Effect of farmyard manure (FYM) and inorganic fertilizers on the yield of maize in wheat-maize system on eroded inceptisols in northern Pakistan

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Abstract

Crop productivity of eroded lands is very poor due to removal of top fertile soil losing organic matter and plant nutrients. Crop productivity of such marginal lands needs to be restored in order to meet the food requirements of increasing population. Field experiments were conducted at Thana, Malakand; Kabal and Matta, Swat; North West Frontier Province (NWFP) of Pakistan for three years during 2003-2004 to 2005-2006 to study the effect of inorganic fertilisers alone and in combination with farm yard manure (FYM) under wheat-maize-wheat system. The fertiliser treatments consisted of farmer's practice: T_1 (60-45-0 kg N-P_2O_5-K_2O/ha), inorganic fertilisers: T_2 (120-90-60-5 kg N-P_2O_5-K_2O-Zn/ha), and combined application of inorganic and organic: T_3 (60-90-60-5 kg N-P_2O_5-K_2O-Zn/ha + 20 t FYM/ha). Maize crop was grown after wheat crop during 2004 and 2005 at all the three sites. Maize crop received the above three treatments but without FYM in T_3. Maize crop failed at Thana and Kabal during 2004. The results of individual as well as the pooled data of three sites during 2005 showed that T_3 which received FYM for wheat crop gave significantly higher grain as well as stover yields over the other two treatments. The increases in grain yield due to T_3 over T_2 and T_1 were 89 and 16%, respectively averaged over sites, while T_2 increased grain yields by 64% over T_1. T_3 also proved economically over the other treatments at all the sites giving higher net returns. It could be concluded that FYM applied to wheat crop has carryover effect on maize crop in wheat-maize cropping system and can restore the crop productivity of eroded lands.

Keywords

Farm yard manure, inorganic fertilisers, maize yield and eroded inceptisols.

Introduction

North West Frontier Province (NWFP) of Pakistan encompasses about 10.17 million ha and northern NWFP is the most important agricultural region growing maize. Winter wheat-maize rotation is dominating cropping system in this area under rainfed conditions. Total area under maize crop in NWFP was 492000 ha with a total production of 784000 tons and an average yield of 1593 kg/ha during 2005-2006 (NFDC, 2006). In northern NWFP, the average yield of maize is very low due to erratic rainfall patterns and poor traditional management practices. Both the cereals are used as food by the local populations as well as the other areas of NWFP. Maize is also a potentially important feed source for livestock industry.

After 1960s, due to replacement of recycling of organic wastes and application of inorganic fertilisers with the introduction of new crop varieties, the physical conditions of the soils have become deteriorated particularly in rainfed areas of NWFP. This ultimately has accelerated soil erosion and there have been heavy losses of soil and plant nutrients (Khan et al., 2001). This has resulted in poor soil fertility of eroded marginal lands. There is a need to develop and promote management strategies to use both organic and inorganic sources of plant nutrients for sustained crop production. In addition to restricted use of organic manures, inorganic fertilisers are applied at very low rates and imbalanced proportions. During 2005-2006, N: P use ratio was 3.44:1 in Pakistan (NFDC, 2006). Balanced application of plant nutrients and integrated plant nutrient management have proved to enhance crop yields. (Bhatti and Khan 2000; Jadoon et al., 2003; Dong et al., 2006).

Wheat-maize is a common crop rotation in northern NWFP of Pakistan. With current soil fertility management in wheat-maize-wheat system, external organic matter sources are rarely supplied which in the long run has affected soil organic matter decline, nutrient recovery as well as crop productivity of cropping system. Keeping in view the importance of food security and sustainability of crop production, a study was carried out in the northern NWFP, Pakistan to assess effects of inorganic and organic sources (FYM) on the yield of maize in wheat-maize-wheat cropping system on eroded lands.

Material and Methods

A field survey was conducted in the Malakand and Swat district of North West Frontier Province (NWFP) of Pakistan for selection of sites for field experiments during 2003. Three eroded fields were selected. The geo position of the selected fields is given in Table 1. Soils of all three sites were classified according to the U.S.D.A. Classification System. Soil series and taxonomic class of the three sites is as follows (Table 1)

Table 1. Location and soil classification of experimental sites.

Site	Geo-Position	Elevation	Soil Series	Taxonomic class
Thana	34^0-36′ N, 72^0-05′ E	796 m	Burhan	Clayey, mixed, hyperthermic, Udic Haplustepts
Kabal	34^0-45′ N, 72^0-15′ E	888 m	Missa	Coarse silty, mixed, thermic, Typic Dystrudepts
Matta	34^0-56′ N, 72^0-23′ E	1175 m	Buner	Fine loamy, mixed, thermic, Typic Dystrudepts

Field Experiments

Field experiments were started on wheat during 2003-2004, and continued during 2004-2005 and 2005-2006 in the same layout according to the plan. The experiment consisted of cropping system and fertiliser treatments. Cropping system was wheat-maize-wheat. Fertiliser treatments for wheat and maize crops are given in Table 2. Randomised Complete Block was used with three replications at each location.

Table 2. Rates of N, P_2O_5, K_2O, Zn (kg/ha) and FYM (t/ha) applied in different treatments.

	Wheat					Maize			
Treatments	N	P_2O_5	K_2O	Zn	FYM	N	P_2O_5	K_2O	Zn
T_1	60	45	0	0	0	60	45	0	0
T_2	120	90	60	5	0	120	90	60	5
T_3	60	90	60	5	20	60	90	60	5

Farmyard manure (FYM) was collected from the cattle barnyard and was applied at the rate of 20 t ha^{-1} to T_3 (NPKZn+FYM) plots about one month before sowing of wheat crop during all the three winter seasons. All the PKZn fertilisers were applied at the time of sowing and well incorporated into the soil. In case of nitrogen (N), half N was applied at sowing and the remaining half N after about one month. Sowing of wheat was done in November each year. Crop was harvested from a net area of 1 m^2 in duplicate from each treatment plot in May each year and threshed. Grain yield was recorded in kg/ha. During summer 2004 and 2005, maize was grown according to the plan.

The maize variety Azam was sown in July in the respective treatments after wheat during 2004 and 2005 at all the three sites. Fertilisers were applied to respective treatment plots. Half N was applied at sowing and half N at knee stage, while all PKZn fertilisers were applied at sowing. Crop was harvested from a net area of 1 m^2 in duplicate from each treatment plot in October each year at all the sites and threshed to measure grain yield.

Soil Analysis

Composite soil samples were collected at the depth of 0-30 cm from the experimental sites before starting the experiment in 2003 and were analysed for various soil properties (Table 3). Soil texture in the surface soil at all the three sites was loam in nature and the Kabal site had a little higher clay content.

Table 3. Soil analysis of experimental sites.

Site	Depth	pH	ECs	Lime	OM	**ABDTPA Extr. (mg/kg soil)**					
	(cm)	(1:5)	(dS m^{-1})	(g kg^{-1})	(g kg^{-1})	P	K	Zn	Cu	Fe	Mn
Thana	0-30	7.80	0.1236	172.5	11.0	3.98	88.00	0.30	1.95	7.46	9.00
Kabal	0-30	7.81	0.181	180.0	5.2	2.19	104.8	0.70	1.74	7.70	9.31
Matta	0-30	7.76	0.161	130.0	16.9	3.33	176.0	0.56	3.17	14.55	18.22

Statistical Analysis

The data collected on maize yields were statistically analysed using Randomised Complete Block design with three replications. Treatment means were compared using Least Significant Difference (LSD) test of significance at 5 and 1% level of significance and the combined analyses of maize yield data were done according to Gomez and Gomez (1984).

Results and discussion

Maize grain yield at Matta during summer 2004

The maize crop failed at Thana and Kabal due to severe drought during summer season 2004, while the maize crop at Matta survived and was harvested. Treatment effects were highly significant ($P < 0.01$), with T_2 producing the highest yield of 3117 kg/ha but on a par with T_3 (Table 4).

Table 4. Effect of fertiliser treatments on the yield of maize at Matta, Swat during summer 2004.

Treatments	Grain yield (kg/ha)	Increase over (%)	
		T_1	T_2

T_1	1825 b	-	-
T_2	3117 a	71	-
T_3	3050 a	67	-

Comparison of maize yields over locations during summer 2005

Combined analysis of the pooled data on grain yield of maize over locations showed that the effect of treatments and locations were significant ($P<0.01$, $P<0.05$, respectively). Treatment mean grain yield differed significantly from one another (Table 5). The highest yield of 2510 kg/ha was obtained from T_3. The highest yield was obtained at Matta and was significantly different from the other two sites.

Table 5. Grain and stover yields (kg/ha) of maize as influenced by fertiliser treatments at different locations during summer 2005.

Treatments	Thana (Grain kg ha^{-1})	Kabal	Matta	Mean	% increase over	
					T_1	T_2
T_1	974	1018	1985	1326 c	-	-
T_2	1634	1661	3212	2169 b	64	-
T_3	2325	1771	3433	2510 a	89	16
Mean	1645 b	1484 c	2877 a			
	Stover (kg/ha)					
T_1	1592	1727	2107	1808 c	-	-
T_2	3004	2680	3817	3167 b	75	-
T_3	4081	3443	4101	3875 a	114	22
Mean	2892 ab	2617 b	3342 a			

Combined analysis of the pooled data on stover yield over locations showed that the treatment differences were highly significant ($P<0.01$), and all three treatments differed significantly from one another (Table 5). The highest yield of 3875 kg/ha was obtained from T_3 followed by 3167 kg/ha from T_2. As regards sites, the differences among sites were significant ($P<0.05$). The highest yield of 3342 kg/ha was obtained at Matta followed by 2892 kg/ha at Thana being comparable with each other.

Temporal Variation

Combined analysis of the data on grain and stover yields of maize at Matta, Swat over the two years i.e. summer 2004 and 2005 as influenced by various treatments showed that the results were significant only for treatments ($P<0.05$) and non-significant for years regarding grain. In case of stover yield the results were highly significant ($P<0.01$) for years, treatments, and their interactions.

Table 6. Economic analysis of fertiliser use on maize.

Years	Sites	Treatments	Value of grain yield	Value of stover yield	Total value	Cost of fertilisers	Net Return
?	?		Pakistani Rupees (Rs./ha)				
Summer 2004	Matta	T1	14053	4388	18441	2771	15670
		T2	25618	5285	30903	8112	22791
		T3	23547	5758	29305	6891	22414
Summer 2005	Thana	T1	7792	2068	9860	3015	6845
		T2	13072	3905	16977	9021	7956
		T3	18608	5435	24043	7696	16347
	Kabal	T1	8144	2245	10389	3015	7374
		T2	13296	3484	16780	9021	7759
		T3	14168	4476	18644	7696	10948
	Matta	T1	15880	2735	18615	3015	15600
		T2	25696	4962	30658	9021	21637
		T3	27464	5331	32795	7696	25099

Economics of fertiliser use on maize

Maize crop failed at Thana and Kabal during 2004 while it could be harvested at Matta only. At Matta, the net return from T_3 increased in 2005 over 2004 while the other treatments gave almost equal net profit during both the years (Table 6). As regards the other sites, net return from T_3 was considerably higher than the other two treatments. This is due to higher maize yield in T_3 with reduced N application and the residual effect of FYM.

Discussion

The maize crop at Thana and Kabal failed during 2004 due to low rainfall, while it was successfully grown at all the three sites in 2005. The results of individual as well as averaged over locations showed that the treatment receiving 60-90-60-5 kg N-P_2O_5-K_2O-Zn/ha (T_3) increased the yields of maize significantly over the other treatments. This was followed by T_2 receiving 100% NPK Zn, while the lowest yields were recorded in T_1. All the three treatments differed significantly from one another. The performance of T_3 was due to FYM application to the previous wheat crop and its carryover effect on maize crop. Dong et al. (2006) also suggested that FYM should be applied to wheat crop in wheat-maize rotation. The major reason for the performance of T_3 on maize was due to the effect of FYM on the organic matter and consequently moisture conservation (Jadoon et al., 2003; Bhatti and Khan, 2000; Dong et al., 2006).

Organic matter content and available water holding capacity in T_3 were increased consistently over time and can explain the yield increase, as both are the yield limiting factors in rainfed areas. (Jadoon et al., 2003; Dong et al., 2006).

T_3 was followed by 100% NPKZn (T_2) at all the sites. The reason was the low to medium soil fertility status of the experimental sites as shown in the original soil analysis. This treatment (T_2) is a balanced one in respect of N, P, K and Zn and thus produced significantly higher yields than the T_1. Balanced applications of FYM with NPKZn have also been reported in earlier studies (Jadoon et al., 2003; Dong et al., 2006).

Though N was reduced by 50% in T_3 to maize, the yield was increased significantly over 100% NPK Zn. This saved N on the one hand and increased yield on the other hand, due to increased efficiency of applied fertilisers.

Conclusion

Combined application of inorganic fertilisers and FYM (T_3) applied to wheat followed by NPK Zn applied to maize increased the yields of maize significantly over the other treatments though half N was applied as compared with 100% N in T_2. This was followed by 100% NPK Zn. This indicates that there was a carryover effect of FYM applied to the previous wheat crop. This was most likely a combination of several factors such as improved nutrient supply capacity and water retention of the soils under rainfed conditions. It can be concluded that combined application of inorganic fertilisers with FYM would restore crop productivity of eroded lands if continued over a long period. Moreover, it will also have an environmental impact through controlling runoff and soil erosion.

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