crop demand for nutrients is met only with sub optimal rates of NPK fertilizers. This has resulted in a decline in SOM and has negatively affected soil fertility and crop productivity. Chemical fertilizers applied to soils can provide crops with specific nutrient elements, but not with all the essential elements they need. Decreasing SOM is one of the main factors affecting the productivity and the effects are more pronounced in cases of lower NPK fertilizer application.

Imbalanced inorganic fertilization and lack of recycling of nutrients from natural sources adversely effected the fertility and productivity of our soil. Successful restoration of soil fertility require SOM improvement (Banning et al., 2008). Plant nutrient input from a variety of sources has proved to enhance SOM and crop yield on initially poor quality soils (Nawaz et al., 2000; Jadoon et al., 2004). Recently, with the introduction of alternative energy sources (natural gas and LPGs) in many villages of the experimental area, it is the time to inspire the concerned farming community to utilize their livestock bi-products for the restoration of their degraded soils and to obtain a satisfactory level of crop yield and profitable return. This experiment was planned with the objective to determine a reasonable ratio nutrients applied through natural and chemical fertilizers for improvement in yield and soil physico-chemical characteristics of water eroded land.

Methods and Materials

The study was planned in Randomized Complete Block Design (RCBD) at Jagganath village of District Swabi, KPK, Pakistan, during the year 2007-08. Soil was silt loam in texture, non-saline, alkaline (pH 8.1), calcareous (lime 13.75 %) with low SOM (8.04 g kg^{-1}) and poor in P (2.34 mg kg^{-1}) and K (55.25 mg kg^{-1}) availability. Physico-chemical properties of the site are provided in Table 1.

Table 1: *Physico-chemical characteristics of soil before sowing*

Properties	Units	Values
Bulk density	Mg m^{-3}	1.40
Available water	%	16.53
Saturation water	%	34.55
Texture class	-	Silt loam
pH	-	8.10
Electircal conductivity ($EC_{1:5}$)	dS m^{-1}	0.68
Soil organic matter (SOM)	%	0.80
$CaCO_3$	%	13.75
Mineral N	mg kg^{-1}	10.10
Plant available (AB-DTPA Extracted)		
phosphorus	mg kg^{-1}	2.34
Potash	mg kg^{-1}	55.25
Zinc	mg kg^{-1}	0.72
Iron	mg kg^{-1}	2.77
Copper	mg kg^{-1}	1.47
Manganese	mg kg^{-1}	5.25

Table 2: *Qualitative analysis of farm yard manure applied during the experiment*

Parameter	Value
Moisture (%)	53.5
Nitrogen (%)	1.13
Carbon (%)	21.51
C to N ratio	19.04
Phosphorus (%)	0.04
Potassium (%)	0.28
Fe (%)	0.01
Cu (mg kg^{-1})	15.17
Zn (mg kg^{-1})	22.44
Mn (mg kg^{-1})	78.87

The treatments consisted of the control, NPK_{50} (50% of the recommended NPK), NPK_{75} (75% NPK), NPK_{100} (100% NPK), FYM_{10} (10 t ha^{-1} FYM), $NPK_{50}+FYM_{10}$, $NPK_{75}+FYM_{10}$, $NPK_{100}+FYM_{10}$, FYM_{20} (20 t ha^{-1} FYM), $NPK_{50}+FYM_{20}$, $NPK_{75}+FYM_{20}$, $NPK_{100}+FYM_{20}$. Treatment size was 10 m^2 and the experiment was replicated three times. Urea, DAP and Potassium sulphate (SOP) applied as NPK sources. Nitrogen dose was applied in two splits, half during cultivation and half at second irrigation. All P and K were applied during cultivation whilst well decomposed farmyard manure (FYM) of known physico-chemical characteristics (Table 2) was applied one month before sowing. Wheat (*Triticum aestivum*) variety "*Tatara*" was sown as a test crop. Besides soil physico-chemical properties, data on grain, biological and straw yield and grain weight were noted in each treatment.

After crop harvest, data on biological yield was recorded by air drying wheat bundles and weighing them separately at interval until a constant dry weight was achieved. Grain yield was recorded by threshing wheat bundles from each plot separately and weighed with top load balance after air drying until a no change in weight was arrived 200 normal grains from each plot were counted, weighed on top load balance and multiplied by a factor of 5 to convert it to 1000 grain weight.

Soil samples at two depths (0 to 15 and onward to 30 cm) were taken from each plot after crop harvest in the form of undisturbed core samples and disturbed soil samples for further fertility analysis.

In soil physical parameters, bulk density (ρ_b) = Ms/Vt (Mg m^{-3}) (Blake and Hartge, 1984), Saturation percentage (ω_s)= (Mt-Ms)/Ms * 100 (Gardner, 1986) and available water holding capacity (ω_a)= (ωfc–ωpwp)/dry weight of the soil sample (g) * 100 (Cassel and Nelson, 1986) were determined through their respective standard procedures where ω_{fc} and ω_{pwp} are water content (g g^{-1} soil) at 0.3 and 15 bar, respectively. Amongst soil chemical parameters, SOM (Nelson and Sommers, 1982), Mineral N (Mulvaney, 1996), electrical conductivity (Rhodes, 1996) and pH (McClean, 1982), lime content by acid neutralization (Method 23c, USDA HB 60), Plant available phosphorus, potassium, zinc, iron, copper and manganese after AB-DTPA extraction (Soltanpour and Schwab, 1997) were determined by the using their respective standard procedures. Spectrophotometer set at 880 nm was used for phosphorus, flame photometer for potashium and atomic absorption spectrophotometer (Perkin Elmer Model 2380, USA) for micro-nutrients.

Statistical Procedures

Results were subjected to analysis of variance in RCB design using STATISTIX 8.1 software. Significantly different means comparison was carried out by LSD test (Steel and Terrie, 1980). For economic analysis, after considering the cost of fertilizers NPK (Economic Survey of Pakistan 2008-09) and FYM (local market), the incomes from grain yield and straw yield (local market) were used as; Net return = value of increased yield – cost of fertilizers.

Table 3: *Effect of single and combined application of chemical fertilizers and FYM on yield parameters*

Treatments	1000 grain wt. (g)	Grain yield (kg ha^{-1})	BY (t ha^{-1})	SY (t ha^{-1})
Control	36.2 h	2020 g	6.2 k	4.2 h
NPK_{50}	38.1 g	2481 f	6.8 j	4.3 g
NPK_{75}	39.2 f	2863 e	8.4 h	5.5 f
NPK_{100}	40.2 e	3043 e	8.8 g	5.8 e
FYM_{10}	38.2 g	2440 f	8.2 i	5.8 e
$NPK_{50}FYM_{10}$	40.2 e	3033 e	9.9 f	6.9 d
$NPK_{75}FYM_{10}$	41.2 d	3323 d	10.4 e	7.1 c
$NPK_{100}FYM_{10}$	42.3 c	3443 cd	10.6 d	7.2 b
FYM_{20}	40.2 e	2880 e	8.6 g	5.5 f
$NPK_{50}FYM_{20}$	44.3 b	3676 bc	10.8 c	7.1 c
$NPK_{75}FYM_{20}$	45.4 a	4020 a	11.4 a	7.4 a
$NPK_{100}FYM_{20}$	45.2 a	3790 ab	11.2 b	7.4 a

Recommended dose of NPK (120:90:60); **wt.:** *Weight;* **BY:** *Biological yield;* **SY:** *Straw yield; Means with different letters are significantly different from one another at the P<0.05 level*

Results and Discussion

Crop Yield

Results (Table 3) revealed significant (p<0.05) increase in yield parameters where the highest 1000 grain weight (GW_{1000}) and maximum grain yield (GY) were obtained with the application of $NPK_{75}FYM_{20}$. Whilst being statistically at par with $NPK_{100}FYM_{20}$, $NPK_{75}FYM_{20}$ showed 26, 20 and 14% higher GW_{1000} and 99, 76 and 48% higher *GY* over the control, NPK_{50} and NPK_{100}, respectively (Table 3). On the other extremity, same treatment ($NPK_{75}FYM_{20}$) resulted in 20 and 15% more GW_{1000} and 65 and 23% more *GY* compared to FYM_{10} and FYM_{20}, respectively. These results counsel the addition of 20 t ha^{-1} FYM in conjunction with low NPK by 25% of the recommended dose for highest production. The results further endorsed that integrative use of nutrients from organic and synthetic sources can restitute the fecundity of eroded lands and has asset over their unshared applications. Whilst, Nadeem et al. (2016) termed it the second favourable choice after the recommended inorganic NPK and micronutrients fertilizers in the planner part of Khber Pakhtunkhwa (Dera Ismail Khan) for higher grain yield, highest grain yield (maize) obtained by Jadoon (2004) after the conjunctive cure of FYM and chemical fertilizers in the northern Khyber Pakhtunkhwa supports our results. Such integrated use of nutrient sources have been advocated for improvement in soil OM content (Swarup, 2001), physical characteristics (Hati et al., 2006) and crop productivity (Jadoon, 2004).

Data obtained further showed that chemical fertilizers and FYM, applied singly and united, significantly ($P<0.05$) augmented the biological yield (*BY*) and straw yield (*SY*) over the control (Table 3). The higher *BY* and *SY* were obtained with cure of $NPK_{75}FYM_{20}$ registering an increment of 86, 40 and 30% in *BY* and 80, 71 and 29% in *SY* over the control, NPK_{50} and NPK_{100}, respectively. It was further noted that with regard to *BY*, FYM_{10} alone was comparable with NPK_{50} and FYM_{20} alone was comparable with NPK_{100}. With regard to *SY*, $NPK_{75}FYM_{20}$ was comparable with $NPK_{100}FYM_{20}$. Yet, all of these nutrient types and combinations were significantly potent compared to the control. Mineral fertilizers alone (NPK_{50} and NPK_{100}) also showed significant improvement in *BY* (11 and 43%, respectively) and *SY* (5 and 39%, respectively) over the control (Table 3). Plant nutrient supplementation through organic manure results in sustaining crop productivity (Patra et al., 2000). Nutrient application from inorganic (NPK) alone and its combination with organic fertilizer significantly improve crop growth rate (Nadeem et. al., 2016). Nutrients from mineral fertilizers get pronto free for the plants uptake to cater for early growth requirements whilst FYM slow decomposition ensure nutrients availability at the latter growth stages. Combination of both sources results in continuous nutrient supply throughout plant life resulting in higher biological yield (Ibrahim et al., 1992; FAO, 1995). Mussgnug et al. (2006) obtained higher yield with FYM application to nutrient deficient soils whilst Sohu et al. (2015) recommended to amend soil for nutrients half from organic and half from inorganic sources. It can be visualized from these results that conjunctive use of FYM and chemical nutrient sources has remodeled eroded soil capacity for crop production. Similar results have been reported by other scientists as well (Nawaz et al., 2000; Jadoon et al., 2004; Bhatti et al., 2005).

Economic Analysis of Fertilizers Application

Economic analysis of crop yield obtained from different fertilizer treatments (Table 4) showed that $NPK_{75}FYM_{20}$ produced the extremum net economic return (Rs. 43108 ha^{-1}) indicating thrifty significance for profitable wheat yield. Application of inorganic fertilizers (50, 75 and 100% NPK of the recommended dose) excluding any organic fertilizers produced the lowest economic return (Rs.1907, 14208 and 14648, respectively). It can be terminated from these results that the net return per unit area was raised due to the integrated use of organic and artificial nutrient sources and this may provide probably the most viable and sustainable option for cereal based cropping schemes under limiting soil conditions. This further indicated the amelioration of crop productivity of eroded lands making it more profitable and sustainable if practiced over time.

Table 4: *Economic analysis of fertilizers (Pak Rs.)*

Treatments	GY	SY	GYI	Value of GYI	SYI	Value of SYI	Cost of fertilizers	Net return
	-------kg ha^{-1} --------			Pak Rs.	kg ha^{-1}	-----------Pak Rs. ----------		
Control	2020	4105	-	-		-	-	-
NPK_{50}	2481	4314	461	11064	209	1463	10620	1907
NPK_{75}	2863	5518	843	20232	1413	9891	15915	14208
NPK_{100}	3043	5717	1023	24552	1612	11284	21188	14648
FYM_{10}	2440	5721	420	10080	1616	11312	6000	15392
$NPK_{50}FYM_{10}$	3033	6832	1013	24312	2727	19098	16620	29790
$NPK_{75}FYM_{10}$	3323	7122	1303	31272	3017	21119	21915	30476
$NPK_{100}FYM_{10}$	3443	7170	1423	34152	3065	21455	27188	28419
FYM_{20}	2880	5508	860	20640	1403	9821	12000	18461
$NPK_{50}FYM_{20}$	3676	7136	1656	39744	3031	21217	33188	29516
$NPK_{75}FYM_{20}$	4020	7394	2000	48000	3289	23023	27915	43108
$NPK_{100}FYM_{20}$	3790	7385	1770	42480	3280	22960	22620	41077

GY: *Grain yield;* **SY:** *Straw Yield;* **GYI:** *Grain yield increased;* **SYI:** *Straw yield increased*

Table 5: *Effect of inorganic fertilizer alone and in combination with FYM on soil physico-chemical properties*

Treatments	B. density Mg m^{-3}	WHC %	Saturation %	pH	$EC_{(1:5)}$ dS m^{-1}	OM g kg^{-1}
(0-15 cm)						
Control	1.40 a	17.3 h	35.4 d	8.25	0.39	6.3 i
NPK_{50}	1.40 a	17.9 g	36.7 d	8.16	0.40	6.9 h
NPK_{75}	1.40 a	17.9 g	36.6 d	8.14	0.50	7.1 h
NPK_{100}	1.41 a	18.0 f	36.8 d	8.10	0.64	7.8 g
FYM_{10}	1.29 b	19.7 e	41.3 c	8.07	0.30	9.0 f
$NPK_{50}FYM_{10}$	1.28 b	19.9 d	42.4 c	8.10	0.54	10.2 e
$NPK_{75}FYM_{10}$	1.25 c	19.9 d	42.0 c	8.11	0.31	10.3 de
$NPK_{100}FYM_{10}$	1.24 c	20.1 d	42.3 c	8.06	0.46	10.8 d
FYM_{20}	1.17 d	22.7 c	46.6b	8.04	0.54	12.2 c
$NPK_{50}FYM_{20}$	1.16 d	23.1 bc	47.2 a	8.12	0.57	12.7 bc
$NPK_{75}FYM_{20}$	1.14 a	23.2 b	48.7 a	8.11	0.64	12.8 b
$NPK_{100}FYM_{20}$	1.08 e	23.4 a	50.1 a	8.01	0.48	13.8 a
(15-30cm)						
Control	1.51 a	14.2 bcd	33.2 b	8.16	0.41	5.0 i
NPK_{50}	1.52 a	14.4 d	33.8 b	8.14	0.81	5.5 i
NPK_{75}	1.50 a	14.4 d	34.3 b	8.07	0.82	5.8 h
NPK_{100}	1.51 a	14.6 d	35.2 b	8.04	0.71	6.4 g
FYM_{10}	1.39 b	16.7 bc	40.3 a	8.06	0.94	7.5 f
$NPK_{50}FYM_{10}$	1.38 b	16.7 bc	40.8 a	8.09	0.83	8.5 e
$NPK_{75}FYM_{10}$	1.36 c	16.7 bc	41.6 a	8.11	0.76	8.9 de
$NPK_{100}FYM_{10}$	1.34 c	16.6 bc	41.5 a	8.03	0.81	9.3 d
FYM_{20}	1.28 d	19.7 b	46.0 a	8.08	0.90	10.8 c
$NPK_{50}FYM_{20}$	1.28 e	19.6 a	46.1 a	8.11	0.61	11.0 bc
$NPK_{75}FYM_{20}$	1.25 f	19.7 a	46.3 a	8.13	0.85	11.4 b
$NPK_{100}FYM_{20}$	1.21 g	19.9 a	47.0 a	8.11	0.80	12.4 a

Recommended dose of NPK (120:90:60); Means with different letters are significantly different than one another at the P<0.05 level

Post-harvest Soil Properties

Looking at overall changes in soil physico-chemical characteristics (Table 5), the physical properties like bulk density (ρ_b), available water (ω_a) and saturation water (ω_s) were affected by combined use of nutrient sources (FYM and commercial fertilizers). The lowest values of ρ_b (1.08 and 1.21 Mg m^{-3}) were noted with $NPK_{100}FYM_{20}$ (Table 5) followed by $NPK_{75}FYM_{20}$ (1.14 and 1.25 Mg m^{-3}) in plough layer (0-15 cm) and deep (15-30 cm), respectively. Soil ρ_b in FYM_{10} (1.29 Mg m^{-3}) FYM_{20} (1.17 Mg m^{-3}) reduced significantly from its peak level in the control (1.4 Mg m^{-3}). This showed that FYM_{20} was more effective in decreasing ρ_b. Available water (ω_a) and saturation water (ω_s) were maximum (23.37 and 50.13%, respectively) in the soil treated with $NPK_{100}FYM_{20}$ followed by $NPK_{75}FYM_{20}$ (23.16 and 48.73%, respectively) in 0-15 cm soil (Table 3). Compared to the control (17.27 and 35.37%, respectively), ω_a and ω_s with FYM_{10} were 19.68 and 41.32%, while with FYM_{20}, it were 22.67 and 46.65%, respectively. Similar trends in ω_a and ω_s were also observed at 15-30 cm soil depth. Increased SOM after FYM input and higher biomass production might be responsible for higher ω_a and ω_s. Sohu et al. (2015) recommended half of the required inorganic fertilizer in combination with organic sources of nutrients for improved organic matter stock and soil fertility status whilst Hati et al. (2006) and Ahmad et al. (2014) reported improved soil physical characteristics after application of similar soil amendments. Farmyard manure, on its decomposition, might have released Ca^{2+} helping flocculation of soil particles and resulting in increased total porosity (Sanchez et al., 1989) and subsequent increase in ω_s and ω_a whilst decreasing the ρ_b (Haynes and Naidu, 1998). Previous work also shows correlation between ρ_b and ω_s and ω_a to be significantly negative (Ahmad et al., 2014). Role of FYM in conservation of soil moisture has been reported by many researchers (Jadoon et al., 2004; Hati et al., 2006).

The lowest pH value (8.01) was noted in the soil treated with $NPK_{100}FYM_{20}$ followed by FYM_{20} and FYM_{10} alone (Table 5). This drop down in pH might be the result of H^+ produced during the degradation and nitrification of FYM and commercial fertilizers (Akram et al., 2007). Soil depth of 15-30 cm also showed similar results with regard to soil pH..There was no significant change in $EC_{1:5}$, which, however, was higher deep into the soil (15-30 cm) compared to the plough layer (0-15 cm).

Soil Organic matter (OM) content increased significantly (P<0.05) after the application of conjunctive nutrient sources. Highest OM content (13.83 g kg^{-1}) was observed in $NPK_{100}FYM_{20}$ followed by $NPK_{75}FYM_{20}$ (12.83 g kg^{-1}). Compared to the control (6.30 g kg^{-1}), OM content with the application of FYM_{10} and FYM_{20} was 9.0 g kg^{-1} and 12.23 g kg^{-1} respectively. The same trend of augmented OM was also found at the 15-30 cm depth. Wang et al. (2000) concluded that application of organic materials increased OM by 1.17 to 2.85 g kg^{-1} soil and reduced the oxidation stability of soil OM. The increased OM might be due to increased root mass and added FYM. Rasool et al. (2007) obtained 44% more OM, 2.5 fold higher total C and 5 fold higher labile C in manured (35 t FYM ha^{-1} yr^{-1}) plots. Eventually, proper manuring become an essential practice for optimum soil health and sustained crop production (Chaudhri et. al., 1998).

Table 6: *Effect of sole inorganic fertilizer and in combination with FYM on plant available nutrients concentration in soil*

Treatments	N	P	K	Cu	Zn	Fe	Mn
	……………………mg kg^{-1}……………………						
(0-15 cm)							
Control	8.2 l	1.8 c	56.2 h	1.29	0.78	3.09	4.73
NPK_{50}	8.8 k	4.6 bc	64.3 g	1.18	0.67	3.18	4.98
NPK_{75}	9.1 j	5.6abc	72.1cf	1.27	0.78	3.03	4.76
NPK_{100}	11.0i	6.1abc	81.9 c	1.11	0.71	3.21	3.95
FYM_{10}	12.2h	3.5ab	67.8fg	1.29	0.67	3.01	4.06
$NPK_{50}FYM_{10}$	13.4g	4.9ab	74.7de	1.32	0.59	3.09	4.22
$NPK_{75}FYM_{10}$	14.6f	5.9abc	85.0 c	1.11	0.74	3.15	4.62
$NPK_{100}FYM_{10}$	15.5e	6.5abc	91.9 b	1.14	0.80	3.05	4.50
FYM_{20}	20.2d	4.5abc	71.5 ef	1.27	0.57	2.92	4.18
$NPK_{50}FYM_{20}$	21.3c	6.2abc	77.4 d	1.37	0.87	3.18	4.36
$NPK_{75}FYM_{20}$	22.5b	6.5abc	95.1 b	1.33	0.77	2.89	4.84
$NPK_{100}FYM_{20}$	23.4b	7.6 a	121.3a	1.36	0.97	3.08	4.99
(15-30 cm)							
Control	7.9 k	1.4 g	48.5 i	1.54	0.52	2.96	4.33
NPK_{50}	8.6 j	3.8 e	54.3 h	1.50	0.78	2.87	4.68
NPK_{75}	8.9 j	4.2 d	44.1fg	1.59	0.76	3.31	4.46
NPK_{100}	10.4 i	5.3 c	79.9cd	1.02	0.61	2.59	3.95
FYM_{10}	12.1h	2.4 f	57.1gh	1.39	0.78	3.22	4.06
$NPK_{50}FYM_{10}$	13.2g	4.4 d	64.7ef	1.63	0.75	2.93	4.22
$NPK_{75}FYM_{10}$	14.4 f	5.1 c	75.0 c	1.44	0.84	3.20	4.72
$NPK_{100}FYM_{10}$	15.5e	5.8 b	81.9 b	1.44	0.87	3.95	4.80
FYM_{20}	20.2d	3.7 e	61.5 fg	1.35	0.83	2.99	4.68
$NPK_{50}FYM_{20}$	21.3c	5.3 c	64.0de	1.60	0.78	3.16	4.76
$NPK_{75}FYM_{20}$	22.2b	6.1 b	85.0 b	1.50	0.88	3.34	4.54
$NPK_{100}FYM_{20}$	22.9a	6.7 a	108.0a	1.52	0.89	3.27	4.59

Recommended dose of NPK (120:90:60); Means with different letters are significantly different than one another at the P<0.05 level

Mineral N and plant available P and K were increased to adequate levels in $NPK_{100}FYM_{20}$ followed by $NPK_{75}FYM_{20}$ (Table 6). The increase in Cu, Zn, Fe and Mn was non-significant. Iqrar and Tariq (2002) also reported that AB-DTPA extractable Zn and Cu were not affected with organic material application in short term experiments. However, despite their low nutrient concentration (Zaman et. al., 2004), organic manure possesses the potential to improve soil health and quality if used correctly for long time (Ahmad et. al., 2013). Initial levels of N, P and K were deficient and their levels increased due to the cumulative effect of commercial fertilizers and FYM. It was evident from the data (Table 6) that in the plough layer, sole inorganic and combined with FYM significantly ($P<0.05$) increased the post-harvest soil mineral N. Maximum post-harvest soil N of was observed in $NPK_{100}FYM_{20}$ (23.41 mg kg^{-1}) treatment followed by $NPK_{75}FYM_{20}$ (22.27 mg kg^{-1}). Soil mineral N with FYM_{10} was 12.16 mg kg^{-1}, while with FYM_{20} it was 20.23 mg kg^{-1} while with control it was 8.21 mg kg^{-1}. The maximum post-harvest soil mineral N concentration of 22.92 mg kg^{-1} was recorded in $NPK_{100}FYM_{20}$ followed by 22.23 mg kg^{-1} in $NPK_{75}FYM_{20}$ (Table 6) in the second depth (15-30cm).

The highest plant available P and K (7.61 and 121.32 mg kg^{-1}, respectively) were recorded in $NPK_{100}FYM_{20}$ followed by $NPK_{75}FYM_{20}$ (6.53 and 85.01 mg kg^{-1}). Plant available P and K contents after the addition of FYM_{10} were 3.53 mg kg^{-1} P and 67.80 mg kg^{-1} K, while with FYM_{20}, the extractable P and K contents were 4.48 and 71.46 mg kg^{-1}, respectively, compared to soil native values in control (1.81 mg kg^{-1} P and 56.17 mg kg^{-1} K),. Similarly, with depth (15-30 cm) the maximum post-harvest available P and K contents of 6.66 and 107.99 mg kg^{-1}, were recorded in $NPK_{100}FYM_{20}$ followed by 6.07 mg kg^{-1} P and 85.01 mg kg^{-1} K in $NPK_{75}FYM_{20}$ (Table 6). Nutrient loss from top soil with sheet and rill erosion (Bhatti et. al., 1997) and the agricultural activities with elevated nutrient exhaustion from soil plant system and the attendant small and imbalanced fertilization resulted in deteriorating soil fertility status (Sohu et. al., 2015). Use of fertilizers from both organic and inorganic origin not only elevate the nutrient status of soil (Pratt, 2008) but also bring about variation in physical, chemical and biological soil characteristics (Motavalli et al., 2003). Rasheed et al. (2003) and Ahmad and Khan (2014) also reported that use of organic fertilizer in conjunction with inorganic NPK increased plant available nutrient content in soil. There was also another possible effect of FYM through releasing organic acids after microbial decomposition (Ayaga et al., 2006) which could have solubilized soil P (Ahmad, 1999) and chelated Zn (Bhatti et al., 1982; Barak and Helmke, 1993).

Conclusions

This study concluded that integrated use of 75% NPK+20 t FYM ha^{-1} produced better and economical yield of wheat grown under rain-fed conditions along with improved physical condition of the soil and its fertility status. If practiced in long term, it will reclaim degraded soil conditions through ameliorating its physical and chemical characteristics and thus will have favourable impact on the environment.

Authors' Contribution

Prof. Dr. Farmnaullah Khan designed and managed the conduction of the experiment, Mr. Samad Khan was involved in field installation of the experiment, agronomic management and data collection, Dr. Wiqar Ahmad contributed in statistical analysis and manuscript writing and Mr. Imran Khan helped in data entry, storage and tabling and review collection.

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