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Review

Potash need assessment and use experience in Khyber Pakhtunkhwa (KP)

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Abstract

After nitrogen and phosphorus, potassium is the third major plant nutrient which is becoming deficient in the soils of Khyber Pakhunkhwa Province of Pakistan. Responses of various crops to potash application and soil analysis results of various areas of KP clearly indicated deficiencies of potash. In a survey of nutrient status of different districts of KP, twenty one percent of the soil samples analyzed were deficient in K, while 50 percent were marginal. However, major areas of K deficiency are observed in Malakand agency, Swat, and Mansehra districts. A recent survey of orchard soils (citrus, apple, and peaches) showed that 9% soils were deficient in K while 47% were marginal. Usually the addition of K increased the yields giving higher value cost ratios (VCRs) and crop response ratios especially for cereal crops under irrigated conditions. Balanced application of NPK and Zn produced significantly higher yields of wheat on eroded lands in Swat and Rod-Kohi soils in D.I. Khan. The available data showed that, complex fertilizers proved better than straight fertilizers. As regards muriate of potash (MOP) vs sulfate of potash (SOP), the superiority of one over the other depends upon the type of soil and climatic conditions, and the crop. In D.I. Khan SOP proved better for rice, and equally effective for wheat and maize. On the other hand, MOP improved the quality of wheat regarding protein content as well as the uptake of K by maize and wheat, however, increased the chloride content of soil. In Peshawar and Swat, both the sources were found equally effective as regards yield without any accumulation of chloride by MOP at Tarnab but its application increased chloride content significantly at the depths of 31-60 and 61-90 cm in Swat district. Use of potash needs to be promoted as it is very important for improving the quality of crop products. As regards source of K, SOP should be preferred for sulfur loving and quality crops, low rainfall areas and heavy textured soils. Use of the source of K should be site and crop specific. Future strategies for promotion of K should include research on K-fixing capacity and clay mineralogical investigation of benchmark soil series important for agriculture purposes, application of K on the basis of crop requirement and fixing capacity of soil, mapping of K in addition to other nutrients in different areas of KP.

Keywords: Potash, crop improvement, soil fertility, VCR

Potassium is the third major element in plant nutrition and is vital for many important metabolic functions. Prior to the introduction of high yielding fertilizer responsive varieties and intensive use of nitrogen, the soils were not stressed for their phosphorus and potassium supply. Realizing the importance of lack of other nutrients, farmers started using phosphorus, with consequent mining of potassium, and therefore, the demand for potassium has increased, and slow releases from the soil's inherent capacity barely meet crop requirement. As a result, potassium deficiency is now becoming a limiting factor on soils previously having sufficient levels of available potassium. To meet the K requirements of crops, chemical fertilizers are commonly used, which undergo different changes in the soil and therefore it has to be applied carefully to avoid major losses of K. In K deficient areas, the improvement of wide spread phosphorus deficiencies has contributed to a better response of crops to potash application. The ratio of nutrients (N:P:K) use in Pakistan has been very wide (1:0.30:0.01) during 2000-2001 (NFDC, 2002). In addition to other crops, the major use of potassium in KP is on potatoes, tobacco, and sugarcane crops.

Crop responses to K application have been variable on soils of different textures, this is perhaps due to different clay contents and mineralogical composition leading to K-fixation (non-extractable K), however, this requires further clay mineralogical investigation in KP soils. Some research workers in KP summarized the results of field trials on various crops and identified K deficiencies in soils and also reported crop responses to application of K (Rehman *et al.*, 1982, 1983; Gurmani *et al.*, 1986; Khattak and Bhatti, 1986).

Issues related to the use of K for various crops include: need for K fertilization, suitable source of K, complex vs. straight fertilizers, time of application, quantity, and future strategies of using K for enhancing crop yields and quality.

Keeping in view the importance of K in plant nutrition, an effort has been made to review some research work on

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balanced fertilization with particular reference to different aspects of K fertilization carried out in KP.

It is worth emphasizing that due to the inaccessibility to the unpublished data, the review was limited to easily accessible and published information on the subject matter. It is envisaged that the information in this paper may provide enough information to the researchers and scientists to develop future strategies on the use of K in agriculture and its fate in soil after application.

Fertility status of KP soils

A number of studies have been conducted on the fertility status of KP soils, however, only the most pertinent to this study are reported here. In an effort to evaluate fertility status of soils from different districts of KP, Rehman *et al*. (1993) analyzed a total of 6681 soil samples and found 21 percent deficient in K, 50 percent were marginal and 29 percent were found adequate in K. In another study, Bhatti (1993) surveyed rain-fed areas of some districts of KP and 29 percent soil samples were reported K deficient. Most of the K-deficient areas exist in Swat district and Malakand agency. In Mansehra district, Rashid (1994) reported 19% of acid and 15% of alkaline soils deficient in K., whereas in Swat district, 21% of the acid and 26% of alkaline soils were low in K availability in Swat district.

In a recent study, Bhatti (2006) evaluated 423 soil samples for fertility status from six districts of KP (Peshawar, Charsadda, Kohat, Bannu, D.I. Khan and Tank). He found 2 percent samples in low, 16 percent in marginal and 82% in adequate categories in AB-DTPA extractable K. Ali (2008) while working on soils of Thana, Malakand Agency; Kabal and Matta, Swat reported soils of Thana and Kabal in marginal K and Matta in adequate categories.

Some eroded soil series (Pirsabak, Missa, Makhnial, Chapri, Missa gullied, and Gullibagh) of river Swat catchment area was investigated by Khan *et al*. (2008). They reported Pirsabak, Missa, Makhnial and Chapri soil series in marginal K category, while Missa gullied and Gullibagh were deficient in K due to past sever erosion.

Recently, Shah and Rehman (2009) have completed a soil fertility status survey of 50 citrus, 52 apple and 47 peach orchards in Swat. In their evaluation they reported 6% citrus orchards in low and 66% in marginal K level, whereas 13% apple orchards were low and 27% marginal in K, 9% peach orchards were low and 49% marginal in K.

Balanced application of fertilizers

Due to wide ratio of N:P:K in KP soils, it is imperative to use balanced fertilizers to offset the crop nutrient requirements for optimum yields. In a number of studies in KP the researchers reported increases in crop yields by the application of balanced fertilizers for major plant nutrients (Bhatti, 1980; Rehman *et al*., 1982, 1983; Khattak and Bhatti, 1986). This practice also proved to be economical. In later studies on farmers' field on paddy and wheat by Bhatti and Bakhsh (1994), application of 120-90-60 kg N-P_2O_5-K_2O ha^{-1} increased the yield over N alone or NP with the highest VCR values. In case of paddy the highest VCR of 4.25 and wheat a VCR of 5.58 was recorded due to NPK application (Table 1).

Bhatti *et al*. (1995) evaluated the effect of low (60-45-0) and high rates (120-90-60 kg NPK ha^{-1}) in 53 wheat field trials under irrigated conditions in KP. They reported that the balanced rate of fertilizer application increased the grain yield of wheat significantly over low and imbalanced rates with an increase of about 37%.

In a study similar to the above, Bakhsh *et al.* (1999) conducted 19 fertilizer trials at farmers' irrigated field conditions in D.I. Khan district to evaluate the effect of balanced application of N, P and K on the yield of wheat. They found the rate applied as 160 kg N plus 90 kg P_2O_5 plus 100 kg K_2O ha^{-1}.relatively better for optimum wheat yields.

Bakhsh (2005, 2006) reported the results of experiments conducted during 2004-2005 and 2005-2006 on the effect of NPK and Zn on the yield of wheat under Rod Kohi conditions of D.I. Khan (farmers' fields). The treatments comprised of NPK Zn @ 0-0-0-0, 30-20-0-0, 60-40-20-0, 90-60-30-0, 90-60-20-2, 90-60-30-4 and 90-60-30-6 kg ha^{-1}, while the test variety was Daman-98. The data (Table 2) illustrate that the grain yield of wheat was significantly affected due to fertilizers application during both the years. The significantly highest mean grain yield of 5350 kg ha^{-1} was achieved from treatment receiving NPK Zn @ 90-60-30-4 kg ha^{-1} (T6) during 2004-05. It was followed by T7 (NPK Zn @ 90-60-30-6 kg ha^{-1}) that gave grain yield of 5290 kg ha^{-1}. Both (T6 and T7) were statistically at par. Similarly, T7 and T5 also produced statistically similar yields. Among the fertilizer treatments (2005-2006), the highest yield of 3665 kg ha^{-1} on average was recorded from T7 plots receiving NPK Zn @ 120-90-40-6, kg ha^{-1} which was at par with T6 being comparable with T5. The yield of all the three treatments differed significantly from the yields with treatments where Zn was not applied. It can be concluded from the observations that application of zinc in addition to NPK enhanced grain yield of wheat under Rod Kohi conditions. The optimum dose of NPK and Zn for getting maximum yield is 90-60-30-4 kg ha^{-1} under Rod Kohi conditions.

Ali (2008) conducted field experiments on eroded lands to evaluate the effect of integrated plant nutrient management on the yield of wheat at Thana, Malakand Agency; Kabal and Matta, Swat from 2003-2004 to 2005-2006. Three treatments viz., farmer's practice, balanced application of plant nutrients, and integrated plant nutrients were used. He reported that balanced application increased the yield over farmer's practice by 36% during 2003-2004, 45% during 2004-2005, and 14% during 2005-2006 on average of three sites.

Gurmani *et al*. (1997) conducted eight fertilizer trials for three consecutive years (1990-91 to 1992-1993) in farmers' irrigated fields in D.I. Khan district to evaluate the effect of different combinations of N, P and K on the yield of sarson (*B. compestris*). Their results showed that the effects of treatments as well as sites were significant during all the three years of study. Most of the experimental sites were deficient in N, and either in P or K, and responded to the combined application of the three major nutrients (Table 3). The highest mean grain yields of sarson were obtained with the application of 60 kg N plus 40 kg P_2O_5 plus 150 kg K_2O ha^{-1}.

Bhatti *et al.* (2002) used the data of 10 field trials conducted to evaluate the response of onion to application of K in Swat district to develop the response curves. All the sites were low in K. Quadratic model was the best fit to the data of all the sites with r^2 ranging from 0.50 to about 1.0 (Table 4). Economic optimum rates calculated from equations ranged from 116 to 235 kg K_2O ha^{-1} for different sites in Swat district.

Similarly, apple yields were increased significantly with K application in 6 field trials in Swat district, and the quadratic equations were the best fit to the data with r^2 ranging from 0.62 to 0.92. Economic optimum rates calculated ranged from 1.77 to 2.60 kg K_2O $tree^{-1}$ (Bhatti *et al*., 2002).

Complex vs straight fertilizers

The simplest and most economical way of supplying plant nutrients together is to use a complex fertilizer. These have multiple properties and are balanced in their nutrient content and can be evenly distributed due to their granular structure as compared with straight fertilizers. Bhatti (1980) summarized the results of complex vs straight fertilizers on

Table 1: Effect of NPK on the yield of paddy and wheat (D.I. Khan)

Treatment			Yield	Net return	VCR
N	P_2O_5	K_2O	kg ha^{-1}	Rs ha^{-1}	
			Paddy		
0	0	0	2382	-	-
120	0	0	3576	1643	2.46
120	90	0	5787	5843	3.84
120	90	60	6810	7856	4.25
			Wheat		
0	0	0	908		-
120	0	0	2270	4817	5.21
120	90	0	3632	9668	5.30
120	90	60	4540	13041	5.58

Source: Bhatti and Bakhsh (1994)

Table 2: Effect of NPK and Zn on the yield of wheat under Rod-Kohi conditions of D.I. Khan

Treatment	2004-2005			2005-2006		
N-P_2O-K_2O -Zn	Wanda Feroze	Abizer	Treatment Mean	Wanda Feroze	Abizer	Treatment Mean
0-0-0-0	4534	2833	3684f	3100	2700	2900c
30-20-0-0	5266	3333	4300e	3233	2967	3100d
60-40-20-0	5500	3850	4675d	3313	3160	3236cd
90-60-30-0	5766	4200	4983c	3400	3266	3333c
90-60-30-2	6166	4275	5221b	3620	3350	3485b
90-60-30-4	6400	4300	5350a	3767	3386	3576ab
90-60-30-6	6300	4280	5290ab	3380	3450	3665a
Location Mean	5705a	3867b	-	2473a	3182b	-

Source: Bakhsh (2005, 2006)

various crops (Table 5). Nitrophoska fertilizer (15-15-15) gave the highest yields of maize, millet, and rice, and proved better than the mixtures of straight or nitrophos and SOP fertilizers. However, wheat yield was the highest in Nitrophos treatment. It is clear from these results that complex fertilizer should be preferred over straight fertilizers.

Table 3: Effect of various combinations of N, P and K on the grain yield of sarson

Treatments (kg ha^{-1})			Grain Yields (kg ha^{-1})		
N	**P_2O_5**	**K_2O**	**1990-91[1]**	**1991-92[2]**	**1992-93[3]**
0	0	0	750	1776	1060
0	40	100	877	2284	1591
30	40	100	1099	2944	200
60	40	100	1610	3289	3049
90	40	100	1556	4355	4185
60	0	100	1260	2389	3238
60	20	100	1291	2972	3619
60	60	100	1560	4080	4504
60	40	0	1250	3721	3671
60	40	50	1201	3702	3778
60	40	150	1344	4418	4809

[1]Average of two sites [2]Average of four sites [3]Average of two sites Source: Gurmani *et al.,* 1997

Table 4: Coefficient of quadratic yield equations for potash experiments on onion (t ha^{-1})

Location	Coefficient			
	a	**b**	**C**	**r^2**
Kot	14.76	0.3044	-0.00092	0.93
FatehpurI	32.89	0.0498	-0.00019	0.58
FatehpurII	38.16	0.1776	-0.00057	0.90
Chalegay	31.97	0.0770	-0.00029	0.50
Shingerdara	35.92	0.1495	-0.00049	0.88
Malki DherI	41.19	0.1129	-0.00036	0.87
Aboha	28.67	0.0896	-0.00030	0.90
Malki DherII	28.45	0.0694	-0.00020	0.95
Matta	30.48	0.1003	-0.00020	0.96
Batkhela	45.45	0.0900	-0.00025	0.998

Source: Bhatti *et al.,* 2002

Comparison of MOP vs SOP

Among straight fertilizers of K, there are two sources i.e. muriate of potash (MOP- KCl containing 60% K_2O)) and sulfate of potash (SOP- K_2SO_4 containing 50 % K_2O). Both sources are water soluble and do not affect pH. The potassium sulfate has been the preferred form due to its sulfur content and non-hygroscopic nature whereas the chloride fertilizer (KCl) has the advantage of being cheap relative to SOP. Work on the comparison of MOP and SOP has been in progress since last three decades and has some contradictory results. Bhatti *et al.* (1984) reported the results on paddy (Table 6) showing better performance of SOP to increase paddy yields over those where MOP was used. Moreover, SOP application was more economical than MOP (Table 7) due to relatively higher returns. Bakhsh *et al.* (1986) compared the effect of SOP vs MOP on the yield and quality of wheat. They found that the application of 37 kg K ha^{-1} in the form of MOP and 74 kg K ha^{-1} of SOP proved better but on the average both treatments were at par with each other (Table 8). However, SOP gave relatively higher net return than MOP (Table 9) and also improved the protein content of wheat as well as uptake of K (Table 10). Moreover, MOP increased the chloride content of soil significantly (Table 10). In another study by Rasool *et al.* (1987), grain yield of maize was almost equal from SOP and MOP but uptake of K was higher from SOP treatments than MOP treatments, and MOP application increased the chloride content of soil (Table 11). Haq (1999) reported the average results of MOP vs SOP trials conducted on different crops in various areas of KP which showed that MOP and SOP were equally effective in increasing the yields over control and NP treatments (Table 12). Average results of chloride content showed that MOP slightly increased the chloride content of surface soil.

Table 5: Comparative effects of straight and complex fertilizers (kg ha^{-1}) on the yields of different crops (kg ha^{-1})

Crop	N-P_2O_5-K_2O	Control	Nitrophos (23-23-0)	Nitrophoska 15-15-15	*A/S or Urea + TSP+PS	Nitrophos (23-23-0) + P.S
Maize (Swabi white)	135-135-135	906	1746	2031	-	1805
Cotton (13/26)	67-67-67	587	970	950	2051	880
Millet (ACC2781)	101-101-101	532	-	1503	957	1142
Rice (IR9-60)	135-135-135	934	1985	2187	-	1895
Wheat (Mexipak-65)	135-135-135	1073	2549	2205	2426	-
Wheat (Khushal)	135-135-135	963	2840	2542	2422	-

*A/S-Ammonium sulfate, TSP-Tripe Superphosphate, P.S.-Potassium Sulfate Source: Bhatti, (1980)

Table 6: Effect of MOP vs SOP on the yield of paddy (D.I. Khan)

Treatment			Yield		
N	P_2O_5	K_2O	1979 (8 trials)	1980 (11 trials)	1981 (5 trials)
	(kg ha$^{-1)}$			kg ha^{-1}	
120	80	0	4326c	4612 c	5479 b
120	80	100 MOP	5205 b	5343 b	5037 b
120	80	100 SOP	5751 a	5972 a	6251 a

Source: Bhatti *et al.* (1984)

Table 7: Economics of fertilizer use on paddy (D.I. Khan)

Treatment			1979		1980		1981	
N	P_2O_5	K_2O	Net return	VCR	Net return	VCR	Net return	VCR
					Rs ha^{-1}			
120	80	0	-	-	-	-	-	-
120	80	100 MOP	997	13.46	815	11.15	114	2.42
120	80	100 SOP	1326	14.55	1546	13.88	826	7.88

Source: Bhatti *et al.* (1984)

Table 8: Effect of MOP vs SOP on the grain yield of wheat (D.I. Khan)

N	P	K	Grain yield (average of 3 rotations)		
	kg ha^{-1}		Source	kg ha^{-1}	Average
135	44	0		2205	
135	44	37	MOP	2553	
135	44	74	MOP	2270	
135	44	111	MOP	2172	
135	44	148	MOP	2251	2312
135	44	37	SOP	2284	
135	44	74	SOP	2253	
135	44	111	SOP	2382	
135	44	148	SOP	2343	2386

Source: Bakhsh *et al.* (1986)

Table 9: Economics of fertilizer (Average of 3 rotations) D.I. Khan

Treatment				Net return	VCR
N	P	K		US $ ha^{-1}	
	kg ha^{-1}				
135	44	0		147.49	2.86
135	44	37	MOP	194.35	3.35
135	44	74	SOP	214.25	3.05

Table 10: Effect of MOP vs SOP on the protein content of wheat, K content of leaves and chloride content of soils (D.I. Khan)

Treatment	Protein content	Protein yield	K content of leaves	Chloride content
	(%)	($kg\ ha^{-1}$) (Average of 3 rotations)	(%)	($meq\ L^{-1}$)
Control	12.04	77	1.75	1.99
NPK	12.11	267	1.94	1.89
NPK-MOP	12.54	281	2.27	2.26
NPK-SOP	12.87	295	2.39	2.02

Source: Bakhsh *et al.,* 1986

Table 11: Effect of MOP vs SOP on the yield of maize and soil properties (D.I. Khan)

Treatment	Grain yield	K content of leaves at silking	Chloride content in soil
	($kg\ ha^{-1}$)	(%)	(meq/100 g)
NP	1705	1.89	0.233
NPK MOP	2455	2.13	0.400
NPK SOP	2419	2.28	0.269

Source: Rasool *et al.* (1987)

Table 12: Summary of Crop response to Potash and its Sources (1993-97, Tarnab)

Treatment	Mean Yield ($kg\ ha^{-1}$)				
	Wheat (20)	Maize (8)	Rice (6)	Sugarcane (2)	Chloride content ($meq\ L^{-1}$)
Control	1780	1315	3412	31896	1.07
NP	3591	2721	5099	45919	1.04
NPK SOP	3942	2948	6059	47784	1.14
NPK MOP	3981	2878	6048	47327	1.18

Source: Haq, 1999

Ghani (2003) conducted experiments on MOP vs SOP on various crops in Swat district and results of experiments on wheat for seven years are reported (Table 13). These results showed that MOP and SOP were equally effective in increasing the yield of wheat, however, MOP increased the chloride content of soil at the depths of 31-60 and 61-90 cm significantly (Table 13). Maraby (1968) showed that K_2SO_4 greatly out yielded KCl as regards their effect on the yield of rape seed.

A more general study on the use of MOP versus SOP has been conducted and results are reported by PARC (1998). This is an excellent source of information for developing future strategies on K uses. Detailed reviews regarding comparison of K_2SO_4 versus KCl have been made by Zehler *et al.* (1981), and Kafkafi *et al.* (1991) which can be of great use to the researchers.

Toxic effects of Cl on plants

Higher concentration of chloride in soil has toxic effects on plants, as it inhibits ammonium oxidation (Haq and Jakro, 1996). Crops on salt affected soils show symptoms of chloride toxicity which include burning of leaf tips or margins, bronzing, premature yellowing, and abscission of leaves (Eaton, 1966; Berger, 1973). Reduction in yield and quality in crops is associated with tissue levels of 0.2 to 2.0% Cl^- for sensitive crops and 4.0% or more in dry matter of tolerant crop species (Reisenhauer *et al.*, 1973). Large quantities of Cl^- tend to inhibit phosphorus uptake by plants (Berger, 1973). Maraby (1968) also reported that KCl reduced the yields of rape at increasing levels of P, showing negative interaction of Cl^- with P (Table 14).

Zehler *et al.* (1981) reported that high Cl^- concentration in plants results in lowering chlorophyll content consequently reducing photosynthetic activity, lowering of the saturation of soils, thickening of leaf cuticle, and delaying growth and flowering.

K-fixation

Lack of crop responses to K addition have been commonly reported in the literature. This may be due to fixation of added K by the expanding type of clay minerals in soil (Bajwa, 1985). Khattak (2002) reported that fixation of added K depends upon soil clay content and type of clay minerals it contains and on the recovery of non-exchangeable K. The decrease in the percent K fixation with increasing concentration of the added K (Table 15) suggested that different soil series have variable K fixation capacity depending upon the amount and type of clay, however, this information is lacking on the reported soil series. The comparison on K fixation show that Peshawar soil series had the highest K fixation at all the levels of K added followed by Tarnab and the lowest value was recorded for Warsak soil series. Texture of Tarnab and Peshawar soil series was silty clay loam while Warsak soil series was silt loam.

Table 13: Effect of MOP vs SOP on the yield of wheat and chloride content in MOP treated plots (Swat, average of 7 years)

Treatment	Yield (kg ha^{-1})
Control	2364
NP	3869
NPK-MOP	4420
NPK-SOP	4405
Soil depth (cm)	**Chloride content (meq L^{-1})**
0-15	0.076
16-30	0.086
31-60	0.118
61-90	0.138

Source: Ghani, 2003

Table 14: Influence of K form on the yield of rape seed (kg ha^{-1})

P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})		
	0	150	
		KCl	K_2SO_4
0	500	700	1200
75	550	560	1470
150	570	550	1760

Soruce: Maraby, (1968)

Table 15: Release/fixation of K in different soil series

Treatment	% K fixed		
K (mg kg^{-1})	Tarnab	Warsak	Peshawar
0	-	-	-
31.1	55	47	63
62.3	42	34	46
93.4	34	27	38

Source: Khattak (2002)

Conclusions

Based on the review of past work on K nutrition of various crops of various crops in KP soils, it is clearly demonstrated through various published literature that it is imperative to use K fertilization in soils of KP especially due to poor inherent capacity of soils to supply K to achieve optimum yields of various crops. This is true for soils of Malakand and Swat areas, eroded lands and Rod-Kohi soils. A careful selection is to be made on the use of MOP versus SOP as K source based on the performance of soils for Cl^- accumulation and crop yields.

It is known that clay mineralogical information of soil series in KP in general is not known, however, the amount and type of clay minerals play important role in the availability and fixation of K applied in the form of fertilizers. It is, therefore, strongly recommended that K fixation capacity of the Benchmark soils important for agriculture activities in KP is to be established for better formulation of fertilizer application. The K status and supplying capacity of the soils is needed to be determined. Blended fertilizers have shown better performance, on investigated soil series, therefore, these can be promoted on same soils occurring in other areas of KP. Mapping of K status of different area of KP should be developed for site specific nutrient management.

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