Chapter 3

Potassium status and its impact on crop production

The response to the application of fertilizer nutrient is related to its inherent status in soil. In other words, the status of nutrients, especially its available forms in the soil is prerequisite to plan nutrient applications to achieve targeted sustainable yield of crops. With respect to potassium, especially in soils that are rich in K containing minerals, it implies that the primary goals could be: (a) maintenance of same levels of potassium in soils by compensating loss of K caused by plant removal in “high” K soils, so that soil quality is maintained over a long time - the economic implication in this measure lies in the long term benefits drawn from accelerated production, which has become a global theme to address increase in prices of food grains and widespread hunger, (b) for soils “low” in available K, dose of application has to ensure that soil fertility builds up through encompensating loss of K caused by all previous and on going plant removals, and soils are slowly brought to high fertility status, and they become capable of producing crops at the same levels of the former, (c) for soils of medium fertility, the approach of nutrient management could be in between high fertility and low fertility soils. It is pertinent to remind the readers that depletion of fertility led to stagnation of yields of crops for more than 40 years in sub-Saharan Africa that eventually culminated into a vicious cycle of hunger - susceptibility to the ravages of malaria, HIV-AIDS and tuberculosis and death (Sanchez, 2002). For the soils of Punjab, NH4OAc-extractable K_2O at ≥ 337 kg ha^{-1} is considered high, while a range between 137 and 337 kg K_2O ha^{-1} is medium, and ≤ 137 kg K_2O ha^{-1} is treated as low.

In Punjab, out of more than 0.307 million surface soil samples that were analysed about 20 years ago in the soil testing laboratory at the Punjab Agricultural University, it was found that about 10 percent samples were low, 47 percent were medium and 43 percent samples were high in available potassium (Table 10). Amongst the geographic regions, potassium deficiency occurred widely in the soils of north-east of the state, while it was in patches in the south west districts. More than 25 percent soil samples were low in available potassium in Gurdaspur district, whereas only 1.5 percent soil samples had same status in Bathinda district. If, Punjab is divided into three regions on the basis of available potassium status in the surface soils, then Gurdaspur, Hoshiarpur, Ropar, Nawan Sahar, SAS Nagar, Ludhiana, and Jallandhar fall into first region that depicts about one-forth of the samples falling into low status of available K and a few samples falling into high status of available K. The other extreme is south-wast districts comprising Ferozepur, Moga, Barnala, Sangur, Faridkot, Muktsar, Bathinda, and Mansa. The soils of these districts are mostly high in the status of available K (Fig. 3). The Amritsar, Tarn taran, Kapurthalla, Fatehgarh Sahib and Patiala fall in between of these two regions. Even on the basis of samples tested two decades ago for available potassium, out of the 7.9 million hectare gross cropped area under field crops in the state, about 0.60 million hectare tested low and 3.47 million hectare tested medium in available potassium. If the area testing low in available potassium is considered for the calculation of the requirement of K_2O for field crops as per recommended doses of application, then it comes out to be more than 36 000 tones, which is equivalent to 61 000 t of muriate of potash (MOP). Presently, about 42 000 tones potassium is consumed in the state and most of it is used either for growing vegetables or, for supporting plantations in orchards. This indicates the immediate additional requirement of 36 000 tons of potassium to meet the K requirement of field crops grown on low K testing soils, to sustain the productivity of field crops in Punjab. The results of the latest studies conducted on maize, sunflower, peas and Bt-cotton in different districts have

Fig. 3. Geographical distribution of levels of available K in the soils of Punjab (GIS Mapping Courtesy: Punjab Remote Sensing Centre, Ludhiana)

Table 10. Percent samples under different categories of available K, total cropped area (field crops), area under low in available K, and additional requirement of potassium fertilizer in Punjab [a]

Districts	Total Number of soil samples tested	Percent samples in different categories			Total cropped area ('000 ha)	Area testing low in available K (ha)	Additional MOP requirement (t)
		Low	Medium	High			
Gurdaspur	28 914	25.7	63.5	10.8	498	12 7488	12 749
Jalandhar	20 959	17.0	53.5	29.5	418	71 060	7 106
Ropar and Fatehgarh Sahib	26 405	13.5	60.5	26.0	409	54 806	5 480
Hoshiarpur and Nawanshahr	10 438	13.2	64.3	22.5	542	71 002	7 100
Ludhiana	68 363	11.5	49.9	38.7	605	68 970	6 897
Kapurthala	10 561	7.5	52.4	40.1	271	20 054	2 005
Patiala	21 164	6.9	45.6	47.5	589	40 758	4 076
Amritsar	8 732	6.9	46.9	46.2	800	53 600	5 360
Ferozepur	18 769	4.9	38.9	56.2	907	43 536	4 354
Sangrur	28 663	3.5	36.8	59.7	872	29 648	2 965
Faridkot, Mukatsar and Moga	30 729	1.7	32.6	65.7	1084	18 211	1 821
Bathinda and Mansa	33 834	1.5	24.7	73.8	910	13 286	1 329
Total	30 7531	9.5	47.5	43.0	7905	61 2419	61 242

[a] Adapted from Sekhon (1976), and Benbi and Brar (1993) with modifications.

established that these crops respond to the application of potassium in soils that are medium, apart from their responses in the soils that test low in available potassium. Therefore, it seems that the demand of potassium fertilizer will keep on increasing with time, and its deficiency would appear in near future.

The potassium status of Punjab soils seems to be related to soil moisture regime and rainfall. The soils under udic and ustic moisture regimes are more K deficient than those under aridic moisture regime (Sidhu and Bhangu, 1993). The observation was further supported by the data provided in Table 11, where it was being reported that 50 percent of the soils of Gurdaspur series under Udic and

Ustic moisture regimes were low, and remaining medium in available-K (Rajinder-Singh et al., 1995). Contrary to it, in the soils of Abohar series, 83 percent samples were high, and 17 percent were medium in available potassium (Brar et al., 1999).

Our studies along with the studies reported by Sharma et al. (2006) could be used to infer that about 50 percent samples were low in available potassium in Hoshiarpur district, while Benbi and Brar (1995) earlier observed that 11.6 percent were low, which indicate that the rate of depletion of potassium from soils has got accelerated under Intensive cultivation. Monitoring potassium status of soils over the period of 10 years, Sekhon (1999) reported a significant decline in ammonium acetate extractable K from 104±54 mg kg^{-1} to 63±41 mg kg^{-1} in the soils under rice-wheat system of cropping in Nabha series in Ludhiana district.

Table 11. Available K status in some soil series in Punjab

Soil series	Location	Percent samples			Source
		Low	Medium	High	
Gurdaspur	Northern Punjab	50	50	0	Singh et al. (1995)
Naura	Central Punjab	12	85	3	Sharma et al. (1997)
Abohar	Southern Punjab	0	17	83	Brar et al. (1999)

3.1 Potassium balance in soil-plant system

Data of a 13 year long fertilizer experiment on maize-wheat system that involved 26 crops showed that exchangeable and non-exchangeable forms of potassium decreased in the fields that did not receive potassium fertilizer. Alongside, there was substantial amount of release of K from the non-exchangeable sources (Table 12). In the absence of applied potassium fertilizers, the net negative balance was 136 kg K_2O ha^{-1} yr^{-1}. Even with the application of 83 kg K_2O ha^{-1} yr^{-1}, the removal of K was 179 kg K_2O ha^{-1} yr^{-1} and about 100 kg K_2O ha^{-1} yr^{-1} was contributed from the soil-reserve sources. After taking into consideration of total removal of K, amount applied and changes in exchangeable and non-exchangeable forms of K, some of the K remained unaccounted, which was contributed by the ground water used for irrigation. The coefficient of correlation between K depleted from soil with uptake of K by crops indicated that the main contribution towards K nutrition of crops was from the reserve-K sources (Singh and Brar, 1986). Therefore, it could be inferred that the uptake of K by crop exceeds its addition from all sources.

Table 12. Potassium removed by 13 crop cycles (maize-wheat) and its effect on exchangeable- and non-exchangeable potassium in soils (1970-71 through 1983-84) [a]

Treatments	Total K removed	Total K applied	ΔEK	ΔNEK	Total Exch + NEK	Release from NEK	Unaccounted K
	($kg\ ha^{-1}$)						
	a	b	c	d	e = c+d	f = a-c	a-e
Control	803	0	-51	- 597	-648	752	155
N_{100}	1392	0	-72	- 1110	-1182	1320	210
N_{100} P_{22}	1766	0	-78	- 1483	-1561	1689	205
$N_{100}P_{22}K_{41}$	2323	1097	+6	- 1101	-1095	1250	149

ΔEK= changes in exchangeable K, ΔNEK= changes in non-exchangeable K
[a] Adapted from Singh and Brar (1986).

Under the intensive and high input-output rice-wheat system, the removal of potassium from the soil is more than 300 kg K_2O ha^{-1} yr^{-1} (Yadvinder-Singh et al., 2004). Considering the inputs - 50 kg K_2O ha^{-1} yr^{-1} from fertilizer, 100 kg K_2O ha^{-1} yr^{-1} from irrigation water, and another 8 kg K_2O ha^{-1} yr^{-1} from rain and seed - the net negative balance was worked out to be 150 kg K_2O ha^{-1} yr^{-1}. Even after considering the contribution of total incorporation of straws of rice and wheat, which can contribute an additional 60 kg K_2O ha^{-1} yr^{-1}, the net negative balance is 90 kg K_2O ha^{-1} yr^{-1} (Fig. 4). The negative balance will be still higher since, farmers are not applying K fertilizer to wheat and rice. Thus the reserve source of K (non-exchangeable) will be depleted at much faster rate and will ultimately affect the K-mineralogy in soils of Punjab. The depletion of K reserve sources should be a matter of concern and it may necessitate re-look on the fertilizer use strategy in Punjab.

The decline in HNO_3-soluble K from 965±255 to 875±230 mg kg^{-1} over the period of 10 years in the soils under rice-wheat system in Nabha series was reported by Sekhon (1999). The analysis of data on 33 rice-wheat long-term experiments in the Indo-Gangetic plain (Ladha et al., 2003) showed that yields of rice and wheat stagnated in 72 and 85 percent experiments, and a significant decline in 22 and 6 percent long term experiments. In all long term experiments, which experienced significant decline in yield, had large negative balance of K. It could be discerned that it may not be possible to sustain the present production

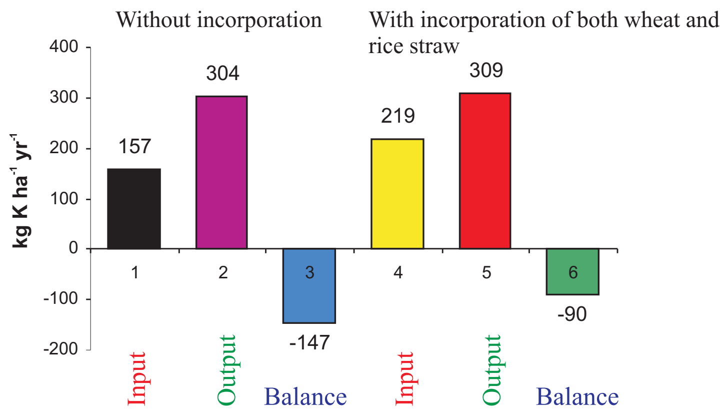

Fig. 4. Annual balance of potassium (kg K ha^{-1} yr^{-1}) in long term wheat-rice system at Ludhiana (1988 through 2000). [Adapted from Yadvinder-Singh et al (2004)].

level of rice-wheat system in the long run without the application of K and proper management of crop residue in Punjab.

3.2 Fertilizer use and nutrient consumption ratios

A look at the nutrient consumption and total fertilizer use has shown that the total fertilizer consumption in the state has progressively increased from 1970 through 2005 (Table 13). The nutrient consumption ratio, which was comparatively narrow due to economy of use of NPK mixtures during 1980's, drifted during the fertilizer decontrol era of 1990's to a wide ratio. Although, the consumption ratios are since then (2000 onwards) narrowing down, but are far away from an ideal ratio of 4:2:1.

Table 13. Temporal changes in nutrient consumption ratios and nutrient use in Punjab

Year	N: P_2O_5: K_2O	N+P_2O_5 +K_2O (kg ha^{-1})	N+P_2O_5 +K_2O ('000 t)	K_2O ('000 t)
1970-71	25.0: 4.4 : 1.0	37.5	213	7
1980-81	18.1: 7.1 : 1.0	112.5	762	29
1990-91	58.5: 21.7: 1.0	168.6	1220	15
2000-01	42.0: 11.7: 1.0	166.3	1314	24
2004-05	29.3: 7.6 : 1.0	195.0	1555	41

3.3 Role of potassium in improving nitrogen use efficiency

Potassium being a physiological stimulator in the growth of plants, plays an important role in efficient utilization of N. At insufficient K supply, NO_3^- accumulates in the roots, then partially reduced and converted into amino acids. The build up of amino acids signals in a feed back effect on the plant to further reduce N uptake. As a consequence, with increased K depletion both yield and N use efficiency are decreased. Mondal (1982) demonstrated that yield of rice depended not only on the application of N, but also on the application of K. If K is combined with N, then at every doses of N, there is substantial gain of grain yield over the yields obtained when N is applied without K. The results of the 15 field trials in Bihar (Umar et al., 1986) indicated that K did not compete with NH_4^+ for selective binding sites. The increase in yield was due to rapid assimilation of absorbed NH_4^+ in plant because K is an essential requirement for the metabolism of absorbed N. Under upland conditions it has been observed that cassava which is particularly not responsive to N application, responds to N application only in the presence of applied potassium (Muthuswamy and Rao, 1979). The spectacular increase in yield of pineapple, with the combination of N and K application over the individual application of these elements again suggest that there is a synergetic effect of K on N utilization by plants (Roy, 1986).

Application of inadequate amounts of potassium to crops like rice and wheat decrease nitrogen use efficiency, which in turn increase amounts of unutilized mineral N in soil. In irrigated agricultural system, like that in Punjab, nitrate-N accumulated in root-zone soil can leach during subsequent irrigation events and may eventually contaminate ground water. In the absence of applied K, a large amount of NO_3^-–N get accumulated in pedosphere as well. On the other hand, when balanced fertilization is practiced, the accumulation of NO_3^--N in the profile was negligible that suggest absorption of N by plants, even in quantities more than that would have been required for optimum economic yields (Bijay-Singh and Yadvinder-Singh, 2006).

Table 14. Effect of K and N application on tuber yield of potato (q ha^{-1}) [a]

Rate of N application (kg N ha^{-1})	Rate of K application (kg K_2O ha^{-1})			
	0	60	90	120
120	96.4	152.9	185.3	204.4
180	98.1	200.9	205.1	211.7

[a] Adapted from Brar and Kaur (2008).

The interaction effect of levels of applied K and N (Table 14) showed that in the absence of applied potassium, there was no effect of increased level of nitrogen on the yield of potato tubers (Brar and Kaur, 2008). The increased levels of nitrogen increased the yield only in the presence of applied potassium. This indicated that potassium supply determines the efficiency of nitrogen utilization by the potato plant.