Research Article

Integrated Nutrients and Cropping Patterns Management on Eroded Soil for Yield and Fertility Restoration

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Abstract | This paper describes soil fertility and crop productivity restoration measures for an eroded soil. The study was conducted in RCB split plot (4*5 m^2) design with; a) cropping patterns (CP); i. cereal-cereal rotation ii. cereal-legume rotation and iii. cereal-cereal+legume intercrop rotation in main plots and b) soil amendments (SA); i. The control (C), ii. Farmers practice (FP; 60:45:0 N: P_2O_5: K_2O), iii. Recommended NPK dose (RD; 120:90:60 N: P_2O_5: K_2O) and iv. 60:90:60 N: P_2O_5: K_2O integrated with FYM 20 t ha^{-1} ($N_{1/2}$PKF) in sub plots. Maize (*Zea mays* L.) CV Azam (yield data contained in this paper belongs to maize only), wheat (*Triticum aestivum* L.) CV Uqab and lentils (*Lense Culinarus* M.) CV NM-89 were cultivated in rotation. Results revealed that during 2006, maize yield did not improve significantly, however, during 2007, grain yield (GY) increased by 17% with $N_{1/2}$PKF over the RD. Similarly, the cropping pattern effect was significant during 2007 only and the cereal-legume rotation showed 9 and 12% higher GY over the cereal-cereal+legumes intercrop and cereal-cereal rotation, respectively. With regard to soil properties and nutrient status, the $N_{1/2}$PKF improved the total N, OM and EC by 33, 64 and 11%, respectively, macro (NPK) and micro (Fe, Zn, Cu and Mn) nutrients, from 8% to nearly 2-fold, bulk density (ρ) lowered by 4% and porosity (f) saturation (ω) and available water content (θ) increased by 3.6%, 5% and 11%, respectively, over the RD. The cereal-legume rotation recorded 16, 15 and 32% higher total N, mineral N and soil OM, respectively, whilst it reduced ρ by 3% with increase in f, ω and θ by 3, 11 and 3% over the cereal-cereal rotation, respectively. The study concluded that yield potential and fertility status of eroded soil can be restored by replacing 50% of the required N from organic and inorganic sources with P_2O_5 and K_2O as per recommended dose and including legumes in the traditional cereal-cereal crop rotation.

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Introduction

Khyber Pakhtunkhwa (KP) is 9.4% of the Pakistan's geographical area and hosts 13.4% of the country's population (Federal Bureau of Statistics, 2009; Bureau of Statistics, KP. 2015; Pakistan Economic Survey, 2011-12). The Central KP's five districts vise Peshawar, Mardan, Swabi, Nowshera and Charsadda comprise 36% of the KP's population with all, except Nowshera, carrying more than 1,000 people's km^{-2} (International Growth Center, 2015). Agriculture with 13% contribution to the KP's GDP (International Growth Center, 2015) serves as the main public profession in this zone. Soils are deep alluvial and loess and silt loam in texture but productivity of the major corps, wheat (1.8 t ha^{-1}) and maize

(1.9 t ha^{-1}) is far below than India (2.8 and 2.32 t ha^{-1}), Korea (3.82 t ha^{-1}) and China (4.76 and 5.56 t ha^{-1}) (Chand et al., 2011; Bureau of Statistics, KP. 2015). Natural (erratic rainfall and soil erosion) as well as anthropogenic factors (less irrigation facilities, traditional farming practices and non-recommended fertilization etc.) resulted in soil fertility reduction and crop productivity declination with time.

In the Central KP, District Swabi (34°7'12"N, 72°28'20"E) is well known for maize crop. Soils are formed from piedmont alluvium, river alluvium and loess deposits, parts of which have been removed by erosion acting over it for a long time (Soil Survey Reports, 1973). Total area under maize crop in the District ranged from 35.9 thousand ha in 1989-90 to a maximum of 41.9 thousand ha in 2001-2002 that declined again to 32.8 thousand ha in 2008-09. Likewise decline in the area under the crop, production by following the same trend ranged from 64.6 thousand tons during 1989-90 to a maximum of 89.1 thousand tons during 2001-02 and then showed decline to 71.2 thousand tons during 2008-09 (Federal Bureau of Statistics, 2009). Because of its location at the foothills of northern mountains, soil fertility depletion has been reported in the district due to unnoticed soil erosion on farmer's field. Continuous loss of soil from surface has resulted in the low quality sub-surface soil exposure to surface with cumulative damper effect on crop yield (Ahmad and Khan, 2014). Erosion not only removes soil particles but OM and nutrients enriched aggregates and leaves a depleted surface behind (Aguilar et al., 1988). Khan et al. (2004) reported decreasing content of the plant nutrients and declining quality of the chemical properties of slightly eroded toward those of moderately eroded soils and recommended stringent measures for the control of soil erosion including the addition of organic matter and water harvesting techniques. Previous work carried out by Khan et al. (2003) has also indicated degradation of soil physical characteristics with increasing extent of erosion resulting in higher bulk density and low porosity, saturation and available water percentage. Khan et al. (2013) presumed the deterioration in soil physico-chemical properties to be due past soil erosion leading to removal of the finer soil particles, OM and mineral nutrients and suggested, along with other conservation practices, the adoption of a restorative crop such as legumes in the cropping patterns on such lands. Adversity of the situation is further intensified with low fertilizer application rate and no incorporation of agricultural residues and wastes into the soil. Such practices are common amongst farmers of the District, perhaps, due to poor financial position and illiteracy, rendering in none of the scientific recommendations are properly exercised. Thus, after each crop harvest, soil remain more depleted in nutrients compared to previous crop. Continuity of the practice for years has resulted in a steady decline of soil fertility and crop productivity of cultivable lands unless and until a restorative crop is grown or nutrients are provided from external sources.

While a significant portion of literature exists reporting the effectiveness of the integrated fertilizer and crop management for fertility and crop yield restoration (Arif et al., 2012; Khan et al., 2013; Ahmad et al., 2013; Ahmad et al., 2014; Ahmad and Khan, 2014; Soho et al., 2015), however, manipulating the same sort of technology for eroded soil would further facilitate the growers cultivating similar kinds of soil. Moreover, adopting legumes as restorative crop in the existing cropping pattern would protect the soil from rain beat action and may even counteract the runoff forces and restore the fertility of such depleted soil. The introduction of high yielding but exhaustive maize hybrids in the area further necessitate the adoption of such practices. Objectives of the current experiment was the assessment of the integrated nutrient and cropping pattern management on soil fertility and crop productivity of eroded farmer's fields in District Swabi and to provide suggestions for cost effective soil fertility and productivity restorative measures for farmers of the area.

Materials and Methods

Characterization of the study site

The study site was a silt loam with higher sand content at the surface than the sub-surface that confirmed the effect of past water erosion. Soil was low in organic matter (<1%), non-saline but alkaline and calcareous in nature and was deficient in available P, Zn, total and mineral N content, moderate in available K and optimum in Fe, Mn and Cu. Soil showed less than 50% porosity, thus, showing more compactness than normal soils, and were, therefore, low in saturation and available water (Table1). Description of the experimental soil was made according to the principles laid down in the key to soil taxonomy, USDA (1998) for soil description as Fine, mixed, hyper thermic, Typic Haplustalfs.

Layout of the experiment

Field layout of the experiment was executed according to randomized complete block split plot design and each factor/treatment was replicated three times. Factors studied were; (a) cropping patterns (CP); i. cereal-cereals rotation (CCR), ii. Cereal-legume rotation (CCR) and iii. Cereal-cereal+legume intercrop rotation (CCR) and (b) soil amendments (SA); i. The Control (C), ii. Farmers practice (FP; 60:45:0 N: P_2O_5: K_2O), iii. Recommended NPK dose (RD; 120:90:60 N: P_2O_5: K_2O) and iv. 60:90:60 N: P_2O_5: K_2O integrated with FYM 20 t ha^{-1} ($N_{1/2}$PKF). Maize (*Zea mays* L.) CV Azam (yield data contained in this paper belongs to maize only), wheat (*Triticum aestivum* L.) CV Uqab and lentils (*Lense Culinarus* M.) CV NM-89 were cultivated in respective rotations. The FYM (Table 2) obtained from the University's Dairy Farm was applied to the soil and ploughed one month before cultivation. The inorganic fertilizers used were urea, SSP and K_2SO_4.

Table 1: *Pre-sowing physico-chemical parameters of the site under the study.*

Property	0-20 cm	20-40 cm
Sand (%)	14.5	12.2
Silt (%)	59.4	59.8
Clay (%)	26.1	28
Textural Class	Silt Loam	Silt Loam
B. Density (Mg m^{-3})	1.43	1.46
Saturation (%)	26	25.8
AW (g kg^{-1})	186.4	163.3
N_{total} (%)	0.04	0.02
$N_{mineral}$ (mg kg^{-1})	15.46	12.54
$P_{ext.}$ (mg kg^{-1})	2.95	1.25
$K_{ext.}$ (mg kg^{-1})	94.5	84.6
OM (%)	0.6	0.4
$pH_{(1:5)}$	7.87	7.89
EC(1:5) (dS m^{-1})	0.22	0.16
Lime (%)	6.23	7.51

AW: *Available water,* **Ext.:** *Extractable.*

Table 2: *Nutrient concentration and C/N ratio of the FYM.*

Parameter	Unit	Value
Total N	%	1.06
Total Organic Carbon (O.C)	%	20.6
C/N ratio	-	19.47
Total P	%	0.05
Total K	%	0.3

Crop sowing and data collection

Maize was sown in rows 60 cm apart and plants 20 cm apart in July, 2006 in all sub-plots (5*4 m^2). All PK and half N of the required fertilizers were mixed in soil during cultivation whilst the other half N dose was given to the crop after 40 days of emergence. The crop was managed as per recommend agronomic procedure and data on grain and biological yield and 1000 grain weight were recorded. In the same fixed layout wheat, lentil and lentil intercropped with wheat in the designated main plots (data not shown) were sown in November 2006 whilst fertilizers treatments were applied in sub-plots. The same sequence of cropping with same fertilizer treatments were continued for maize 2007 and wheat-lentil 2007-2008 using the same cultural practices. Each plot was sampled at 0-20 and 20-40 cm depths after each crop harvest to assess the impact of integrated nutrients and cropping patterns on soil fertility status.

Soil analysis

Recommended procedures were used to analyze soil texture as described by Taggar and Bhatti (1996), OM by acid digestion as indicated in Nelson and Sommers (1982), soil $pH_{1:5}$ (McClean, 1982) and the extractable P, K and micronutrients Fe, Zn, Mn and Cu after soil extraction with AB-DTPA (Soltanpour and Schwab, 1977) and read with spectrophotometer, flame photometer and Atomic Absorption Spectrophotometer (Perkin Elmer 2380, USA), respectively. Nitrogen total was estimated by the Kjeldhal procedure (Bremner, 1996), mineral N by the Mulvaney (1996) procedures and the P, K and micronutrients in FYM by the method described by Kue (1996). Soil bulk density was assessed in samples obtained in steel core of known volume (Vt), oven dried for 24 hours at 104 C° for soil mass (Ms) and the values were put in the model: ρ_b = Ms/Vt (Blake and Hartge, 1984). Porosity (f) of the soil was calculated as (100 – ρ_b/ρ_p) x 100. Where ρ_p is the partical density=2.65 Mg m^{-3} (Danielson and Sutherland, 1986). The saturation (ω) was estimated as; (Mt – Ms)/Ms × 100 (Gardner, 1986) where Mt = mass of soil paste. Available water content (θ) was assessed using pressure membrane apparatus (Raza et al., 2003).

Statistical analysis

The data collected were analyzed statistically in STATISTIX 8.1 software using procedures for RCB split plot design (Gomez and Gomez, 1984). In case of significantly different means, The Least Significant

Difference test was applied to separate significantly different means (Steel and Torrie, 1980).

Results and Discussion

Yield and yield parameters

Results indicated significant ($P<0.01$) increase in maize yield parameters; grain yield (GY), biological yield (BY) and 1000 grain weight (GW) because of fertilizer amendments during both 2006 and 2007. During 2006, GY, BY and GW in the RD was 62, 40 and 10% higher over the FP and 158, 90 and 19% higher over the Control, respectively (Table 3) indicating that soil were nutrients demanding for successful crop production. Nutrient application on poor soil improved the crop performance (Haefele et al., 2006) and its repeated application at the recommended doses ensured constantly greater yields (Yadav et al., 2000). During 2007, the RD was again 75, 72 and 15% higher in GY, BY and GW over the FP and 142, 102 and 26% higher over the control, respectively. However, when the RD was compared with $N_{1/2}$PKF, the difference in GY in favour of $N_{1/2}$ PKF was -1.4 and 17%, in BY was 9 and 15% and in GW was 5 and 7% during 2006 and 2007, respectively. Since the FYM releases the nutrients slowly and especially for the current crop (Gitari and Friesen, 2001), NPK ensure an emergent nutrient availability at the early crop growth stage thereby superseding the RD. This further, indicated that low nutrients application in the FP seems to be the yield controlling factor and their application as per the RD showed high agronomic efficiency (Yadav et al., 2000; Haefele et al., 2006) during 2006 whilst during 2007, further increase in the yield can be ascribed to the residual effect of soil amendments. However, reduction of N by 50% in the $N_{1/2}$PKF seems to have been well compensated by the FYM resulting higher GY, BY and GW during both years. Results were in agreement with Yadav et al. (2000) who obtained higher yield with NPK full or 50% dose of NPK along with organic materials. Crop growth requirements include sufficient water and air along with inorganic nutrients. Application of mixed FYM and mineral fertilizers satisfied these plant requirements by improving soil porosity, available water and by replenishing mineral nutrients from the applied amendments. Nadeem et al. (2016) documented that nutrient incorporation from NPK or its combination with organic material improved crop growth rate. NPK ensures pronto free nutrients at early growth stage whilst FYM slow release of nutrients ensures its supply at latter growth stages (Khan et al., 2016). With sufficient nutrients in soil and optimum soil conditions, grain become the dominant sink of photo-assimilates giving it plumpness and weight. Previous investigations also credited the mixed application of organic and inorganic soil amendments for catering the early and late growth requirements of the crop (Gitari and Friesen, 2001) and producing higher BY due to optimized physical parameters, restored nutrient status and improved crop stand (Badruddin and Meyer, 1994; Matsi et al., 2003). In the same pattern, the net economic return (NER) in the RD was 7% higher over the $N_{1/2}$ PKF and 162% higher over the FP whilst during 2007, the NER in the $N_{1/2}$ PKF was 23% higher over the RD and 4 fold over the FP (Table 4).

The cropping patterns (CP) effect on GY, BY and GW was non-significant during 2006 whilst these parameters showed significant ($P<0.01$) improvement during 2007 in the CP with legume (lentil) sown as alternate winter crop (cereal-legume rotation) recording 9, 12 and -2% higher GY, BY and GW over the

Table 3: *Effect of soil amendments and cropping patterns on maize yield parameters.*

Treatments	Cont.	FP	RD	$N_{1/2}$PKF	$LSD_{(<0.05)}$	CCR	CLR	CIR	$LSD_{(<0.05)}$
2006									
GY($kgha^{-1}$)	1505	2398	3883	3831	258.4	2862	2996	2856	ns
BY($t\ ha^{-1}$)	12.6	16.3	22.2	24.3	1.1	18.8	19	18.8	ns
1000GW(g)	186	200	219	230	9.6	209	211	208	ns
2007									
GY($kgha^{-1}$)	1425	2383	4179	4887	223.5	3075	3432	3150	88.5
BY($t\ ha^{-1}$)	11.9	16.1	27.7	31.8	1.6	21.6	23.2	20.8	1.6
1000GW(g)	184	204	235	251	14.2	207	222	225	13.1

Cont.: *Control,* **FP:** *Farmer's practice,* **RD:** *recommended dose,* **CCR:** *cereal-cereal roation,* **CLR:** *cereal-legume rotation,* **CIR:** *cereal-intercropped cereal+legume rotation,* **GY:** *grain yield,* **BY:** *biological yeild,* **GW:** *grain weight.*

Table 4: *Economic analysis of fertilizer treatment during 2006 and 2007.*

Fertilizer / Treatments	Yield value (Rs.)	Yield increase (Rs.)	Input cost (Rs.)	Net return (Rs.)
2006				
Control	26558	-	-	-
FP	39692	13134	3042	10092
RD	61352	34794	8325	26469
$N_{1/2}$PKF	62237	35679	10998	24681
2007				
Control	29763	-	-	-
FP	46695	16932	2914	14018
RD	81478	51715	5856	45859
$N_{1/2}$PKF	94835	65072	8482	56590

Cont.: *Control,* **FP:** *Farmer's practice,* **RD:** *recommended dose,* **Rs.:** *Pak Rupees.*

cereal-cereal+legumes intercrop and 12, 7 and 9% higher over the cereal-cereal rotation, respectively. When N acts as the major growth limiting factor, its fixation by legumes plays like a vital source of N in cereal-legume rotation resulting in increased dry matter production more than cereal-cereal rotation (Fujita et al., 1992). Legumes provide two sources of additional N for the following cereal crop namely the mineral N conserved in soil and the total N added to the soil in their residues and both of these sources were considered significant to the growth of the following cereal crop (Evans et al., 1991). The additional N acquired by maize from the previous lentil which according to Evans et al. (1991) could be up to 40 kg N along with the disease break might be favourable factor for higher GY and BY. Wright (1990) also reported 21% increase in the subsequent cereal crop yield cultivated for the first year after various legumes and 12% in the second year. Results further revealed that cereal-cereal+legumes intercrop did not show any superiority over cereal-cereal rotation in GY. This might be ascribed to the comparatively tall wheat shading effect over the lentil rows resulting its weaker growth and lower N fixation in its stubble. Results further indicated fertilizer treatments and cropping patterns as to have no interaction on GY, BY and GW both during 2006 and 2007.

Data pooled over seasons also showed significant ($p<0.01$) variation in GY, BY and GW with fertilizer amendments whilst the CP significantly ($p<0.01$) affected the GY only (Table 5). Increase in GY, BY and GW in the $N_{1/2}$PKF was 8, 13 and 6% over RD, 82, 70 and 19% over the FP and approximately 3fold, 132 and 30% over the control, respectively. The cereal-legume rotation produced 7% higher GY over cereal-cereal+legumes intercrop and 8% higher over the cereal-cereal rotation while the cereal-cereal+legumes intercrop and cereal-cereal rotation were statistically similar. Amongst the years, GY, BY and GW in 2007 increased by 11, 18 and 4%, respectively, over 2006 as a result of combined fertilizer and CP and their residual effect, however, increase in GW was non-significant. It was further noted that yield dropped in the control plot by 15% from 2006 to 2007. The soils were deficient and the crop mining of nutrients further deteriorated its fertility. Combined effect of soil amendments and legumes in crop rotation might have improved the soil physico-chemical properties that ensured better crop growth compared to plot devoid of such applications. Ali et al. (2008) also reported higher biological yield for the sites having higher organic matter and improved physical conditions.

Table 5: *Effect of fertilizer treatments and cropping patterns on maize grain yield, biological yield and 1000 grain weight based on combined data over seasons.*

Fertilizer Treatment	GY (kg ha^{-1})	BY (t ha^{-1})	GW (g)
Control	1465	12.2	184.9
FP	2391	16.6	202.2
RD	4031	24.98	227.21
$N_{1/2}$PKF	4359	28.28	240.56
LSD $_{(<0.05)}$	180	0.998	10.17
Cropping pattern			
CCR	2968	20.3	208
CLR	3213	21.5	217
CIR	3003	19.8	216
LSD $_{(<0.05)}$	178	ns	ns
Pooled fertilizer amendments and CP effect			
2006	2904	18.8	209
2007	3218	22.2	218
T-value $_{(<0.05)}$	Ns	0.013	**ns**

Cont.: *Control,* **FP:** *Farmer's practice,* **RD:** *recommended dose,* **CCR:** *cereal-cereal roation,* **CLR:** *cereal-legume rotation,* **CIR:** *cereal-intercropped cereal+legume rotation,* **GY:** *grain yield,* **BY:** *biological yeild,* **GW:** *grain weight.*

It was further clear form the data analysis that the crop season had highly significant interaction with fertilizer treatments to improve GY over the seasons indicating the nutrient build up and availability for the subsequent crop as a result of fertilizer amendments. The interaction between seasons and fertilizer amendments and that between CP and fertilizer amendments was highly significant (P<0.01) to improve BY and GW indicating the contribution of both the fertilizers and legumes in crop rotation as well as their residual effect over the seasons. This might be due to carry over effect of previous legume crops along with the effect of both organic and inorganic fertilizer applications. Legumes have a positive N balance i.e. N_2 fixation is more than that removed in the harvested product (Shah at el., 2004).

Soil properties

Effect of fertilizer amendments on soil physico-chemical properties was highly significant (P<0.01). The $N_{1/2}$ PKF improved the soil total N by 33%, mineral N by 12%, AB-DTPA extractable P by 51%, K by 8%, organic matter (OM) by 64%, $EC_{1:5}$ by 11%, Cu by 64% and the Fe, Mn, and Zn by nearly 100% each compared to the RD. Decrease in soil pH in $N_{1/2}$PKF was 3% over the RD (Table 6). Amongst the physical properties, the $N_{1/2}$ PKF recorded 4% decrease in bulk density (ρ) which resulted increase in total porosity (f) by 3.6%, saturation (ω) by 5% and available water (θ) by 11% over the RD (Table 6). Patra et al. (2000) reported that co-application of inorganic and organic amendments help increasing the nutrients availability for crop growth. FYM also improve the fertilizer use efficiency (Nawaz et al., 2000; Swarup, 2001; Morari et al., 2008) thereby reducing losses and increasing the availability of applied nutrients. Application of FYM increased organic matter (Alvarenga et al., 2007) the decomposition of which released the nutri

Table 6: *Integrated soil amendments and cropping patterns effect on soil fertility after maize harvest during 2007.*

Fertilizer Treatment	Control	FP	RD	$N_{1/2}$PKF	LSD (<0.05)	CCR	CLR	CIR	LSD (<0.05)
N_{total} (g/kg)	0.6	0.7	0.9	1.1	0.05	0..8	0.9	0.8	0.06
$N_{mineral}$ (mg/kg)	19.4	27.5	42.2	47.5	3.19	33.0	37.9	31.5	2.88
O.M (g/kg)	3.3	5.7	10.8	17.8	2.22	8.5	11.2	8.6	1.43
Soil pH	8.0	7.6	7.6	7.4	0.21	7.6	7.7	7.6	ns
E.C. (dS/m)	0.1	0.2	0.3	0.3	0.07	0.2	0.2	0.2	ns
P (mg/kg)	2.8	5.9	10.3	15.1	1.88	8.2	9.6	7.8	ns
K (mg/kg)	96.7	103.2	180.6	195.3	7.69	153.8	133.6	144.4	10.19
Fe (mg/kg)	5.9	6.0	6.0	12.2	1.04	7.2	7.8	7.6	ns
Zn (mg/kg)	1.0	1.2	1.3	2.6	0.39	1.5	1.6	1.5	ns
Mn (mg/kg)	3.0	4.3	4.1	8.2	1.80	3.6	5.4	5.7	ns
Cu (mg kg^{-1})	1.9	2.2	2.4	3.9	0.50	2.4	2.7	2.6	ns
B. Density (M/m^{-3})	1.4	1.3	1.2	1.2	0.04	1.3	1.3	1.3	0.02
Porosity (%)	47.3	49.9	52.9	54.8	1.40	50.7	52.4	50.7	0.58
Saturation (%)	30.4	33.9	35.7	37.6	1.83	33.1	36.8	33.3	2.64
AW (g/kg)	131.5	143.1	168.7	187.4	10.2	153.9	162.6	156.5	3.16

Cont.: *Control,* **FP:** *Farmer's practice,* **RD:** *recommended dose,* **CCR:** *cereal-cereal roation,* **CLR:** *cereal-legume rotation,* **CIR:** *cereal-intercropped cereal+legume rotation,* **EC:** *electrical conductivity,* **AW:** *available water .*

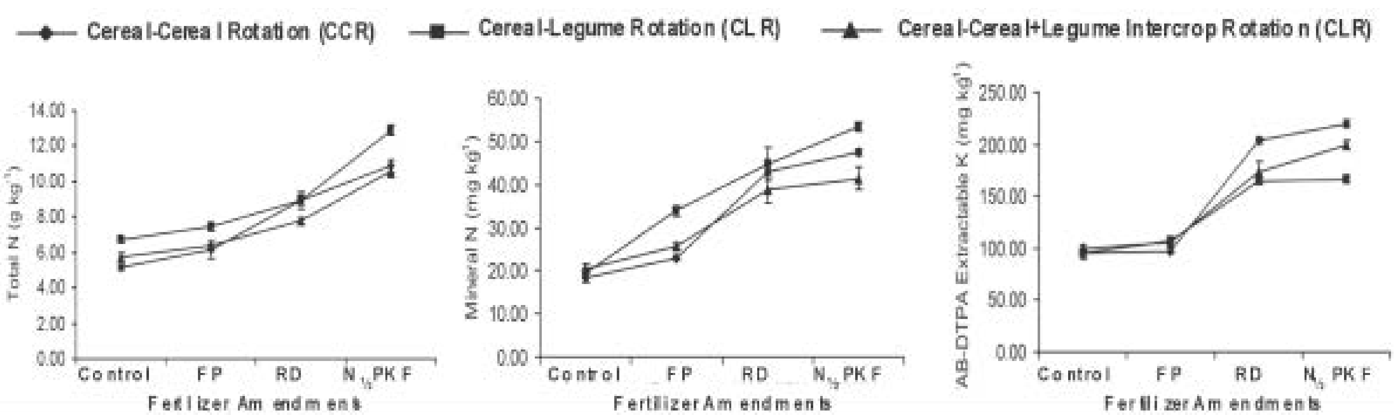

Figure 1: *Interaction effect between fertilizer treatments and cropping patterns on total and mineral N and K in soil.*

ents trapped in it (GUO et al., 2008). Many researchers have affirmed the FYM addition to agricultural soils for increasing soil and plant nutrition (Timsina and Connor, 2001; Dawe et al., 2003; Pratt, 2008).

Previous work indicated FYM for increasing acid soil pH (Ashiono et al., 2005), reduction in soil pH can be ascribed to the application of sole or mixed N fertilizer and FYM. It was observed from the data that EC of the soil increased with increasing fertilizer level. These finding affirm the findings of Stamatiadis et al. (1999) who reported increase in EC with ammonium nitrate application whilst Hao and Chang (2003) reported that livestock manure as a source of considerable amount of salts for agricultural soils.

The CP effect on the soil total and mineral N, OM and K was significant (P<0.01) with the cereal-legume rotation showing 16, 15 and 32% higher total and mineral N and soil OM over the cereal-cereal rotation. The extractable K was 15% higher in the cereal-cereal rotation over the cereal-legume rotation (Table 6). Amongst physical properties, the cereal-legume rotation recorded the lowest ρ (lower by 3%) over the cereal-cereal rotation while the f, ω and θ were 3, 11 and 5% higher over the cereal-cereal rotation, respectively (Table 6). It was further noted that CP effect on soil $pH_{1:5}$, $EC_{1:5}$, extractable P, Fe, Zn, Mn and Cu was non-significant. The CP with legumes in crop rotation is an effective way of supplying N and improving soil properties (Yang, 2006). The higher P in cereal-legume rotation might be ascribed to P fertilizer addition as per recommendations and altering of the pH of the rhizosphere (Wilson et al., 1982). Sharma and Sharma (2004 a) reported that cropping systems containing legumes in rotation have high organic carbon (OC) whereas continuous cereals cause reduction in soil OC. The CP effect on micronutrients was non-significant despite significantly different OM indicating the suspected higher microbial activity with increased immobilization of these nutrients. Shah and Khan (2003) also reported that legume residues showed immobilization during the first four weeks of incubation

It was also noted that amongst chemical properties interaction between CP and fertilizer treatments on total and mineral N and extractable K was significant (P<0.05) while it was non-significant on AB-DTPA extractable P, EC, pH, Fe, Zn, Mn and Cu. It was further noted that interactions effects between fertilizer treatments and FP on physical properties (ρ, f, ω, θ) were also non-significant.

Conclusions

Results concluded that yield potential and fertility status of eroded soil can be restored by replacing the required N from organic and inorganic sources on 50% basis with P_2O_5 and K_2O as per recommended dose and including legumes in the traditional cereal-cereal crop rotation. The practice is worth considering for saving the costly inorganic N and is vital for environmental protection.

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Author's Contribution

Dr. Wiqar Ahmad conducted the experiment, data collection, analysis and write up of the manuscript; Dr. Farmanullah Khan was the supervisor and helped throughout the experiment.

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