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I Potassium Nutrition of the Potato Crop - the Indian Scenario

S.P. Trehan[(1)], S.K. Pandey[(2)], and S.K. Bansal[(3)].

Introduction

In India, the potato continues to be a remunerative crop benefiting from increasing access to irrigation and chemical inputs such as fertilizers, as well as from the continued expansion in post-harvest infrastructure such as of roads and cold storage facilities. More than 80 per cent of the potato crop is cultivated on the Indo-Gangetic plains during the winter season (Figs. 1 & 2, Table 1), the three major states of the country producing potatoes being Uttar Pradesh, West Bengal and Bihar which contribute almost 68 per cent of the total area and 78 per cent of production (Table 1).

Potato plays a pivotal role in potato based cropping systems in India, the productivity and profitability of these entire systems being dependent upon it. High efficiency in nutrient management of the potato crop therefore assumes special significance. As compared with other crops, potato has a shallow root system which limits its foraging capacity in the soil. On the other hand, uptake of fertilizer nutrients (NPK) by potato per unit area and time is high because of the rapid rate of early growth and tuber bulking (Singh and Trehan, 1997). Potato is a less efficient user of potassium than other crops (Trehan and Claassen, 1998, 2000). A healthy crop of potato removes about 170-230 kg K_2O/ha indicating a requirement for K much higher than that of cereals. Being a shallow rooted crop, fertilizer use efficiency for K ranges between 50-60 per cent (uptake efficiency). As such potato invariably responds to potassium application in the various kinds of soil and agro-climatic conditions in which it is grown. Application of K increases plant height, crop vigour and imparts resistance against drought, frost and diseases. Potassium increases leaf expansion particularly at early stages of growth and extends leaf area duration by delaying leaf shedding near maturity. It increases both the rate and duration of tuber bulking. Its application activates a number of enzymes involved in photosynthesis, carbohydrate and protein metabolism, and assists in the translocation of carbohydrates from leaves to tubers. Potassium increases the size but not the total number of tubers (Grewal and Singh, 1980; Trehan *et al.*, 2001). Potassium application thus increases yield by the formation of larger sized tubers (Plate 1).

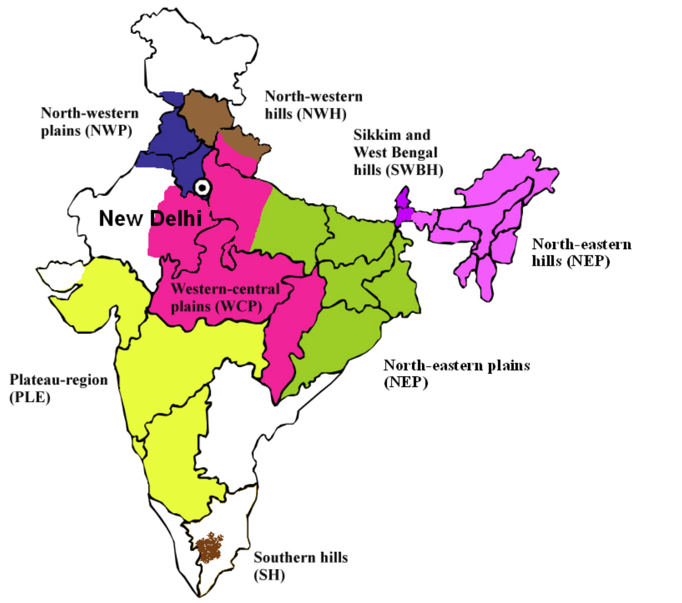

Fig. 1. Agro-ecological zones of potato in India (adapted from Singh *et al.*, 2008).

In the north-western plain, potassium plays an active role in protecting this rather sensitive crop from frost damage. In the north-western hills, under long day and rainfed conditions, K application prevents the crop suffering from moisture stress during the early stages of growth.

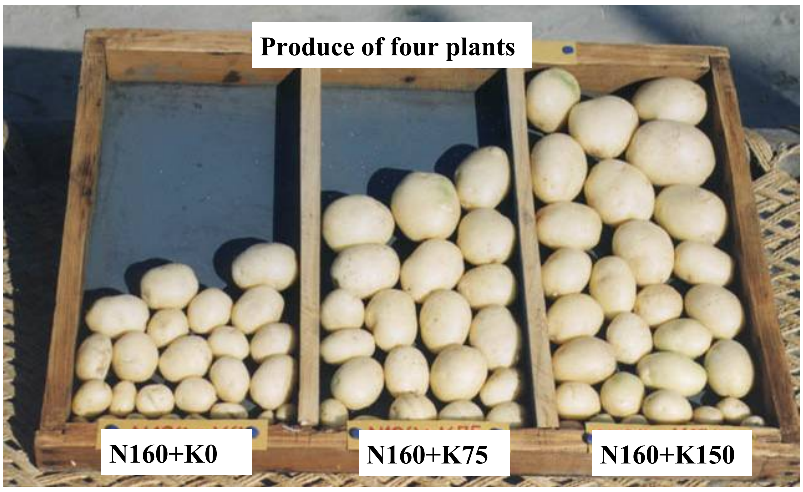

Plate 1. Potassium application increases tuber size (Jalandhar, Punjab, India). Photo from IPI-CPRI project.

(1) Corresponding author. Central Potato Research Station, Jalandhar, Punjab-144 003
(2) Central Potato Research Institute, Shimla, Himachal Pradesh-171 001
(3) Potash Research Institute of India, Gurgaon, Haryana-122 016

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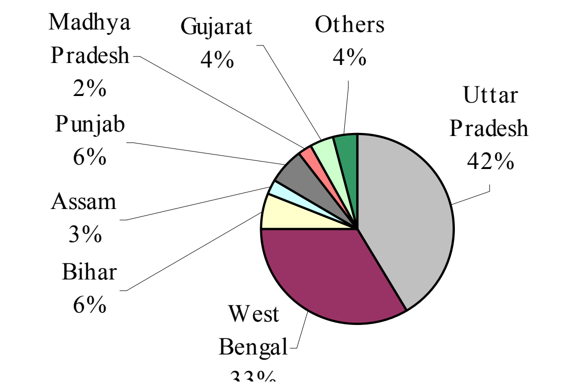

Fig. 2. Contribution of different states in potato production in India. *Source*: Singh *et al.*, 2008.

Table 2. Optimum potassium requirement of potato crop in different potato growing zones of India and the typical response and agronomic efficiency (AE_K; the response in yield to the application of 1 kg of nutrient K_2O).

Potato growing zone	Typical application rate	Typical yield response	Agronomic efficiency of K (AE_K)
	K_2O, kg/ha	*kg/ha*	*kg/kg*
North-western plains	120	5,700	47
West-central plains	120	3,400	28
North-eastern plains	160	6,700	42
Plateau region	110	3,600	33
North-western hills	100	6,400	64
North-eastern hills	130	6,400	49
SWB* hills	110	5,200	47
Southern hills	110	3,800	35
Mean	120	5,100	42

Note: * Sikkim and West Bengal hills.

Crop response to potassium in the Agro-climatic zones of potato crop in India

Potatoes are grown over the length and breadth of the country wherever conditions are favourable, on about 1.2 million ha. However, 80 per cent of the area under potato is confined to the Indo-Gangetic plains extending from the Punjab to West Bengal. Potato response to applied K varies between soil types, agro-climatic zones and varieties grown.

Table 1. Contribution of individual states in Indian potato area and production. *Source*: Pandey *et al.*, 2007.

State	Area	Production	Yield
	'000 ha	*'000 mt*	*mt/ha*
Uttar Pradesh	418.8	9375.4	22.4
West Bengal	314.9	7439.2	23.75
Bihar	147	1370.3	9.3
Assam	77.4	604	7.8
Punjab	65.8	1341.7	21.66
Karnataka	40.5	345	9.32
Madhya Pradesh	37.8	521.3	13.52
Gujarat	34.2	825.1	24.01
Meghalaya	18.5	155.6	8.38
Uttarakhand	16.8	228.6	13.82
Maharashtra	16.6	74.9	4.51
Haryana	16.3	329.5	20.17
Himachal Pradesh	13.2	155	11.73
Chhatisgarh	9.5	63.1	6.71
Orissa	7.6	77.9	10.21
Sikkim	6.8	28.5	4.16
Nagaland	6	47.8	8.25
Tripura	5.5	99.1	18.12
Tamil Nadu	4.8	84.3	17.38
Arunachal Pradesh	4.4	30.5	6.97
Manipur	4	20.4	5.23
Rajasthan	3.1	31.7	10.45
Andhra Pradesh	2.7	19.7	7.64
Jammu & Kashmir	1.6	17.1	10.19
Delhi	1.1	9	5.32
Mizoram	0.4	2.2	5.13

A large number of trials have been conducted in different potato growing agro-climatic zones in India (Grewal *et al.*, 1991). The optimum rate of K fertilization in different zones based on tuber yield response from these investigations is given in Table 2. Processing varieties of potato Kufri Chipsona 1 and Kufri Chipsona 3 and the like, grown specifically to produce large processing grade tubers, require a high rate of K fertilization - as much as 33 to 50 per cent more than those normally recommended.

Potato growing alluvial soils on the Indo-Gangetic plains are mostly coarse in texture, low in organic carbon and neutral-to-alkaline in pH. On the north-western plains, the mean optimum requirement is 120 kg K_2O/ha with a likely response of 5,700 kg/ha (Table 2). The corresponding values for the western and central Gangetic plain are 120 kg K_2O/ha with a likely response of 3,400 kg/ha. The highest requirement for K of 160 kg K_2O/ha with a likely response of 6,700 kg/ha is found on the eastern Gangetic plains. In plateau regions, potato is grown in Black Cotton and Red soils mostly as a rainfed crop. The mean optimum requirement for these soils is 110 kg K_2O/ha with a likely response of 3,600 kg/ha (Table 3). Potato growing acidic hill soils are characterized by high organic carbon and low pH. In the north-western hills the mean optimum requirement is 100 kg K_2O /ha with a likely response of 6,400 kg/ha (Table 2). Corresponding values for the north-eastern hills are 130 kg K_2O/ha with the same likely response. In the Nilgiri hills the optimum rate of application is 110 kg K_2O/ha with a likely response of 3,800 kg/ha.

The mean response to the optimum rate of K fertilizer was 5,100 kg/ha, or 42 kg of product for each kg K_2O applied (Table 2).

Physiological aspects of K nutrition in the potato crop

K needs of potato

The potassium needs of the crop vary with the agro-climatic region, variety, crop sequence taken and soil type. Indian soils are generally high in total K but only a small fraction of it is in available form which relates to the

Table 3. Critical levels of soil available K for potato in alluvial soils.

Soil potassium status	Ammonium acetate-K (ppm)
Low	<105
Medium	105-150
High	>150

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dynamic equilibrium between fixed, non-exchangeable and exchangeable K. Under conditions of high crop intensity and high rates of K removal, soils are likely to become deficient in K with time. A healthy crop of potatoes removes on average 4.60 kg K_2O per ton of tuber yield corresponding to about 170-230 kg K_2O/ha depending upon the variety, crop duration and agro-climatic region. Maximum accumulation of K takes place between 30 to 60 days of planting in the plains and between 65 to 85 days in the hills (Grewal and Trehan, 1993). Therefore, a ready supply of K from the soil is required during the early stages of growth of the fast growing potato crop. Most of the light textured potato growing soils are poor in fertility and unable to meet the demands of the growing crop (Grewal *et al*., 1991) so that crop growth is retarded. Additional supply of K through fertilizers and manures is therefore essential.

Potassium deficiency symptoms

Potassium deficiency normally coincides with the onset of tuber initiation. Mild K deficiency starts with the appearance of dark bluish green leaves and shortened internodes. Terminal leaves show bronzing accompanied by necrotic spots as the severity of K deficiency increases (Plate 2). In the case of acute deficiency, leaf margins may dry up and premature death of the plant often occurs.

Deficiency limits in soil and plant

Alluvial soils with less than 105 mg/kg K (NH_4OAC-K) have been classified as deficient (Table 3) for potato (Singh and Grewal, 1985). In experiments on three alluvial soils of Patna, the average responses to four levels of K application (60,120, 180 and 240 kg K_2O/ha) were 9,100, 4,300 and 600 kg/ha corresponding to soil test values of ammonium acetate extractable K of 55, 131 and 177 mg/kg, respectively, indicating that the lower the available K in soil, the higher the response to the K applied. Likewise, for the acidic hill soils average responses to applied K were 6,400, 3,900 and 1,800 kg/ha when soil test values of ammonium acetate extractable K were 140, 182 and 212 mg/kg respectively (Grewal *et al*., 1991). Plant tests measuring K concentration in tissues are indicative of the supply from the soil medium. However, this concentration rapidly changes during the growth period as a consequence of several factors which limits the use and reliability of this determination as a means of detecting deficiencies under field conditions. In alluvial soils, a leaflet K concentration of 3.62 per cent or less at 50 days after planting has been classified as deficient whereas concentrations ranging from 3.8-5.0 per cent as adequate (Singh, 1987a, b). The concentration of K is highly variable with crop age and even between cultivars (Trehan and Grewal, 1994).

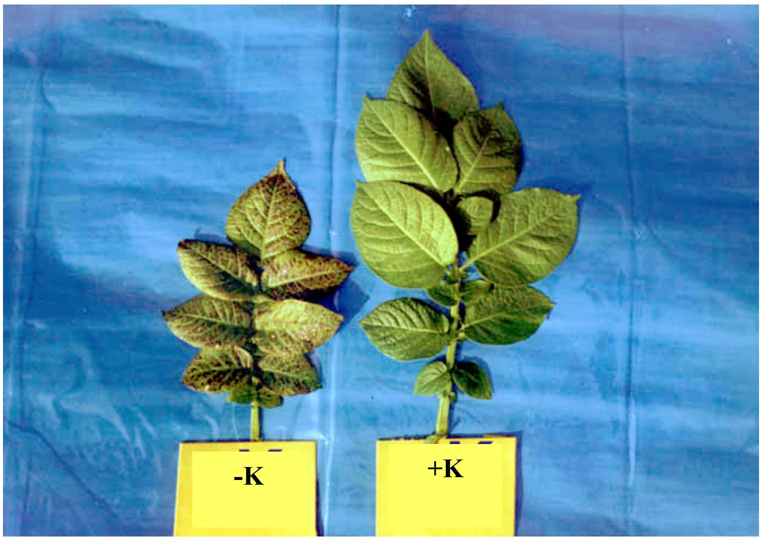

Plate 2. Potassium deficiency symptoms in potato (Jalandhar, Punjab, India). Photo from IPI-CPRI project.

Potato response to K as affected by variety

Potato response to applied K is considerably influenced by the variety grown (Trehan and Sharma, 2002; Trehan and Sharma, 2003; Trehan and Sharma, 2005; Trehan, 2007). The low response in some varieties to K is attributed to their capability in utilizing more K from the soil source. The varietal response to applied K is often related to its yield potential and the number of large sized tubers it can produce. In general, rapid bulking potato varieties producing large size tubers respond more to K than do the varieties with small sized tubers, as application of K is known to increase the tuber size (Trehan and Grewal, 1990). Kufri Jyoti was more responsive to K than Kufri Chandramukhi in the plains of West Bengal (Dasmahapatra *et al.,* 1984). Results of field experiment conducted at the Central Potato Research Station, Jalandhar, Punjab showed wide variation in potassium efficiency of different potato cultivars (Trehan, 2007). The cv. Kufri Pukhraj was the most K efficient followed by Kufri Sutlej, Kufri Badshah, Kufri Bahar, Kufri Sindhuri, Kufri Ashoka, Kufri Jawahar, Kufri Jyoti, Kufri Lalima and Kufri Chandramukhi based on tuber yield without potassium application (Fig. 3) and with potassium fertilizer required to produce maximum achievable fixed yield. The potassium efficient cultivars gave higher tuber yields with less applied K fertilizer than less efficient cultivars. The most K

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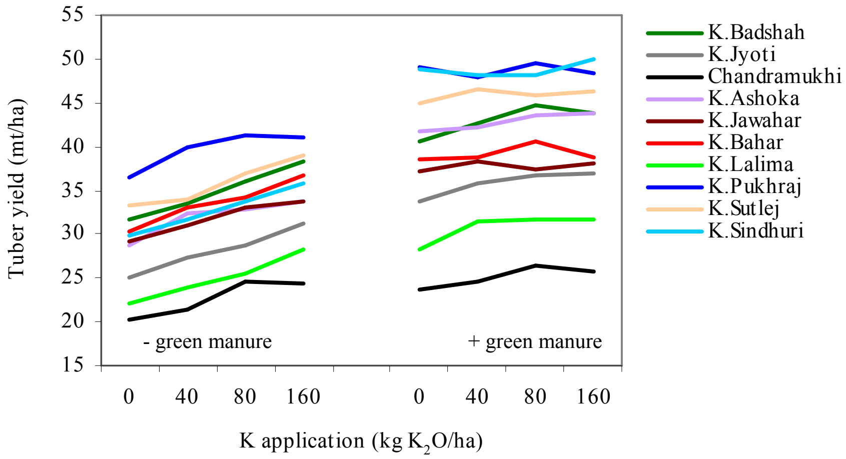

Fig. 3. Effect of K application on tuber yield of ten potato cultivars with and without green manure (GM); (The CD (0.05) was 17.0, 10.6 and 34.0 without GM and 23.7, NS and NS with GM for cultivar mean, K rate mean and cultivar x K rate, respectively). *Source*: Trehan, 2007.

efficient cv. Kufri Pukhraj produced a yield of 36,400 kg/ha without K whereas Kufri Badshah and Kufri Sutlej needed 80 kg K_2O/ha to produce yields of 36,100 and 37,000 kg/ha, respectively in the same field.

It can be thus concluded that varieties behave differently in relation to K requirement in their response to K application so that selection of the rate of K application should be based on variety in addition to the soil test value.

Effect of K on tuber quality

Apart from its effect on tuber size, application of K has a significant influence on nutrient composition of tubers and tuber quality parameters viz. dry matter content, sugar, vitamin C content. Application of K has a direct influence on tuber quality. It increases total and reducing sugar contents but decreases tuber dry matter content, the decrease being associated with potassium chloride (MOP) rather than potassium sulphate (SOP). The negative effect of MOP on dry matter is mainly due to the accompanying chloride ion in MOP. However, the decrease in dry matter was not significant in alluvial soils. Application of SOP produces tubers higher in dry matter, starch and Vitamin C contents. The chip quality of potato tubers is also affected by K source. Application of K as MOP has been reported to decrease enzymatic discoloration and phenol content thereby reducing the browning of potato chips (Joshi *et al*, 1982). Potassium fertilization promotes a lustrous appearance on the surface of the tubers. Potassium application has a significant role in enhancing tuber keeping quality under storage.

Fertilization of the potato crop in India

Comparative evaluation of sources of K

Several potassium fertilizers have been tried out on the potato crop but of these, potassium chloride (60% K_2O) and potassium sulphate (50% K_2O), the most common forms of inorganic potash supply, have been studied in depth in various agro-climatic regions. Although SOP has been found to be best in terms of its beneficial effect on tuber quality viz., dry matter, ascorbic acid and sugar content, its high cost has meant that it has not found much use in potato cultivation (Sharma *et al.,* 1976). However, in sulphur deficient soils, it can be more effective because of the sulphur it contains. By far the most commonly used salt is MOP which constitutes 97 per cent of potassium fertilizer consumption in the potato crop. Another potassium fertilizer, i.e. potassium schoenite, an indigenous source, the double salt of potassium and magnesium sulphate, has also been found to be equally good for potato in acidic and alluvial soils (Sharma *et al.*, 1998).

Organic sources

Farmyard manure application can supplement the K needs of potato, the extent depending upon the quantity of FYM applied. Studies on the acidic soils of Shimla and alluvial soils of Jalandhar have shown that application of 30 mt/ha of FYM can not only meet the full K needs of potato but also of a succeeding wheat crop, besides maintaining higher yield than with K from inorganic fertilizers (Grewal and Sharma, 1980,). Subsequent studies indicate that at 15 mt/ha, FYM along with a 50 per cent rate of K application is as effective as 100 per cent K inorganic rate (Grewal and Trehan, 1988). The combined use of FYM and K in general is more effective than their separate use. Later studies have also revealed a higher K use efficiency and 25 per cent saving in the K rate of application with even smaller quantity of FYM i.e. 5 mt/ha applied along with K fertilizers in furrows at the time of planting (Grewal and Sud, 1990). Green manuring with *dhaincha* and sunnhemp in alluvial soils is also beneficial in substituting in K crop requirement and hence the K application rate for potato (Sharma and Sharma, 1990).

Time and method of K application

Because of the sparse root system of the potato crop, the proper placement of the fertilizer has a great influence on K utilization by the potato roots and subsequently on the effectiveness of the roots on fertilizer use efficiency. Where,

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the crop is taken under rainfed conditions, moisture stress at early growth stages or excess rains after planting have a direct bearing on the utilization of applied nutrients. This is particularly true for K, a highly mobile nutrient prone to leaching to lower horizons in light soils or being washed out by surface run off from hill soils. Several approaches to increase the efficacy of K fertilizers by the potato crop have been found to be quite effective. Application of K at planting time in furrows is better than its application above or below seed tubers or broadcasting in hill soils (Sud and Grewal, 1992). In the ware potato crop, that is for potatoes grown for seed purposes, split application (i.e. half at planting and the rest at earthing up along with the N application) increases the yield of large size tubers suitable for seed (Sud and Grewal, 1991; Singh and Grewal, 1995).

Foliar application of K by a 2 per cent solution of KCl to potato at 50 or 70 days after planting has been found to be quite effective in Kufri Badshah in the northern plains and has helped to lower the K rate of application by 40 kg K_2O/ha but not to replace soil application (Trehan and Sharma, 1998). Foliar application was not beneficial over soil application in West Bengal (Dasmahapatra *et al*., 1984). Foliar application can therefore be resorted to only in the case of severe K deficiency visible in the standing crop and then only with limited benefits. To avoid scorching of foliage due to salt and chloride toxicity, spraying should be restricted to the morning and evening hours.

Effect of continuous K application

Firstly, no deleterious effect of continuous application of K has been reported. Reversible reaction between available, exchangeable and fixed K fraction in soils is attributed to the maintenance of available K levels in the soil. Secondly, a build up of K in the soil is precluded because the uptake of K from soil is often in excess of that applied thus resulting in a negative balance of K in the soils of potato based cropping systems.

Residual effects of K fertilizers

Among the inorganic and organic sources of K, the residual effect of FYM has been found to be higher than that of fertilizer K (Sharma, 1998). Soil analysis also indicates the superiority of organic manures like FYM over K fertilizers in improving the available K content in soils. The residues of wheat and paddy straw have been found to be superior to FYM in increasing K availability to the crop in acidic hill soils. This report has also been further supported by the radiotracer studies using ^{86}Rb by Sud and Sharma (2002) and Sud (2005).

Long-term studies on alluvial soils of Indo-Gangetic plains and in hill soils have revealed a residual effect of K both from inorganic or organic sources on crops like maize, paddy rice wheat, mung, jute etc. This can be attributed to the fact that the cereals and legumes are more efficient extractors of K from residues left over from K applied to potato. The residual effect of K applied to cereals on the other hand, however, is not sufficient for the potato crop because of its sparse rooting system indicating that direct application of K to potato is needed in order to obtain optimum yields. The residual effect of K is more pronounced in acidic hill soils than in alluvial soils of the plains. The potato crop has thus a priority for the use of K fertilizers whereas other crops including cereals or pulses in a crop sequence can thrive well on the K derived from the residual effect.

Nutrient interactions

Nutrient interaction is a common feature in agricultural crops as they play a vital role in modifying the nutrient needs of many crops including potato. Studies show that K has a significant interaction with N indicating that the rates of N and K application are interdependent. Studies conducted on alluvial soils of the Indo-Gangetic plains show that application of N induces K deficiency in the plant thereby necessitating a balanced K application. Studies conducted by Chadha *et al.* (2006) in cold desert soils of the Lahaul Valley and Sharma and Sood (2002) in the Shimla hills showed a significant interaction between N and K. According to these researchers, application of N induces K deficiency in the plant thereby necessitating a balanced K application. Application of K on the other hand helps to increase N utilization in drought years. Singh and Ragav (2000) attributed the significant interaction between N and K in the tarai belt of Uttrakhand to the better utilization of N in the presence of K as reflected by increased plant height. There are also reports that high levels of K application depress the Ca concentration in potato leaf petioles and haulms.

Maintenance fertilization of potassium

Application of P and K to only the potato crop in the potato based cropping systems was recommended during the eighties (Grewal and Sharma, 1981; Sharma *et al*., 1983) because succeeding cereals and other crops failed to respond to direct application of P and K fertilizers. The residuals of K applied to potato fully or partially met the requirement of the succeeding crops (Prasad *et al*., 1981; Mandal *et al*., 1981).

However, long-term experiments have shown that in intensive cropping systems (two to three crops per year) removal of K from soil was far in excess of applied K, resulting in a severe negative balance of K in the soil to the detriment of crop yields (Sharma and Singh, 1989; Singh *et al*., 1997, 2001; Singh *et al*., 2000; Roy *et al*., 2000). The rice-potato-wheat cropping

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system suffered the most from this negative balance (Fig. 4). A negative balance of K in the soil was shown to be responsible to a large extent for the decline in the yield of crops and has rendered potato based cropping systems unsustainable in the long run (Singh *et al.*, 2001).

Potassium and tolerance of potato crop to stresses

Frost tolerance

Frost appears in December-January in the northern plains, i.e. Punjab and western Uttar Pradesh. This coincides with when the crop is in an active bulking phase and its effect is to bring about yield losses up to 40 per cent. Observations on frost injury to the potato plant reveal a strong interaction between frost injuries and K nutrition in K deficient soils (Grewal and Singh, 1980). Potato crops grown on soils supplied with a sufficient quantity of K are protected from frost injury. Similarly, leaf K content is inversely related to the frost damage index. A high concentration of K in leaf depresses the freezing point of the cell sap thereby protecting the plant from the frost. A decrease in intensity of frost damage associated with an increase in K rate of application in alluvial soils has also been reported in western Uttar Pradesh. Potato response to K application is positively correlated with frost damage. Potato varieties also differ in relation to susceptibility to frost injury. Potato varieties like Kufri Chandramukhi and Gulmarg Special are highly susceptible whereas Kufri Sindhuri is most resistant. In general, varieties which are more susceptible to frost injury are highly responsive to K.

Moisture stress

Potassium contributes greatly in maintaining the water economy of plants. This is particularly true in the case of rainfed crop in the hills where moisture stress often occurs during the time of plant emergence and at the tuber initiation stage. Potassium application, although not economizing on the water needs of the potato crop, does increase water use efficiency in terms of tubers yield/mm water.

Disease resistance

In addition adequate K also imparts resistance to late blight, a common feature in the hills (Sharma *et al.*, 1999). Besides this application of K also reduces the occurrence of black scurf in potato. An inverse relationship between available K in soil and disease severity in potato has been observed.

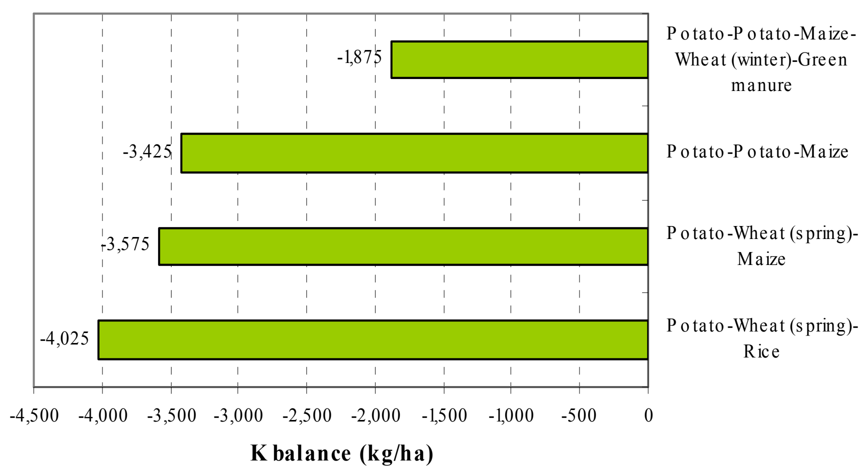

Fig. 4. Mean balance of potassium in soil after 17 years (1970-1987) in different cropping systems. *Source*: Singh *et al.*, 2001.

Conclusions

In India, the potato crop invariably responds to potassium application in terms of improved tuber yield, tuber appearance, and processing and nutritive quality. At higher rates of supply it also improves the keeping quality of tubers in country stores. Direct application of potassium to potato is essential for maximum benefit. Basal application is the preferred mode of fertilization, but split application may be beneficial in light textured soils. Fertilization with potassium is highly cost effective. Considering the mean response to an optimum rate of K fertilizer as 5,100 kg/ha or 42 kg of potatoes for each kg of potash (K_2O) applied (Table 2), a farmer can obtain a return of Rs. 14 for each rupee spent on potash (assuming the cost of potash (K_2O) as Rs. 9 kg and the price of one kg of potatoes as Rs. 3). In intensive potato based cropping systems, all the crops in the system need potassium fertilization particularly in alluvial and hill soils. This is necessary to maintain soil K for long-term sustainability and productivity of the cropping systems.

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