Research Article

Optimizing Farmyard and Poultry Manures Co-Applied with NPK for Improved Yield and Soil Fertility of Water Eroded Land

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Abstract | Fertilizer application from integrated organic and inorganic sources is universally accepted agronomic practice for improved yield and soil properties. However, determination of a suitable dose from either source that could beneficially and easily combine to give maximum output still needs lots of research. The experiment was conducted during wheat season 2014-15 on a selected water eroded site in District Swabi. Fourteen treatments viz the control (T1), recommended dose (RD) (120:90:60 kg ha^{-1} N: P_2O_5: K_2O. T2), four combinations of farmyard manure (FYM) i.e 20, 15, 10 and 5 t ha^{-1} with 0, 25, 50, 75% of the RD (T3, T4, T5, T6, respectively), four combinations of poultry manure (PM) i.e. 10, 7.5, 5 and 2.5 t ha^{-1} with 0, 25, 50, 75% of the RD (T7, T8, T9, T10, respectively) and four combinations of the mixed FYM (5 t ha^{-1}) and PM (2.5 t ha^{-1}) with 0, 25, 50, 75% of the RD (T11, T12, T13, T14, respectively) were evaluated in RCB design. Results revealed that T13 (integrated 5 t ha^{-1} FYM + 2.5 t ha^{-1} PM + 50% RD) resulted in the maximum grain and biological yield (4.2 and 11.2 t ha^{-1}, respectively) and 1000 grain weight (40.57 g). Furthermore, T3 (20 t ha^{-1} FYM+0 NPK) resulted in the highest organic matter (1.42%) in soil as well as reduced soil pH and bulk density over control whilst the maximum soil mineral N, P and K (27.2, 15.4 and 136 mg kg^{-1}, respectively) were recorded in soil treated with 10 t ha^{-1} PM alone. However, due to highest yield as well as improved soil properties, this research suggest the integrated use of FYM+PM (5 + 2.5 t ha^{-1}) + NPK 50% of the recommended dose for sustainably improved production on eroded soils.

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Introduction

Due to increasing population, pressure on the cultivated lands has increased significantly in Pakistan. In some Districts of Khyber Pakhtunkhwa (KP) province, the cropping intensity has reached to 156% (Agricultural Census, 2010). With the changing life patterns, further increase in food and fiber demands of the increasing population resulted in deforestation and faulty cultivation of the cleared and improperly levelled fields. These combined with other land degradation factors like climate change, erratic and uneven rainfall, uncontrolled grazing of vegetation on mountain and steep slopes, the subsistence agriculture system and poor economic position of the farmers has significantly deteriorated the situation in many areas of KP province and soil losses by erosion in some areas of the province have been observed upto 104 t ha^{-1} per year (Ahmad, 1990).

Normal erosion is a constructive process for soil fertility and it becomes destructive only when human induced factors like deforestation and slope land cultivation accelerate it. This degrades the soil through structural, textural and nutritional and biological disturbance (Lal, 2003) resulting in declined crops yield (Arriaga and Lowery, 2003). Wheat, also known as king of cereals, is the main food crop of Pakistani people providing them with 60% of the required calories and protein (Khalil and Jan, 2002) suffers great productivity losses in erosion prone KP province compared to rest of the country. According to national agricultural statistics, average wheat yield in KP was 1.84 t ha^{-1} vs the country's average of 2.8 t ha^{-1} (Federal Bureau of Statistics, 2015). Under such circumstances nutrient replenishment from a variety of sources can restore soil health and productivity (Lamp, 2000).

Soil supplementation with nutrients integrating all their possible sources in order to maintain soil fertility and enhanced productivity per unit area on sustainable basis is technically called integrated plant nutrients management (IPNM) (Mahajan et al., 2008). Either accumulated by the crops or removed by soil erosion, amending soil with organic fertilizer can renovate most of its limiting nutrients. However, the problem with this method is the rate of nutrient release compared to the plant requirements especially for the first crop seasons and to overcome this problem, extra-ordinarily large applications of the well decomposed organic material are required. This could, perhaps, not be possible owing to the unavailability of well decomposed organic material in large quantities. Contrary to this, the application of inorganic fertilizer alone add some specific nutrients but may lead deficiency of others in relation to crop needs resulting in nutritional disturbance as well as decreased yield (Jadoon et al., 2003). However, fertilizing soil from integrated sources not only solve the problem but the practice is also amenable to diversified farming and socio-economic conditions (Lamps, 2000). Three main dimentions can be used to assess nutrients use efficiency in a particular farming system namely; i) Agronomic, ii) Economic and iii) Environmental effects per unit of nutrient input (Robert, 2005). The IPNM is a practice of nutrient's use efficiency optimization from a variety of fertilizer sources, decreases nutrients losses and show positive impact on the environment, yield improvement is economically sustainable. The present work was conducted on land bearing disturbances caused by water erosion in order to determine optimized quantity of farmyard and poultry manures for integration with inorganic NPK fertilizers aiming wheat yield and soil properties improvements of the water eroded lands particularly in Distrcit Swabi and the KP province in general.

Table 1: *Pre-sowing physico-chemical properties of the experimental site.*

Properties	Concentration	Units
Sand	31.6	%
Silt	55.4	%
Clay	13.0	%
Texture class	Silt Loam	-
pH (1:5)	7.8	-
EC (1:5)	0.53	d Sm^{-1}
Lime	14.77	%
Organic matter content	0.69	%
Bulk density	1.42	g cm^{-3}
Mineral N	12.6	mg kg^{-1}
AB-DTPA extractable P	2.43	mg kg^{-1}
AB-DTPA extractable K	65.8	mg kg^{-1}

Materials and Methods

A water eroded site was selected for the experiment at village Jalsai (34.72° N, 72.11° N), District Swabi, Khyber Pakhtunkhwa Province, Pakistan during 2014-15. Pre-sowing soil sampling at 15cm depth was carried out prior to experiment initiation to assess its initial fertility status (Table 1). Fourteen treatments viz the control, recommended NPK dose (RD) (120:90:60 kg ha^{-1} N: P_2O_5: K_2O), four combinations of farmyard manure (FYM, 20, 15, 10 and 5 t ha^{-1}) with 0, 25, 50, 75% of the RD, respectively, four combinations of poultry manure (PM, 10, 7.5, 5 and 2.5 t ha^{-1}) with 0, 25, 50, 75% of the RD, respectively and four combinations of the mixed FYM (5 t ha^{-1}) and PM (2.5 t ha^{-1}) with 0, 25, 50, 75% of the RD, respectively in sub plot size of 3×5 m^2 were arranged in RCB design replicated trice. Sources for farmyard and poultry manure were the local dairy and poultry farms in the area with chemical properties given in Table 2. Sources for inorganic NPK were urea, DAP and SOP, respectively. Nitrogen application was split at sowing and mid tillering stages. Wheat variety Atta Habib was sown in first week of November, 2014 and harvested in late April 2015. Data on biological and grain yield and 1000 grain weight were recorded following standard agronomic procedure. Post-harvest soil samples from 0-15 cm were collected from all treatment plots for analysis. Soil textural analysis was done by hydrometer method (Tagar and Bhatti, 1996), whilst soil-water suspension (1:5) was prepared and analysed for pH and E.C using their respective instruments (Mclean, 1982). Standard analytical methods were used for determination of soil organic matter (Nelson and Sommers, 1996), mineral N (Mulvany, 1996), available P and K (Soltanpour and Schawab, 1977). Nutrient analysis of the FYM and PM for total N (Bremner, 1996) and total P and K (Kue, 1996) were also carried out and are given in Table 2.

Table 2: *Chemical composition of farm yard manure and poultry manure.*

Parameters	FYM	PM	Unit
Total N	0.5	1.83	%
Total organic carbon	9.625	24.05	%
C/N ratio	19.25	13.14	-
Total P	0.204	0.992	%
Total K	0.52	1.36	%

Table 3: *Effect of organic and inorganic fertilizers application on wheat biological yield, grain yield and 1000 grains weight.*

Treatments	Biological yield	Grain yield	Thousand grain
	(kg ha^{-1})		weight (g)
T1	6360	2211	32.75
T2	6925	2493	34.24
T3	7923	2855	34.80
T4	10030	3544	37.05
T5	9158	3311	37.60
T6	7350	2738	34.95
T7	8293	2991	35.95
T8	9634	3597	36.92
T9	10340	3878	38.06
T10	8663b	3042	36.30
T11	8735b	3253	36.27
T12	10370	3900	38.83
T13	11149	4206	40.57
T14	10794	4066	39.01
$LSD_{0.05}$	2093	739	3.15

Statistical analysis

Data were analyzed in MS Excel and statistic version 8.1 to estimate analysis of variance (ANOVA). Least significant differences (LSD) at p=5% was applied to all significant means using Steel et al. (1997) procedure to determine significant different means amongst the treatments applied.

Results and Discussion

Yield parameters

Application of fertilizer from integrated sources has accrued universal acceptance as a successful agronomic practice for improved yield and soil properties. However, determination of site and resource specific doses from either source that could easily and beneficially integrate for maximum output still needs considerable research. In a similar quest, our results match the previously published data showing significant improvement in yield parameters (Table 3). However, the most suitable combination of sources and their respective doses that this research revealed for maximum yield parameters (Figure 1) was the integrated application of FYM and PM (5 and 2.5 t ha^{-1}, respectively) combined with NPK 50% of the recommended dose (T13) showing 75, 90 and 24% increase in the biological, grain and 1000 grain weight over the control (T1), respectively. Higher vegetative growth is ascribed to higher N availability to plant throughout crop life and the same can be accredited to N application from the combined organic and inorganic sources the latter of which is abruptly available to seedlings and making good their vegetative growth before the onset of mineralization and release of nutrients from the applied organic sources. Upon the exhaustion of inorganic N somewhere at mid growth stages, release of nutrients from organic amendments through mineralization sustain the vegetative growth. One of the advantages of the combined application of inorganic nutrients with the organics is that the organic part of amendments increase soil organic matter and the inorganic nutrients are saved from losses of various kinds in soil due to their chelation and release process upon the organic fraction of soil. Secondly, this organic matter improves nutrient availability through increasing water holding capacity of the soil and providing a medium for nutrient uptake by the crop. Similar results were revealed by Abbas et al. (2006), arguing that any yield increase as a result of IPNM could be the outcome of enhanced macro and micronutrients use efficiencies by the crop, as well as their increased photosynthetic activities. However, Swarup and Yaduvanshi (2000) also observed increased biological yield and credited it to utilization of all available

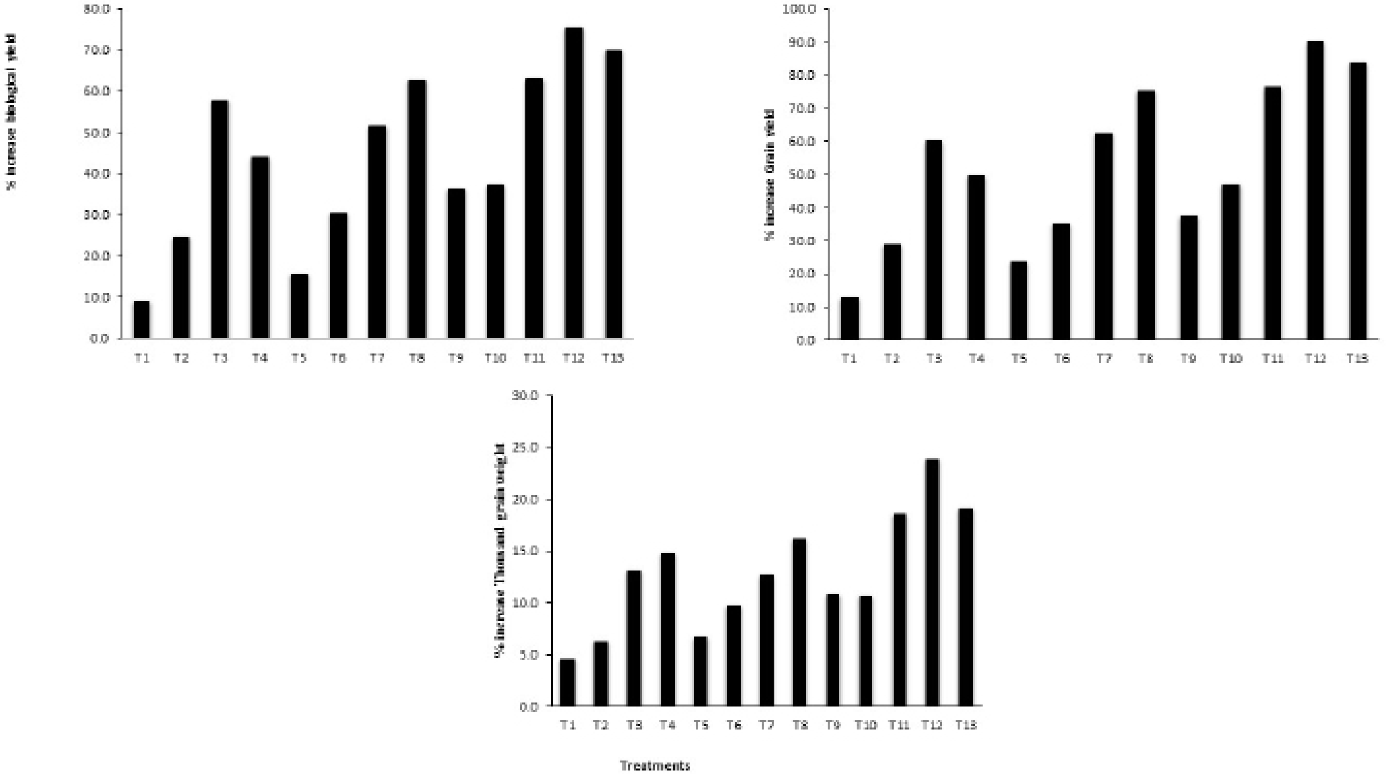

Figure 1: *Percentage variation in biological yield, grain yield and 1000 grain weight due to application of organic and inorganic soil amendments alone or integrated with respect to the control.*

nutrient resource for example continuous supplementation of nutrients from organic matter and an increased water absorption. Our findings closely follow Pooran et al. (2002) who emphasized that crop yield primarily, depends on soil available nutrients and plant absorbable water content and adoption to recommended crop management practices. For this purpose, if fertilization is necessary, it could be carried out from a variety of sources that increase the soil's cation exchange capacity and nutrients availability. Likewise, mineral fertilizer addition for nutrient supplementation could improve crop yield and growth rate (Rani et al., 2001). Robust vegetative growth also ensures efficient rooting system that upon optimum nutrients availability throughout plant life ensures their conduction to the final sink, the grain, and results in improved grain weight and the total yield. Zeidan and Kramany (2001) reported that increased grain may be credited to balanced nutrients availability and absorption. The application of nutrients from different sources enhances photosynthetic efficiency and result in the required grains weight. Similarly, Alam et al. (2005) reported that at early maturity and grain filling stage accumulates photo assimilate and increased grains weight.

Soil properties

Nutrients management practices from organic and inorganic alone or their integrated application significantly ($P \leq 0.05$) affected soil properties (Table 4). Plots treated with FYM 20 t ha^{-1} alone registered the minimum soil pH (7.55) with 3.4% reduction over the control. Drop in pH with NPK alone (T2) or its combination with low doses of FYM (T6) and PM (T9 and T10) were non-significant (0.5, 0.7, 1.2 and 0.7%, respectively) whilst higher doses of FYM (10-20 t ha^{-1}) and PM (7.5-10 t ha^{-1}) in combination with their respective inorganic NPK ratio significantly decreased soil pH. Decomposition of organic manure might have released H^+ in soil solution or produce organic acid resulting in soil pH reduction (Porter et al., 1980). However, as intimated by Stamatiadis et al. (1999), sole N fertilizers could also reduce pH up to 1.4 units.

Treatment with FYM 20 t ha^{-1} showed the minimum bulk density (1.28g cm^{-3}) followed by treatments where the FYM (t ha^{-1}): PM (t ha^{-1}): NPK (% of the RD) ratio was 15:00:25, 00:10:00, 00:7.5:25 and 5: 2.5:50 whilst the maximum bulk density (1.43g cm^{-3}) was noted in the control without any soil amendments. Shirani et al. (2002) also revealed reduced bulk density with manure application that resulted in increase soil porosity because of dilution of the soil body and improved soil conditions. Our results (Table 4) showed FYM (20 t ha^{-1}), PM (10 t ha^{-1}) and

Table 4: *Effect of organic and inorganic fertilizers application on soil properties and nutrient status.*

Treatments	Soil pH	Soil BD	Soil OM	Mineral N	AB-DTPA extractable	
					P	K
		(g cm^{-3})	(%)	(mg kg^{-1})		
T1	7.81	1.43	0.63	10.9	2.1	63.7
T2	7.77	1.40	0.81	14.9	4.3	110.3
T3	7.55	1.28	1.42	17.9	13.6	101.7
T4	7.58	1.29	1.36	21.8	8.2	113.3
T5	7.61	1.31	1.12	19.7	7.3	118.0
T6	7.75	1.33	1.04	16.6	6.0	116.0
T7	7.59	1.29	1.42	27.2	15.4	136.0
T8	7.65	1.30	1.21	19.2	14.2	131.3
T9	7.71	1.34	1.02	17.5	10.5	121.0
T10	7.75	1.36	0.90	15.3	10.2	120.0
T11	7.65	1.32	1.11	18.8	10.9	109.7
T12	7.66	1.31	1.29	20.2	11.4	106.3
T13	7.66	1.30	1.32	22.1	12.2	129.3
T14	7.65	1.31	1.32	25.9	11.0	119.3
$LSD_{0.05}$	0.11	0.058	0.44	7.04	4.97	27.37

FYM 15 t ha^{-1}: NPK 25% of the RD resulted in the maximum soil organic matter contents (1.42, 1.42 and 1.36%, respectively), whilst the control being the lowest in soil organic matter (0.63%). Increasing organic matter due to application of organic amendments had aggregating effect on soil particles thereby increasing soil porosity and reduced bulk density. Release of Ca^{+2}, a soil cementing agent, from organic matter decomposition might be responsible for soil aggregating effect. Similar results have also been reported by Tejada et al. (2009).

Poultry Manure (10 t ha^{-1}) resulted in the maximum mineral N (27.2 mg kg^{-1}; Table 4) and that being accredited to its native higher total N concentration and the lowest C/N ratio (Table 2). Results further indicated that inorganic fertilizer in combination with low dose of organic amendments also enhanced mineral nitrogen and the treatments receiving combined FYM and PM (5 and 2.5 t ha^{-1}, respectively, along with 50% of the recommended NPK increased mineral nitrogen significantly ($p<0.05$) over the control and this could be ascribed to the release of mineral N from organic amendments through mineralization as well as its entrapment with organic fraction and the expected reduced N losses after its direct application through inorganic NPK fertilizers. The expected increase in microbial activity as a result of higher substrate for their consumption in the organically amended treatments might have consumed and locked up the available N into their bodies thus prevent its losses from the soil system. The same N again become available upon microbes death and decomposition. The findings of Khaliq et al. (2006) support our results stating that nutrient availability as well as soil environmental conditions were both improved by organic manuring. Furthermore, the lowest mineral N (10.94 mg kg^{-1}) was observed in the control.

The organic and inorganic fertilizers applied either alone or in combination significantly ($P \leq 0.05$) increased post-harvest soil P and K contents in soil (Table 4). The maximum soil P and K contents were observed for treatment treated with 10t PM alone. Treatments that were treated with combined 2.5 t ha^{-1} PM, 5 t ha^{-1} FYM and 50% of the recommended NPK also showed significantly higher P and K contents in soil over the control whilst the minimum soil P and K were observed in the control. Better availability of both nutrients could be ascribed to both their direct application through organic and inorganic fertilizers and through normalizing soil pH with organic fraction as well the resultant increased microbial activity might solubilize and release the fixed P in soil. Our findings confirm the reported results of Salako (2008) and Ibrahim et al. (2008) stating that available P in soil was increased wherever it was externally applied irrespective of its source or through a combination of its sources. Our findings are also in line with Ayeni and Adetunji (2010) results for integration of poultry manure with mineral fertilizers and the resultant increase in soil K and other nutrients

Conclusion

Results concluded that the practice of IPNM significantly improved soil fertility and productivity. This research, however, recommends further splitting up of the organic and inorganic amendment doses suitable for a particular environment. In soil like those of this research with initially very low OM content (0.69%), application of inorganic fertilizer at the rate of 50% of the recommended NPK in combination with 2.5 t ha^{-1} PM and 5 t ha^{-1} FYM is recommended for enhanced wheat yield and improved soil physico-chemical properties.

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Authors Contribution

Murad Ali conducted the experiment, Farmanullah Khan was involved in planning and supervising and write up, Wiqar Ahmad helped in statistical analysis and write up, Imran Khan helped in field installation and data collection.

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