# Assessing Potassium Needs of Different Crops and Cropping Systems in India

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## Introduction

*Declining potassium fertility:* There is a growing evidence of increasing deficiency of K as a result of imbalanced use of nitrogen (N) or N and phosphorus (P). Even under so-called optimum rates of NPK application in long term experiments, the K balance under most of the soil-cropping systems was negative. The results of long term experiments clearly demonstrated that mining of soil K occurred with NP and even with NPK application. The cropping system of maize-wheat on alluvial soil at Ludhiana and fingermillet-Rabi maize on Alfisol at Bangalore started drawing on the non-exchangeable sources of K when exchangeable K fell below the critical limits. Thus very low K fertility status of the soils started limiting the responses to N and P (Singh and Swarup, 2000).

Potassium fertility status of the soils determines the response of crops to its application. Soil test summaries of 4.5 million samples showed that soils in 20 per cent districts (63 districts) are low, 42 per cent (130) are medium and 38 per cent (117) are high in available potassium (K) (Ghosh and Hasan, 1976). In 29 soil series, all red and lateritic soils were low in available and reserve K; illite dominant alluvial soils were medium in available but high in reserve K; and Vertisols with smectite clay were high in available K but relatively low in reserve K (Sekhon *et al.*, 1992).

*Historical crop responses to K:* Soil application of 60 kg $K_2O$ / ha in alluvial soils at Kanpur, U.P. (Tiwari *et al.*, 1974) and of 30 kg $K_2O$ $ha^{-1}$ for Kalyansona wheat raised on Punjab soils low in exchangeable K gave optimum yield (Stillwell *et al.*, 1975). Based on the result of the experiments on cultivators' fields, Goswami *et al.* (1976) concluded that rice was benefitted more than wheat by K application and further the extent of response in Rabi (November-March) rice was higher than in Kharif (June-October) rice. As crops differ in responsiveness to K, rice and wheat, often respond more to K than sorghum and millets. The magnitude of crop responses to K differed among various soil groups, mainly due to the differences in their K fertility status. Generally laterites, red and yellow and mixed red and black soils have been found to be more responsive of all and required K application to manage their fertility status.

*Negative nutrient balances in cropping systems:* Unfortunately, application of K did not receive due attention, for most Indian soils were believed to be 'adequate' in native K supply. The neglect of K application in India is evident from the highly imbalanced fertilizer consumption ratio in respect of K.

Removal of K in proportion to N is very high in cropping systems, particularly in those involving cereal and fodder crops. A continuous mismatch between nutrient removal and replenishment has been observed in various cropping systems even at the recommended levels of fertilizer application (Yadav *et al.*, 1998) (**Table 1**). Crop requirement of K to produce unit amount of grain / seed / economic produce varies depending on soil, climate (location) and variety (**Table 2**). With current level of food grain production, 206 million

**Table 1. Nutrient uptake in important cropping systems**

| *Crop sequence* | *Applied, kg ha$^{-1}$* | | | *Total yield, t ha$^{-1}$* | *Total uptake, kg ha$^{-1}$* | | |
|---|---|---|---|---|---|---|---|
| | *N* | *P* | *K* | | *N* | *P* | *K* |
| Maize-Wheat-G. gram | 260 | 70 | 50 | 8.21 | 306 | 27 | 232 |
| Rice-wheat-G. gram | 260 | 70 | 50 | 11.15 | 328 | 30 | 305 |
| Maize-wheat | 250 | 54 | 75 | 7.60 | 247 | 37 | 243 |
| Rice-Wheat | 250 | 44 | 84 | 8.80 | 235 | 40 | 280 |
| Maize-Wheat | 240 | 52 | 100 | 7.72 | 220 | 38 | 206 |
| Pigeonpea-Wheat | 144 | 52 | 100 | 4.82 | 219 | 31 | 168 |
| P. Millet-Wheat-greengram | 245 | 66 | 66 | 10.02 | 278 | 42 | 284 |
| P. Millet-Wheat-Cowpea (Fodder) | 245 | 66 | 66 | 9.22<br>19.9(F) | 500 | 59 | 483 |
| Soybean-wheat | 145 | 61 | 0 | 7.74 | 260 | 37 | 170 |
| Maize-Wheat-Greengram | 295 | 74 | 0 | 9.01 | 296 | 47 | 256 |
| Maize-Indian-rape-Wheat | 330 | 69 | 0 | 8.63 | 250 | 41 | 200 |

Yadav *et al.* (1998)

**Table 2. Potassium requirement of different crops**

| *Soil* | *Location* | *Crop* | *Variety* | *K requirement (kg/q)* |
|---|---|---|---|---|
| Acid Alfisol | Kangra (H.P.) | Rice | Norin-18 | 2.96 |
| Black soil | Jabalpur (M.P.) | Rice | IRB, Patel-85, Ratna | 3.8 |
| Black soils | Guntur, Andhra Pradesh | Rice | Mashuri | 2.58 |
| New alluvial soils | Kalyani, West Bengal | Rice | IET-4094 | 1.95 |
| Calcareous soil | Bihar | Rice | | 2.21 |
| Acid Alfisol | Kangra (H.P.) | Wheat | S-308 | 1.66 |
| Alluvial | IARI, New Delhi | Wheat | | 2.83 |
| Typic Chromuserts | Rahuri, Maharashtra | Wheat | HD-2189 | 2.25 |
| Black soil | Jabalpur | Wheat | | 3.79 |
| Calcareous soil | Bihar | Wheat | RR-21 | 1.63 |
| Old alluvial soils | Kalyani, West Bengal | Wheat | Sonalika | 4.48 |
| Acid Alfisol | Kangra (H.P.) | Maize | Early composite | 1.64 |
| Black soil | Jabalpur | Maize | | 3.0 |
| Calcareous soil | Bihar | Maize | | 1.36 |
| Chalka soil | Jagitial, Andhra Pradesh | Maize | DHM-105 | 1.55 |
| Typic Chromuserts | Rahuri, Maharashtra | Gram | Vijay | 2.73 |
| Black soil | Jabalpur | Gram | | 5.77 |
| Calcareous soil | Bihar | Gram | | 1.43 |
| Black soil | Jabalpur | Cotton | | 5.89 |
| Calcareous soil | Bihar | Groundnut | M-13 | 3.8 |
| Calcareous soil | Bihar | Sugarcane | BO-84 | 0.18 |
| | | Sugarcane (Ratoon) | BO-84 | 0.156 |
| Calcareous soil | Bihar | Potato | Kufri Sinduri | 0.234 |
| Calcareous soil | Bihar | Mustard | 66-197-3 | 5.02 |

Subba Rao and Srivastava (2001)

tonnes during 1999-2000 at national level, there is a gap of 10 million tonnes nutrients per year between removal (28 million tonnes) and additions (18 million tonnes) (Anonymous, 2001). If these estimates are any indication, it becomes imperative that to sustain the soil productivity, present trend has to be reversed by adequate replenishment of soil reserves by external K applications.

*Long term crop responses to K:* Pillai *et al.* (1987) summarised the response of crops to K in selected cropping systems in long term experiments in progress at various centres in different regions of India (**Table 3**). Rice responded to K both in rice-rice and rice-wheat systems at several centres. Wheat responded to K in 3 systems at all locations except Rudrur and Siruguppa. Sorghum responded to K at Akola and Siruguppa and failed to respond at Gwalior and Sehore.

**Table 3. Response to K in selected cropping systems from experiments on long-term effect of continuous cropping manuring (AICARP) data for 1982-83: the experiment started in 1977-78**

| *Region* | *Centre* | *Mean yield at $K_0$ t $ha^{-1}$* | | *kg grain per kg $K_2O$* | |
|---|---|---|---|---|---|
| | | *Kharif* | *Rabi* | *Kharif* | *Rabi* |
| I Rice- Rice | Titabar | 1.88 | 2.49 | 12.8 | 3.5 |
| V | Chiplima | 1.64 | 2.99 | 6.8 | 7.5 |
| VIII | Mangalore | 4.10 | 3.04 | 6.5 | 6.3 |
| | Karamana | 4.41 | 2.48 | NS | 6.0 |
| I Rice -Wheat | Palampur | 4.16 | 2.47 | 10.0 | 18.0 |
| V | Rudrur | 3.43 | 1.27 | 9.0 | 2.8 |
| IV Maize-Wheat | Ludhiana | 2.73 | 3.45 | 7.0 | 8.5 |
| VII Sorghum-Wheat | Gwalior | – | 3.43 | – | 15.8 |
| | Sehore | 1.86 | 1.64 | NS | 5.8 |
| | Akola | 1.40 | 1.41 | 4.8 | 5.8 |
| VIII | Siruguppa | 3.39 | 1.75 | 10.5 | NS |

NS : Not significant; responses are to 40 kg $ha^{-1}$ $K_2O$
Pillai (1987)

Long-term studies under AICRP on Cropping Systems Research showed progressive increase in response to fertilizer K (40kg $K_2O$ $ha^{-1}$) in both rice and wheat crops in rice-wheat system, the magnitude and rate of increase in response over years being higher in rice at Faizabad (Inceptisols), Rudrur (Vertisols) and Raipur (Alfisols). In these Experiments, uptake of K by the crops even at optimal NPK dose was far in excess of fertilizer K applied in almost all the soils and cropping systems, indicating inadequate K application and much greater exploitation of native K reserves of the soil (Nambiar, 1994). Because of contribution of non-exchangeable K pool towards K uptake under continuous intensive rice-wheat cropping over years in Inceptisols of

Kanpur with illite as dominant clay mineral, it has become difficult to maintain even initial K status despite K application at recommended rates (Tiwari *et al.*, 1992).

It has been observed that with continuous application of N alone, there was a definite declining trend in productivity of rice-rice at a few locations (**Table 4**). However, with the application of P in combination with N, productivity increased. Even in areas where there was negative response to P and K in initial years, there was gradual increase in the magnitude of response to P and K over years (Hegde, 1993).

**Table 4. Average response to NPK over years in rice-rice system**

| | | | *Control* | *Response (kg ha$^{-1}$) to* | | |
|---|---|---|---|---|---|---|
| *Location* | *Crop* | *Year* | *Yield (kg ha$^{-1}$)* | $N_{120}$ | $P_{80}$ *over N* | $K_{40}$ *over NP* |
| Rajendranagar | Rice (K) | 1983-84<br>1990-91 | 3576<br>1157 | 1553<br>790 | –230<br>308 | 189<br>116 |
| | Rice (R) | 1983-84<br>1990-91 | 2089<br>1108 | 1661<br>842 | 92<br>285 | 194<br>–259 |
| Chiplima | Rice (K) | 1978-79<br>1991-92 | 2665<br>3085 | 663<br>724 | 344<br>1547 | –194<br>542 |
| | Rice (R) | 1978-79<br>1991-92 | 1627<br>2716 | 681<br>1900 | 459<br>966 | 441<br>714 |
| Karmana | Rice (K) | 1977-78<br>1991-92 | 3527<br>2528 | 1652<br>985 | 204<br>1177 | 52<br>344 |
| Karmana | Rice (R) | 1979-80<br>1990-91 | 2283<br>2014 | 389<br>585 | 368<br>689 | 34<br>111 |
| Thanjavur | Rice (K) | 1977-78<br>1986-87 | 3903<br>2155 | 1722<br>2441 | –661<br>177 | 357<br>519 |
| | Rice (R) | 1977-78<br>1986-87 | 2128<br>2085 | 1631<br>1731 | –656<br>602 | 354<br>487 |
| | Rice (S) | 1978-79<br>1986-87 | 1324<br>2686 | 910<br>1042 | 319<br>1059 | 320<br>264 |
| Maruteru | Rice (K) | 1977-78<br>1990-91 | 2100<br>1954 | 1025<br>2072 | 454<br>423 | –404<br>353 |
| | Rice (R) | 1977-78<br>1990-91 | 1635<br>1632 | 3163<br>3659 | –108<br>662 | 434<br>198 |

K = *Kharif*, R= *Rabi*, S= summer

Hegde (1993)

## POTASSIUM MANAGEMENT IN CROPS/CORPPING SYSTEMS

### Rice-Wheat

In a large number of field experiments conducted on cultivators' fields in alluvial tracts of Uttar Pradesh, positive responses to K up to 60 kg $ha^{-1}$ for rice and wheat under irrigated conditions were observed. The yield response was 3 to 8 kg grain $kg^{-1}$ $K_2O$ in rice and wheat (Yadav *et al.*, 1993). Studies on effect of continuous application of potassium on crop yields and potassium availability under different cropping sequences in calcareous soil (pH : 8.3, EC : 0.43 dS $m^{-1}$, organic carbon : 0.45%, $CaCO_3$ : 25% and 1M $NH_4OA_C$ K : 54 kg $ha^{-1}$) indicated that grain yield of rice and wheat increased with increasing levels of K upto 80 kg / ha. Potassium removal by rice-wheat system also increased with increasing levels of K application (**Table 5**). Potassium balance in soil was positive (20.7 kg K $ha^{-1}$) with 80 kg $K_2O$ $ha^{-1}$ application (Prasad, 1993).

**Table 5. Effect of continuous application of potassium on grain yield and K uptake of rice-wheat crops grown on a calcareous soil of Bihar (Data pooled over 5 year 1983-89)**

| *Treatment ($kg\ K_2O\ ha^{-1}$)* | *Grain yield ($q\ ha^{-1}$)* | | *Yield response (kg grain)* | | *K Uptake ($kg\ ha^{-1}$)* | |
|---|---|---|---|---|---|---|
| | *Rice* | *Wheat* | *Rice* | *Wheat* | *Rice* | *Wheat* |
| 0 | 32.5 | 28.6 | | | 95.4 | 77.3 |
| 40 | 41.1 | 31.9 | 21.5 | 8.3 | 126.6 | 89.3 |
| 80 | 43.0 | 33.8 | 13.1 | 5.5 | 167.1 | 107.2 |
| Mean | 38.9 | 31.2 | 17.3 | 6.9 | 129.7 | 91.3 |
| CD (5%) | 1.50 | 1.93 | | | 5.4 | 11.2 |

Prasad (1993)

In a two-year field experiment, response of two verieties of wheat HD 1941 and UP 301 were tested with four rates of K application on sandy loam (pH 7.6) alluvial soil of Varanasi. Application of 50 kg $K_2O$ significantly increased the grain and straw yields, the response being 4 kg grain per kg $K_2O$ applied (Singh *et al.*, 1993).

Split application of K is a better soil fertility management option than basal dressing of K for rice grown in coarse-textured and acid soils in relatively high rainfall areas, as it reduced leaching losses. This practice has also been found useful for low-tillering and late-maturing varieties. Several studies conducted in Tamil Nadu, Uttar Pradesh, West Bengal and Tripura indicated the beneficial effect of split application of K (Tandon and Sekhon, 1988). Pandey *et al.* (1993) studied the response of rice to applied potassium on a Vertisol (available K 287 kg $ha^{-1}$) at Raipur, Chhattisgarh State. Application of 40 kg $K_2O$ $ha^{-1}$ in two equal splits as basal and at panicle initiation stage of rice significantly increased the grain yield.

Application of graded levels of K significantly increased the yield of rice on Rhodic Paleustalf (pH : 5.4, EC : 0.03 dS $m^{-1}$, organic carbon : 0.92%, available P : 4.8 kg $ha^{-1}$ and available K : 102 kg $ha^{-1}$) in all the years (Krishnappa *et al.*, 1990). Similarly, the application of K in two splits was also found to increase the yield significantly over basal application. Increase in the yield of rice might be due to prolonged availability of K in soil, significant decrease in number of chaffy grain, increased tillering and concentration of K in straw and grain. Potassium application 50% at transplanting and 50% at panicle initiation along with N is recommended in Malnad where light textured soils and high rain-fall conditions are prevalent.

## Rice-Gram

An experiment conducted during 1990-92 at Ranchi, Jharkhand state to study the direct and residual effects of P and K in rice (*Oryza sativa* L.) - gram (*Cicer arietimum*) cropping system in a sandy loam soil (pH : 6.4, available N : 147 kg $ha^{-1}$, available P : 14 kg $ha^{-1}$ and available K : 165 kg $ha^{-1}$) (Singh and Prasad, 1996). It revealed that the application of P and K in both the seasons (*Kharif* and *Rabi*) increased the rice equivalent yield of the system significantly (**Table 6**). Addition of high dose of phosphate and potash (60 kg/ha) increased the grain yield of the system by 10.5 and 4.9 per cent, respectively. The results further indicated that application of P and K to this crop sequence resulted in increase in availability of these nutrients in soil.

## Winter Maize-Rapeseed

Prasad and Prasad (1993) studied the response of winter maize and rapeseed to potassium on farmers' fields in Calciorthents of north Bihar (**Table 7**). The largest responses of rapeseed and winter maize to 60 kg $K_2O$ $ha^{-1}$ application were 11.6 and 20.8 kg grain $kg^{-1}$ $K_2O$, respectively. The benefit : cost ratio at

**Table 6. Effect of time of P and K application on yield of rice and gram (Mean of 2 years)**

| *Treatment* | *Rice Grain yield (q/ha)* | *Gram Grain yield (q/ha)* | *Rice equivalent yield of system (q/ha)* |
|---|---|---|---|
| $M_1$ | 32.9 | 7.10 | 61.3 |
| $M_2$ | 30.9 | 6.19 | 55.7 |
| $M_3$ | 30.5 | 6.20 | 55.3 |
| CD {P=0.05} | 1.2 | 0.70 | 3.3 |
| $P_0$ | 33.8 | 6.83 | 61.1 |
| $P_{30}$ | 34.5 | 7.31 | 63.8 |
| $P_{60}$ | 36.1 | 8.78 | 70.9 |
| CD {P=0.05} | 0.7 | 0.67 | 2.7 |
| $K_0$ | 34.5 | 7.19 | 63.2 |
| $K_{30}$ | 35.6 | 6.26 | 60.6 |
| $K_{60}$ | 36.7 | 7.39 | 66.3 |
| CD {P=0.05} | 1.5 | 1.03 | 3.3 |

$M_1$ =P and K in both seasons $M_2$ = P and K in Kharif season $M_3$ = P and K in Rabi season only

Singh and Prasad (1996)

**Table 7. Response of winter maize (var. Laxmi) and rapeseed (var. Varuna) to K application on farmers' fields (Village-Lautan) in jagdishpur-Bagha soil series**

| *K application (kg $K_2O$)* | *Grain yield ($t\ ha^{-1}$)* | *Response ($t\ ha^{-1}$)* | *Response (kg grain per kg) $K_2O$)* | *Cost of potash* | *Return due to additional yield (Rs/ha)* | *Net profit (Rs/ha)* | *Benefit cost ratio* |
|---|---|---|---|---|---|---|---|
| | | | **Winter maize** | | | | |
| 0 | 5.63 | - | - | | - | - | - |
| 30 | 6.25 | 0.62 | 20.7 | 90 | 2170 | 2080 | 23.1 |
| 60 | 6.88 | 1.25 | 20.8 | 180 | 4375 | 4195 | 23.3 |
| 90 | 6.25 | 0.62 | 6.9 | 270 | 2170 | 1900 | 7.0 |
| 120 | 5.75 | 0.12 | 1.0 | 360 | 420 | 60 | 1.2 |
| CD at 5% | 0.26 | | | | | | |
| | | | **Rapeseed** | | | | |
| 0 | 1.38 | – | – | – | – | – | – |
| 30 | 1.75 | 0.37 | 12.3 | 90 | 1110 | 1020 | 11.3 |
| 60 | 2.08 | 0.70 | 11.6 | 180 | 2100 | 1920 | 10.7 |
| 90 | 2.38 | 1.00 | 11.1 | 270 | 3000 | 2730 | 10.1 |
| CD at 5% | 0.18 | | | | | | |

Prasad and Prasad (1993)

this level of $K_2O$ were 10.7 for rapeseed and 23.3 for winter maize. The computed economic dose of potash was 61 kg $K_2O$ $ha^{-1}$ for winter maize.

### Maize-Wheat

A long term fertilizer experiment following maize-wheat cropping sequence in an acidic silt loam soil (pH : 5.8, CEC : 12.1 cmol (p+) $kg^{-1}$, organic carbon: 0.79%, available N : 736 kg $ha^{-1}$, available P : 12 kg $ha^{-1}$ and available K : 194 kg $ha^{-1}$) indicated that the continuously stopping of K application for 19 years has resulted in 54.7 per cent reduction in grain yield of maize in comparison to the balanced application of NPK (Sharma and Minhas, 1996). Application of NP sustained the yield levels of both the crops for the first 9 years and thereafter K became a limiting factor in crop growth. The non-responsive behaviour of K applications during the first 9 years could be due to the release of K from illite mineral (Verma, 1979). However, continuous absence of K application has resulted in depletion of its native reserves and made it a limiting factor in crop growth since 1982-83 onwards. Addition of FYM in combination with 100% NPK produced 34.7 per cent higher yield of maize during 1991. The corresponding increase in the grain yield of wheat crop was 41.6%. The intensive cropping for 19 years has resulted in mining of these soils with respect to K thus, showing drastic reduction in its uptake values. The highest K uptake of 102.5 and 65.2 kg/ha was recorded under 100% NPK + FYM treatment during 1991 in maize and wheat crops, respectively. The K uptake decreased from 96.9 and 79.6 kg/ha under 100 per cent N P during 1973 to as low as 36.4 and 20.5 kg/ha during 1991 in maize and wheat, respectively.

The exchangeable soil K showed a declining trend with continuous cropping for 19 years even at optimal level of NPK. However, the maximum depletion of 50% during 1991 in comparison to 1973 was noted in 100% NP treatment. The exchangeable K content was found to decrease from 194.2 kg/ha to 96 kg/ha during 1991 under 100% NP plots.

### Pulses

In a large number of field experiments on cultivators' fields in alluvial tracts, Uttar Pradesh (U.P.), positive responses to K upto 20 to 30 kg $K_2O$ $ha^{-1}$ in pulses like gram, lentil, blackgram and pigeonpea under rainfed conditions were observed. The yield response was 4 to 8 kg grain $kg^{-1}$ $K_2O$ (Yadav *et al.*, 1993).

### Oilseeds

In a good number of field experiments on farmers' fields in alluvial soils of UP, positive responses to K upto 40 to 60 kg $K_2O$ $ha^{-1}$ were observed in oilseeds. The yield response ranged from 1.5 to 3.5 kg grain $kg^{-1}$ $K_2O$ (Yadav *et al.*, 1993).

Balanced fertilization with NPK has proved beneficial in all the oilseed crops both under rainfed and irrigated conditions. Mustard gave response to 40 kg $K_2O$ $ha^{-1}$ average with response of 4.5-5.5 kg seed $kg^{-1}$ $K_2O$ (Tandon and Sekhon, 1988).

### Groundnut

*Response in short term:* The field response of groundnut to K was studied in the soils of the Saurashtra region of India at 3 different sites by Golakiya (1999). The soil properties of different sites are as follows: Site I : (pH : 8.3, EC : 0.3 dS $m^{-1}$, $K_2O$ : 109 kg/ha), Site II : (pH : 7.5, EC : 0.18 dS $m^{-1}$, $K_2O$ : 712 kg/ha), and Site III ( pH : 7.3, EC : 21.70 dS $m^{-1}$, $K_2O$ : 155 kg/ha). In the summer season, pod yield increased by 36% at Site I (low in available K) when 80 kg $K_2O$/ha was applied. Interestingly, pod yield was increased by 25% with 80 kg $K_2O$/ha at Site II even though this soil had 712 kg $K_2O$/ha available K. This type of result has been reported elsewhere also (Patel *et al.*, 1993). The capacity factor ($PBC^K$) increased whereas intensity ($AR_e^K$, ▲G) and quantity factors decreased with increasing clay content in the Saurashtra soils (Mehta and Shah, 1956). The value of $AR_e^K$ should be between 0.0027 and 0.034 $(ML^{-1})^{0.5}$ to provide balanced K nutrition (Woodruff, 1955). These values for Saurashtra soils range from 0.0011 to 0.005$(ML^{-1})^{0.5}$ which are considered to be on the lower side. The intensity value offers a good explanation why on some soils apparently sufficient in $NH_4OAc$ extractable K, the crop responds to K fertilization. During the Kharif season at Site II, the pod yield was increased by 16% with 120 kg $K_2O$/ha. At site III, there were only small changes in yield.

Beneficial effects of balanced fertilizer application (20-40 kg N, 40-60 kg

$P_2O_5$ and 30-40 kg $K_2O$ $ha^{-1}$) in groundnut was observed in different groundnut-growing regions of the country (Ankineedu *et al.*, 1983). Response of two varieties of groundnut was evaluated under recommended dose of NPK at seven locations (Aliyarnagar, Dharwad, Jalgaon, Kadiri, Karimnagar, Khargone, and Vriddachalam). Improved varieties registered high yields both under recommended and reduced levels of fertilizers. Recommended fertilizer recorded maximum yields at Aliyarnagar, Jalgaon and Vriddachalam while at other places economic response could not be realized. Agasimani and Hosmani (1989) reported that in the west coast of Karnataka on sandy loam soils under receeding moisture conditions combined application of 50 : 100 : 25 NPK kg/ ha resulted in 46% increased pod yield over control.

*Response in long term:* Response to K has been studied in a 15-year old long term fertilizer experiment (LTFE) with groundnut-based intensive cropping (Patel *et al.*, 1994). Compared to the yields of total biomass in the first year, those in the tenth year had decreased by 22, 18 and 3% in the NP, NPK and NPK-ST (soil test) treatments, respectively. Based on the K application on soil K values resulted in a smaller decline in yield compared to applying a uniform K application.

In groundnut, on light soils of Tamil Nadu, K application gave 30% increase in yield over control. Results of permanent manurial trial for the past 20 years revealed that application of 51 kg $K_2O$ $ha^{-1}$ gave higher yield (170.3%) over control (**Fig. 1**) (Ravichandran *et al.*, 1991). Response to K can be expected when the available $K_2O$ in the soil is less than 150 kg $ha^{-1}$.

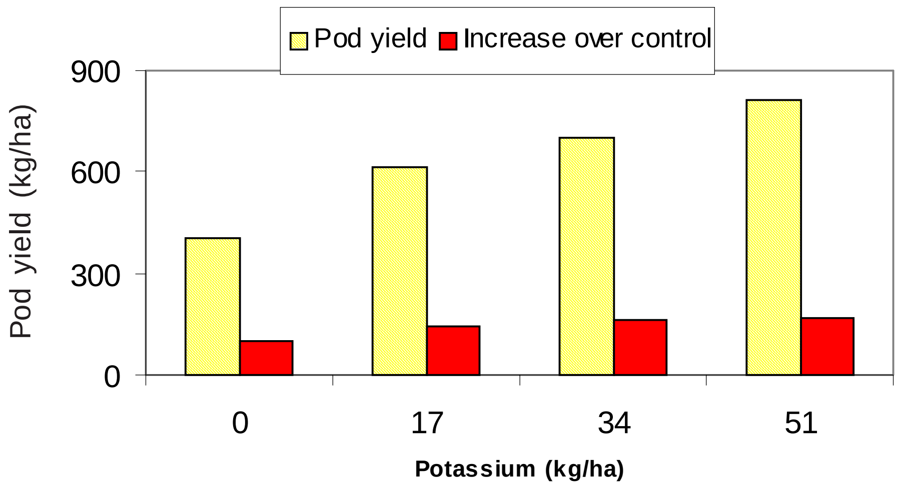


***Fig. 1.*** *Influence of potassium on pod yield of groundnut at Coimbatore (Average 20 years 1967-87).*

## Potato

In north India, potatoes are grown on 0.88 Mha of alluvial soils as an irrigated autumn/winter crop under subtropical short day conditions. Unbalanced fertilization heavily in favour of nitrogen is one of the major reasons responsible for the small yields. Field trials were conducted on farmers' fields at six locations in Jalandhar district. The soils were Typic ustrochrepts (pH : 6.1 to 7.6, organic carbon : 0.13 to 0.66%, CEC : 5 to10 cmol (p+) $kg^{-1}$, available N : 106 to 282 kg $ha^{-1}$, Olsen-P : 12 to 26 kg $ha^{-1}$, 1M $NH_4OAc$ K : 101 to 206 kg $ha^{-1}$). The mean response, average of the six locations, to 75 and 150 kg/ha $K_2O$ was 26 and 40 q/ha tubers (Singh, 1999). The response to 75 kg/ha $K_2O$ was 11, 38 and 29 q/ ha at with 80, 160 and 240 kg/ha N, respectively, while the corresponding response to 150 kg/ha $K_2O$ was 21, 48 and 49 q/ha. For optimum tuber yield, potatoes required 160 kg/ha N plus 150 kg/ha $K_2O$. In the Indo-Gangetic plains, similar optimum levels of N and K were reported for potatoes grown on soils low in available N and K (Singh and Grewal, 1985).

The better response to the larger amount of K in this study may be attributed to the severe frost which occurred during the growing period because K imparts resistance to frost injury (Grewal and Singh, 1980). Potassium fertilization significantly increased the yield of marketable size tubers at the cost of small and medium size tubers (**Fig. 2**) (Singh, 1999). The

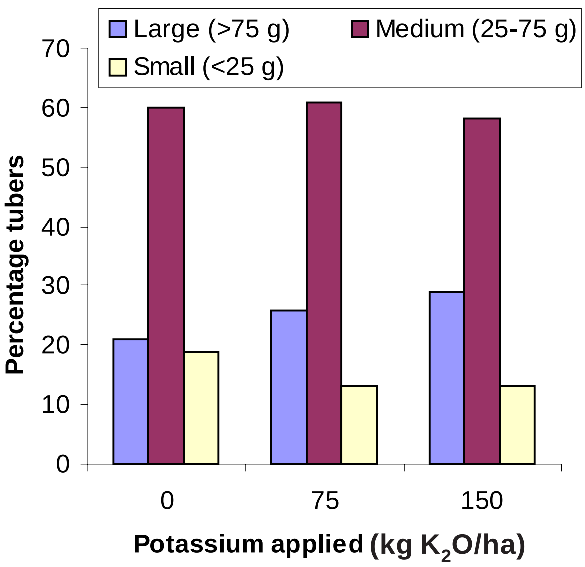


***Fig. 2.*** *Percentage of different size grade tubers in the harvested produce as influenced by K fertilization*

mean increase in the yield of large-sized tubers may be attributed to the stimulating effect of K on photosynthesis, phloem loading and translocation as well as synthesis of large molecular weight substances within storage organs (Beringer, 1978), contributing to rapid bulking of the tubers.

In multilocation experiments, optimum doses for K showed wide variation among soil types and cultivars. Response rates are generally higher in alluvial and hill soils followed by red soils and are low in black soils (Grewal and Sharma, 1997).

*Varietal differences:* Potato varieties differ greatly in their response to K. Optimum doses for Kufri Badshah in alluvial soils ranged from 50 kg $K_2O$ $ha^{-1}$ at Hisar to 180 kg/ha at Kanpur and Jalandhar. Different varieties required from 72 to 150 kg $K_2O$ $ha^{-1}$ for optimum yields. Kufri Dewa, being frost resistant with higher leaf area index (LAI) and longer period of growth, produced higher yield than Kufri Bahar and Kufri Chandramukhi. Also at Jorhat (Assam), Kufri Jyothi, having higher LAI and longer growth duration, produced more dry matter than Kufri Chandramukhi. On an alluvial soil, unlike Kufri Badshah (a long-duration variety), the varieties Kufri Jyothi, Kufri Lalima, and Kufri Bahar responded to K application. The response of Kufri Jyothi, Kufri Lalima, and Kufri Bahar to K was 28,144 and 8% respectively. Kufri Jyothi and Kufri Lalima responded to 60 kg $K_2O$ $ha^{-1}$ whereas Kufri Bahar responded up to 180 kg $K_2O$ $ha^{-1}$ (Grewal and Sharma, 1997).

*Efficient K management:* Both muriate of potash (MOP) and sulphate of potash (SOP) are almost equally effective in enhancing the tuber yield. The SOP is better than MOP in production of tuber with higher dry matter and starch content. The SOP is preferred where potatoes are produced for processing. The MOP is preferred in the NW plains where frost is a problem and it provides more resistance to frost than SOP. Potassium should be applied in furrows along with seed tubers. In Shimla hills, furrow application saved 30 kg $K_2O$ $ha^{-1}$ over broadcast. However, in irrigated coarse-textured soils of the plains, broadcasted K is as effective as furrow applied K (Grewal and Sharma, 1997).

*Integrated K management:* To evaluate the role of FYM on K fertilizer use efficiency field and laboratory studies were undertaken on acidic hill soils of Shimla during 1985-87. Some important properties of the soils are as follows:

pH : 6.1, Clay : 18.3%, organic carbon: 1.16%, available N : 831 kg $ha^{-1}$, available P : 99 kg $ha^{-1}$, available K : 370 kg $ha^{-1}$ (Sud and Grewal, 1990). Application of 5t FYM alone or in combination with K was found to have a significant effect on potato tuber yield, K concentration, K uptake and recovery from applied fertilizers. Application of 63 kg K + 5 t FYM $ha^{-1}$ was found to be the best treatment as it increased K fertilizer use efficiency by over 10%. Both FYM and K application had a positive effect on leaf K concentration at 50 days of plant growth. There was a significant correlation between leaf K and tuber yield. The mean response to applied K at 42, 63 and 84 kg was 5.7, 6.8 and 4.9 t/ha respectively. However, a significant response was obtained at 42 kg K/ha in all the three years. Economic analysis of the data revealed that K application had little effect on optimum K dose which was almost constant i.e. 49 kg K $ha^{-1}$, but yield response to K application vary from year to year.

## Sugarcane

The responses of sugarcane to different rates of K application were observed at Shahjahnapur (Uttar Pradesh), Pusa (Bihar) and Buralikson (Assam), in the sub-tropics and at Kolhapur and Padegaon both in Maharashtra, in the tropics. The highest magnitude of yield response to a kg of K application over the control was 269, 325 and 373 kg cane at Pusa, Buralikson and Kolhapur, respectively with 41.5 kg/ha K application and at Shahjahnapur and Padegaon, it was 182 and 100 kg cane with 83 kg/ha K application. There was no response to K application at Coimbatore (Tamil Nadu). Sugarcane has responded to application of K in terms of increasing cane yield even in alluvial soils rich in K bearing illitic clays. Based on the Coordinated Experiments on sugarcane, the yield responses to K application in Punjab, Haryana, Uttar Pradesh, Bihar, Assam, Andhra Pradesh, Maharashtra and Karnataka have also been reported earlier (Yadav, 1993)

## Cotton

Response to K application has been inconsistent in cotton. Some workers from A.P, Tamil Nadu, Haryana and Punjab have reported positive responses to K application (Kairon and Venugopalan, 1999).

## ECONOMISING POTASSIUM APPLICATION

### Residual effects

Responses of crops to the carry-over effect of nutrients applied to previous crops depend on the amount of nutrients applied, the proportion utilized by the current crop and the residues left over after the harvest of the crop. Residual effects of K applied to potato on succeeding wheat, cheena and maize were small when 48-50 kg $K_2O$ $ha^{-1}$ were applied (**Table 8**). Marked residual effects were seen in the same wheat, cheena and maize when higher rates of K (96 to 100 kg $K_2O$ $ha^{-1}$) were applied to potato. Higher rates of K added to potato have pronounced effect on succeeding crops of maize and jute in potato-maize and potato-jute system at Kalyani. However, similar high rates of K failed to influence the succeeding crops of sorghum in potato-sorghum and pearlmillet in potato-pearlmillet system at Rajgurunagar (black soil) (Grewal and Sharma, 1981).

**Table 8. Some estimates of direct and residual responses of potash added to potato in different cropping systems**

| *Location* | *Crop in sequence* | *Effect* | *Yield response* | |
|---|---|---|---|---|
| | | | *48-50 kg $K_2O$ $ha^{-1}$ added to potato* | *96-100 kg $K_2O$ $ha^{-1}$ added to potato* |
| Jalandhar | Potato<br>Wheat | Direct<br>Residual | 3.3 t/ha<br>0.9 q/ha | 4.4 t/ha<br>1.9 q/ha |
| Patna | Potato<br>Cheena<br>Maize | Direct<br>Residual I<br>Residual II | 4.6 t/ha<br>0.5 q/ha<br>0.5 q/ha | 6.5 t/ha<br>4.0 q/ha<br>4.7 q/ha |
| Kalyani | Potato<br>Maize<br>Jute<br>Rice | Direct<br>Residual I<br>Residual II<br>Residual III | | 3.0 t/ha<br>5.6 q/ha<br>4.1 q/ha<br>1.4 q/ha |
| Rajgurunagar | Potato (Kharif)<br>Sorghum<br>Potato (Rabi)<br>P. millet | Direct<br>Residual<br>Direct<br>Residual | | 0.4 t/ha<br>0<br>2.1 t/ha<br>–0.7 q/ha |

Grewal and Sharma (1981)

The residual effect of 100 kg $K_2O$ $ha^{-1}$ and that of 30 t FYM/ha applied to potato on alluvial soils was sufficient to meet the K needs of the succeeding crops of wheat, maize or rice (Grewal and Sharma, 1978). In the acidic hill soils of Shimla, peas in the potato-wheat-peas rotation showed significant residual effect of 150 kg $K_2O$ $ha^{-1}$ or 50 t FYM/ha applied earlier to potato. In the red soil of West Bengal, the residual effect of 100 kg $K_2O$ $ha^{-1}$ or 50 t FYM/ha applied to potato was important for the succeeding crops of maize, greengram and jute in different rotations (Chatterjee *et al.*, 1978).

Upadhayay and Grewal (1985) studied the direct effect of P, K and FYM on potato and their residual effect on succeeding wheat crop at Modipuram, Meerut on sandy loam alluvial soils (pH : 7.7, organic carbon : 0.32%, Olsen's P : 30 ppm, and 1M $NH_4OAc$ : 80 ppm). Direct effect of 40 and 80 kg K $ha^{-1}$ and 15 and 30 t FYM $ha^{-1}$ were significant on tuber yield of potato but their residual effects on succeeding wheat were not significant. The optimum rates of K and FYM were 112 kg $ha^{-1}$ and 26 t $ha^{-1}$ to obtain 22 t $ha^{-1}$ of tubers. The experimental soil has sufficient amounts of available P and K for wheat and the yield level of wheat was also low.

It is generally advised that in potato based cropping systems, potato should receive potassic fertilizer and other crops may benefit from the K residues in the following seasons (Tiwari *et al.*, 1980). It was also showed that annual application of K have been found to be superior to bi-annual application of double that amount from the stand point of yield responses and K uptake by the main crop potato (Sharma *et al.*, 1980).

### Subsoil K in nutrition

The balance sheet worked out for K in different systems indicated large negative balances. However, the soil test K value did not decrease in proportion to the calculated depletion in the soil K. A substantial amount of K taken up by the plants must have originated from the subsoil or from the originally non-exchangeable K source. Talukdar and Khera (1991) showed that if the whole profile contribution is taken into consideration, the proportion of K utilised from non-exchangeable K decreased and that of exchangeable K increased (**Fig. 3**). They have also showed that pearl millet utilised more non-exchangeable K than maize. Ganeshamurthy (1983) and Ganeshamurthy and Biswas (1984) in their studies showed that the decrease in non-exchangeable K in the upper 30 cm of the soil at Ludhiana site during first 9 years of experiment was very similar to the cumulative net removal of soil K in various treatments.

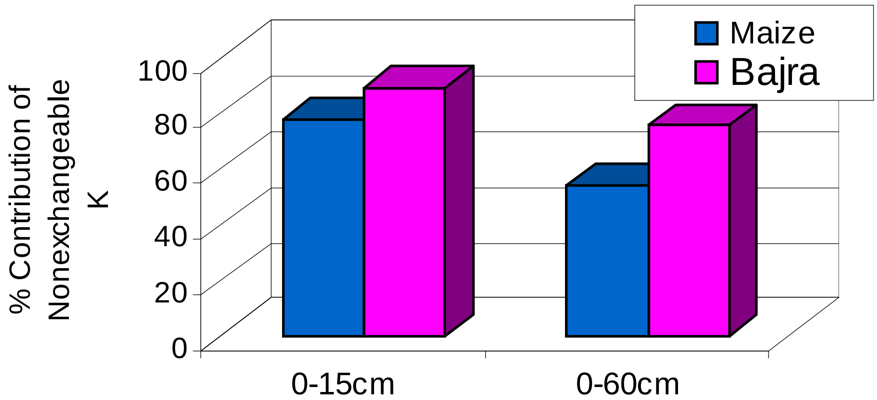


***Fig. 3. Contribution of nonexchangeable K towards plant uptake in an alluvial soil***

Subba Rao *et al.* (1993) showed that in wheat-sorghum (fodder) system on an alluvial soil exchangeable K decreased in subsoil of plots receiving no K and those receiving recommended dose of K.

## Contribution of crop residues to K nutrition

Since additions from the atmosphere and leaching losses are negligible, the maintenance of K status of soil depends on the return of as large a part as possible of crop residues and application of fertilizer K in accordance with the needs of the system. The vegetative portions (straw/stover) contributed 53 to 90% of the K uptake by crops. Return of residues of crops like pearlmillet, sorghum, maize, cotton and soybean compensate/replace 70 to 90% of K removed from the soil (Pieri and Oliver, 1986). These authors suggested that K should preferably be applied to non-cereal crop of the legume-cereal system on account of the tendency of the graminae to take up K in excess of their K requirement. It may be noted that when the crop residues are returned to the soil they should properly be incorporated.

## NEED FOR REVISION OF K RECOMMENDATIONS

Prem Narain *et al.* (1990) estimated the yield maximizing dose and corresponding production with the help of quadratic response functions for crops in multiple cropping system at eight centers of the long term fertilizer experiments of ICAR. The data (**Table 9**) indicated the need for higher rates of application of K than the usually recommended dose for maize and wheat at Ludhiana, rice at Barrackpore, Bhubaneswar and Pantnagar and soybean and wheat at Jabalpur. In some centers, maximum yields tended to decline and K dose required to obtain the maximum productivity tended to increase because of the deficiencies of other nutrients, pest and disease problems and aberrant climatic conditions.

On the basis of crop responses and fertilizer K requirements, some crops like potato, rice, maize and groundnut require relatively larger rates of K application than normally recommended. In potato based cropping systems, potato should be fertilized with K fertilizers and other crops in the system may be benefited from the K residues in the following seasons. For better managing of soil K fertility status it is necessary to add adequate K from fertilizer, manures and crop residues to compensate for gradual loss of the K fertility and to monitor both exchangeable and non-exchangeable K status of soil and thereby check the declining trends in yield under intensive cropping.

## SOIL TEST BASED FERTILIZER K RECOMMENDATIONS

General fertiliser recommendations result in application of excess amounts of fertiliser in such areas where it is not needed and insufficient amounts in some others where it is needed. Soil test based recommendations are essential to economise fertiliser use and to optimize production on a sustainable basis without polluting the environment. Among the various methods of fertiliser recommendation, the one based on yield targeting is unique in the sense that this method not only indicates soil test based fertiliser dose but also the level of yield the farmer can hope to achieve if good agronomic practices are followed in raising the crop. The essential basic data required for formulating fertiliser recommendation for targeted yield are (i) nutrient requirement in kg/q of produce, grain or other economic produce (ii) the per cent contribution from the soil available nutrients (iii) the per cent contribution from the applied fertiliser nutrients (Ramamoorthy *et al.*, 1967).

The above mentioned three parameters are calculated as follows:

Nutrient requirement of N, P and K for grain production

$$\text{kg of nutrient/q of grain} = \frac{\text{Total uptake of nutrient (kg)}}{\text{Grain yield (q)}}$$

**Table 9. Yield maximizing dose and productivity through continuous application of fertilizers**

| *Center/ Soil group* | *Crop/ cycles* | *Kharif Dose (kg/ha)* | | | *Yield (q/ha)* | *Rabi Dose (kg/ha)* | | | *Yield (q/ha)* |
|---|---|---|---|---|---|---|---|---|---|
| | | *N* | *$P_2O_5$* | *$K_2O$* | | *N* | *$P_2O_5$* | *$K_2O$* | |
| *Cropping system Recommended dose ($N$+$P_2O_5$+$K_2O$)* | | *Maize (150-75-75)* | | | | *Wheat (150-75-37)* | | | |
| Alluvial Ludhiana | 3 | 222 | 111 | 111 | 29.5 | 195 | 98 | 48 | 42.0 |
| | 6 | 214 | 107 | 107 | 28.7 | 206 | 103 | 51 | 43.2 |
| | 9 | 211 | 106 | 106 | 27.7 | 208 | 98 | 51 | 46.2 |
| | 12 | 204 | 102 | 102 | 26.2 | 213 | 103 | 52 | 47.7 |
| | 15 | 198 | 99 | 99 | 25.6 | 219 | 104 | 54 | 49.1 |
| | | *Rice (120-60-60)* | | | | *Wheat (120-60-60)* | | | |
| Barrackpore | 3 | 139 | 70 | 70 | 50.4 | Linear | | | |
| | 6 | 150 | 75 | 75 | 48.0 | " | | | |
| | 9 | 163 | 82 | 82 | 46.2 | " | | | |
| | 12 | 162 | 81 | 81 | 45.3 | " | | | |
| | 15 | 174 | 87 | 87 | 44.7 | " | | | |
| | | *Finger Millet (90-45-17)* | | | | *Cowpea (25-50-0)* | | | |
| Medium Black Coimbatore | 3 | 117 | 58 | 22 | 26.7 | 32 | 65 | 0 | 6.3 |
| | 6 | 120 | 60 | 23 | 24.7 | 31 | 62 | 0 | 6.6 |
| | 9 | 110 | 55 | 21 | 26.4 | 31 | 62 | 0 | 5.6 |
| | 12 | 107 | 54 | 20 | 28.8 | 30 | 61 | 0 | 5.7 |
| | | *Soybean (20-80-20)* | | | | *Wheat (120-80-40)* | | | |
| Jabalpur | 3 | 32 | 126 | 32 | 27.9 | 179 | 119 | 60 | 49.1 |
| | 6 | 27 | 106 | 27 | 23.2 | 172 | 114 | 57 | 43.2 |
| | 9 | 27 | 108 | 27 | 22.5 | 166 | 110 | 55 | 40.2 |
| | 12 | 25 | 101 | 25 | 22.6 | 170 | 114 | 57 | 42.0 |
| | | *Rice (100-60-60)* | | | | *Rice (100-60-60)* | | | |
| Laterite Bhubaneswar | 3 | 140 | 84 | 84 | 24.0 | 170 | 102 | 102 | 29.2 |
| | 6 | 158 | 95 | 95 | 28.9 | 152 | 91 | 91 | 31.1 |
| | 9 | 158 | 95 | 95 | 29.6 | 147 | 88 | 88 | 31.6 |
| | 12 | 153 | 92 | 92 | 31.3 | 149 | 89 | 89 | 32.7 |
| | 15 | 150 | 90 | 90 | 30.7 | 153 | 92 | 92 | 33.1 |
| | | *Rice (120-60-45)* | | | | *Wheat (120-60-10)* | | | |
| Foothill Pantnagar | 3 | 166 | 83 | 62 | 78.5 | Linear | | | |
| | 6 | 157 | 79 | 59 | 71.1 | " | | | |
| | 9 | 156 | 78 | 58 | 68.1 | " | | | |
| | 12 | 166 | 83 | 62 | 64.2 | " | | | |
| | 15 | 176 | 88 | 66 | 63.9 | " | | | |

Prem Narain *et al.* (1990)

Contribution of nutrient from soil

$$\% \text{ Contribution from soil (CS)} = \frac{\text{Total uptake in control plots (kg ha}^{-1}\text{) x 100}}{\text{Soil test values of nutrient in control plots (kg ha}^{-1}\text{)}}$$

% Contribution of nutrient from fertilizer

Contribution from (CF) = Total uptake of nutrients in treated plots – (Soil test values of nutrients in fertiliser treated plots x CS)

$$\% \text{ Contribution from fertiliser} = \frac{\text{CF}}{\text{Fertiliser dose (kg ha}^{-1}\text{)}} \text{ x 100}$$

Calculation of fertiliser dose

The above basic data are transformed into workable adjustment equation as follows:

$$\text{Fertiliser dose} = \frac{\text{Nutrient requirement in kg/q of grain}}{\% \text{ CF}} \text{ x 100 x T} - \frac{\% \text{ CS}}{\% \text{ CF}} \text{ x soil test value}$$

$$= \text{a constant x yield target (q ha}^{-1}\text{)} - \text{b constant x soil test value (kg ha}^{-1}\text{)}$$

Hence, the fertiliser doses can be calculated once the soil test values and yield targets are known. Such type of fertiliser recommendations are depicted in **Tables 10, 11, 12, 13, 14, 15, 16, 17, 18 and 19** for rice, wheat, maize, gram, groundnut, mustard, potato, sugarcane and cotton, respectively. It can be clearly seen from the tables that the fertiliser recommendations change with the soil test values in different soils. Fertilizer K recommendations increase with higher yield goals and decrease with increase in soil test values. Similar type of soil test based fertiliser recommendations are available for many field crops on different soils in different agroecoregions of India (Subba Rao and Srivastava, 2001).

**Table 10. Soil test based fertiliser potassium ($K_2O$) requirement for rice on different soils of India**

| *Soil* | *Site* | *Target (q/ha)* | *Soil test values (kg/ha)* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | *100* | *150* | *200* | *250* | *300* | *350* | *400* |
| Acid Alfisol | Kangra (H.P.) | 45 | 59 | 25 | – | – | – | – | – |
| Alluvial soil | Punjab | 60 | 54 | – | – | – | – | – | – |
| Mollisol & Inceptisol | Uttaranchal, Western U.P. | 50 | 36 | 20 | – | – | – | – | – |
| Black | M.P. | 50 | * | * | 69 | 60 | 51 | 42 | 33 |
| Old alluvial gray light textured soil | Bihar | 40 | 50 | 38 | 26 | – | – | – | – |
| Recent alluvial non calcareous non saline | Parts of Bihar | 40 | 52 | 33 | 13 | – | – | – | – |
| Old alluvial heavy textured | –do- | 40 | 38 | 18 | – | – | – | – | – |
| Calcareous | Parts of Bihar | 40 | 92 | 72 | – | – | – | – | – |
| New alluvial | Parts of W. B. | 35 | 60 | 46 | 32 | – | – | – | – |
| Old alluvial | –do— | 40 | 45 | 25 | 6 | – | – | – | – |
| Black | Guntur (A.P.) | 50 | * | 52 | 42 | 33 | 23 | 14 | – |
| Inceptisol | Jagitiyal | 50 | * | 94 | 76 | 58 | 40 | 22 | – |
| Sandy clay loam (alluvial) | Nellore | 50 | * | 65 | 55 | 45 | 35 | 25 | 15 |
| Black soil | Nandyal | 60 | * | * | 50 | 44 | 38 | 32 | 26 |
| Red/alkaline | Parts of Karnataka | 36 | 66 | 62 | 59 | 55 | 52 | 48 | 45 |
| Alluvial (Alfisol) | Coimbatore | 60 | * | * | 68 | 49 | 33 | 17 | 01 |
| Red (Irugur series) | Parts of TN | 60 | * | * | 69 | 39 | 10 | – | – |
| Black (Adanur series) | Parts of TN | 70 | * | * | 91 | 71 | 51 | 31 | 11 |

Subba Rao and Srivastava (2001)
* Means the soils of this region do not have these soil test values
— Means no fertiliser K requirement

## Scheduling fertiliser dressings in cropping systems

Nutrient availability in soil after the harvest of a crop is much influenced by the initial soil nutrient status, the amount of fertiliser nutrients added and the nature of the crop raised. Of late, monoculture is being replaced by cropping system. For soil test based fertiliser recommendations the soils are to be tested after each crop which is not practicable. Hence it has become necessary to predict the soil test values after the harvest of a crop. It is done by developing post-harvest soil test value prediction equations making use

**Table 11. Soil test based fertilizer potassium ($K_2O$) requirement for wheat on different soils of India**

| *Soil* | *Site* | *Target (q/ha)* | *Soil test values (kg/ha)* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | *100* | *150* | *200* | *250* | *300* | *350* | *400* |
| Acid Alfisols | M. P. | 35 | 66 | 57 | 47 | 38 | – | – | – |
| Neutral Inceptisol | –do— | 35 | 52 | 38 | 24 | 10 | – | – | – |
| Acid alluvial/Inceptisol | –do— | 35 | 107 | 85 | 64 | 42 | – | – | – |
| Alluvial/Inceptisol | Delhi | 35 | 49 | 33 | 17 | – | – | – | – |
| Mollisol/Inceptisol | Uttaranchal, Western U.P. | 35 | 47 | – | – | – | – | – | – |
| Typic Chromusterts | Maharashtra | 40 | * | * | 56 | 45 | 34 | 23 | 12 |
| Black (Vertisols) | M.P. | 35 | * | * | 57 | 49 | 41 | 33 | 25 |

Subba Rao and Srivastava (2001)
* Means the soils of this region do not have these soil test values
— Means no fertiliser K requirement

**Table 12. Soil test based fertilizer potassium ($K_2O$) requirement for maize on different soils of India**

| *Soil* | *Site* | *Target (q/ha)* | *Soil test values (kg/ha)* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | *100* | *150* | *200* | *250* | *300* | *350* | *400* | *500* |
| Acid Alfisol | Kangra (H.P.) | 35 | 70 | 65 | 60 | 55 | 50 | 45 | 40 | 30 |
| Entisol/Inceptisol | Kangra (H.P.) | 40 | 72 | 57 | 41 | 26 | 10 | – | – | – |
| Alluvial soils | Parts of Punjab | 40 | 44 | 28 | 12 | – | – | – | – | – |
| Mollisol & Inceptisol | Barielly, Moradabad & Meerut (U.P.) | 40 | 68 | 45 | 23 | – | – | – | – | – |
| Shallow black & medium black soils | Parts of M.P. | 40 | * | * | 67 | 63 | 59 | 55 | 51 | 43 |
| Calcareous soils | Bihar & Jharkhand | 40 | 49 | 35 | 20 | 6 | – | – | – | – |
| Red yellow-light gray catenary (red loam soil) | Koderma, Giridih, Hazaribagh & Ranchi (Bihar) | 40 | 74 | 62 | 50 | 38 | 26 | 14 | – | – |
| Chalka soils | Jagitial (A.P.) | 40 | 44 | 36 | 28 | 20 | 12 | – | – | – |
| Chalka soils | Rajendranagar(AP) | 50 | * | 84 | 69 | 54 | 39 | 24 | 9 | – |
| Red/Lateritic soils | Parts of Kar. | 45 | 31 | – | – | – | – | – | – | – |
| Light black sandy clay loam/red | Hassan & Shimoga (Kar.) | 45 | 42 | 40 | 38 | 95 | 33 | 31 | 28 | 24 |
| Mixed black | Coimbatore (T.N.) | 50 | 209 | 185 | 160 | 136 | 111 | 87 | 62 | 13 |

Subba Rao and Srivastava (2001)
* Means the soils of this region do not have these soil test values
— Means no fertiliser K requirement

**Table 13. Soil test based fertilizer potassium ($K_2O$) requirement for gram on different soils of India**

| *Soil* | *Site* | *Target (q/ha)* | *Soil test values (kg/ha)* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | *100* | *150* | *200* | *250* | *300* | *350* | *400* | *500* |
| Alluvial soils | Parts of Punjab | 25 | 29 | – | – | – | – | – | – | – |
| Typic chromusterts | Rahuri (Maha.) | 25 | * | 26 | 24 | 22 | 20 | 18 | 14 | 12 |
| Medium black soils | Parts of M.P | 20 | * | 51 | 42 | 34 | 25 | 17 | 8 | – |
| Calcareous soil | Parts of Bihar | 20 | 43 | 12 | – | – | – | – | – | – |
| Red-yellow-light gray catenary (red loam soil) | Parts of Bihar | 20 | 30 | 27 | 25 | – | – | – | – | – |

Subba Rao and Srivastava (2001)
* Means the soils of this region do not have these soil test values
— Means no fertiliser K requirement

**Table 14. Soil test based fertilizer potassium ($K_2O$) requirement for grounnut on different soils of India**

| *Soil* | *Site* | *Target (q/ha)* | *Soil test values (kg/ha)* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *100* | *150* | *200* | *250* | *300* | *350* | *400* | *450* | *500* |
| Vertic Ustochrepts, clay loam | Rahuri (Maharashtra) | 20 | 47 | 39 | 31 | 23 | 15 | 7 | – | – | – |
| Calcareous soil | Parts of Bihar | 20 | 42 | 32 | 22 | – | – | – | – | – | – |
| Alluvial soils | Nellore (A.P.) | 25 | 66 | 48 | 30 | 12 | – | – | – | – | – |
| Red/lateritic | Parts of Karnataka | 27 | * | * | 74 | 34 | – | – | – | – | – |
| Red soils (Inceptisol) | Madurai (Tamil Nadu) | 25 | * | * | 78 | 45 | 13 | – | – | – | – |
| Red soils | Coimbatore (Tamil Nadu) | 25 | * | 87 | 71 | 54 | 38 | 21 | 5 | – | – |
| Laterite soils (Tamil Nadu) | Cuddalore | 25 | * | 90 | 61 | 32 | – | – | – | – | – |

Subba Rao and Srivastava (2001)
* Means the soils of this region do not have these soil test values
— Means no fertiliser K requirement

of the initial soil test values, applied fertiliser doses and the yields obtained or uptake of nutrients (Sharma *et al.*, 1982). The functional relationship is as follows:

**Table 15. Soil test based fertilizer potassium ($K_2O$) requirement for mustard on different soils of India**

| Soil | Site | Target (q/ha) | Soil test values (kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 500 |
| Alluvial soils | Parts of Punjab | 20 | 63 | 46 | 29 | 12 | – | – | – | – |
| Alluvial soils | IARI, New Delhi | 20 | 85 | 66 | 46 | 27 | 7 | – | – | – |
| Mollisol and Inceptisol | Bareilly, Moradabad & Meerut (U.P.) | 10 | 44 | 33 | 22 | 11 | – | – | – | – |
| Medium black soils | Parts of M.P. | 16 | * | 55 | 49 | 42 | 36 | 29 | 23 | 10 |
| Alluvial soils | Parts of M.P. | 16 | * | 76 | 66 | 56 | 47 | 37 | 28 | 9 |
| Alluvium calcareous soil | Samastipur, Muzaffarpur & Vaishali (Bihar) | 15 | 27 | 18 | 10 | – | – | – | – | – |

Subba Rao and Srivastava (2001)
* Means the soils of this region do not have these soil test values
— Means no fertiliser K requirement

**Table 16. Soil test based fertilizer potassium ($K_2O$) requirement for potato on different soils of India**

| Soil | Site | Target (q/ha) | Soil test values (kg/ha) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 50 | 100 | 150 | 200 | 250 | 300 | 350 |
| Alluvium calcareous soil | Parts of Bihar | 100 | 53 | 24 | – | – | – | – | – |
| Alluvium calcareous soil | Parts of Bihar | 125 | 73 | 44 | 16 | – | – | – | – |

Subba Rao and Srivastava (2001)
— Means no fertiliser K requirement

YPH = f (F, IS, yield / nutrient uptake) where, YPH is the post-harvest soil test value, F is the applied fertiliser nutrient and IS is the initial soil test value. The mathematical form is:

YPH = $a + b_1F + b_2IS + b_3$ yield / uptake where, a is the absolute constant and $b_1$, $b_2$ and $b_3$ are the respective regression coefficients.

Prediction equations for post-harvest soil test values were developed from initial soil test values, fertiliser doses applied and yield of crops / uptake of nutrients in order to obtain a basis for prescribing the fertiliser amounts for

**Table 17. Soil test based fertilizer potassium ($K_2O$) requirement for sugarcane on different soils of India**

| *Soil* | *Site* | *Target (q/ha)* | *Soil test values (kg/ha)* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *50* | *100* | *150* | *200* | *250* | *300* | *350* | *400* | *450* | *500* |
| Alluvium calcareous soil (I crop) | Parts of Bihar | 100 | 89 | 76 | 64 | 51 | 39 | 26 | 14 | – | – | – |
| Alluvium calcareous soil (Ratoon crop) | Parts of Bihar | 100 | * | 89 | 88 | 70 | 61 | 51 | 42 | 32 | 23 | 13 |
| Black soil | Rudrur (AP) | 100 | * | * | * | 104 | 88 | 71 | 55 | 38 | 22 | 5 |
| Red Alkaline | Chitradurga (Karnataka) | 90 | * | * | * | 262 | 243 | 220 | 205 | 188 | 166 | 146 |
| Mixed black soils | Coimbatore (Tamil Nadu) | 125 | * | * | * | 261 | 220 | 178 | 135 | 94 | 52 | 10 |
| Red soils | Cuddalore (Tamil Nadu) | 125 | * | * | * | 220 | 190 | 163 | 133 | 104 | 76 | 47 |
| Red soils | Bhavanisagar (Tamil Nadu) | 125 | * | * | * | 248 | 212 | 175 | 139 | 103 | 66 | 30 |

Subba Rao and Srivastava (2001)
* Means the soils of this region do not have these soil test values
— Means no fertiliser K requirement

**Table 18. Soil test based fertilizer potassium ($K_2O$) requirement for cotton on different soils of India**

| *Soil* | *Site* | *Target (q/ha)* | *Soil test values (kg/ha)* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *100* | *150* | *200* | *250* | *300* | *350* | *400* | *450* | *500* | *600* |
| Typic chromustert | Rahuri (Maharashtra) | 20 | * | * | 141 | 126 | 117 | 108 | 99 | 90 | 81 | 63 |
| Medium black | Parts of M.P | 20 | * | * | 66 | 59 | 52 | 45 | 38 | 31 | 24 | – |
| Black clayey | Bellary and Raichur (Karnataka) | 36 | * | * | 71 | 67 | 62 | 57 | 52 | 48 | 43 | 34 |
| Mixed black | Coimbatore (Tamil Nadu) | 25 | * | * | 73 | 61 | 48 | 36 | 23 | 11 | – | – |
| Red soils | Coimbatore (Tamil Nadu) | 30 | * | 104 | 79 | 54 | 29 | 4 | – | – | – | – |

Subba Rao and Srivastava (2001)
* Means the soils of this region do not have these soil test values
— Means no fertiliser K requirement

**Table 19. Prediction equations for post-harvest soil test values for Kharif and Rabi rice Year : 1995-96**

| *Nutrient* | $R^2$ | *Multiple regression equation* |
|---|---|---|
| ***Kharif* rice** | | |
| N | 0.98** | PHN = 27.83 + 1.09** SN + 0.145** FN + 0.002 RY |
| P | 0.95** | PHP = –0.66 + 0.975*SP + 0.17**FP + 0.002 RY |
| K | 0.98** | PHK = –14.84 + 1.05**SK + 0.16**FK + 0.0006RY |
| ***Rabi* rice** | | |
| ***Kharif* rice** | | |
| N | 0.98** | PHN = 10.48 + 0.72**SN-0.013FN + 0.015**RY |
| P | 0.91** | PHP = –4.28 + 0.96**SP + 0.07** FP + 0.001 RY |
| K | 0.84** | PHK = 41.34 + 0.71**SK –0.05 FK + 0.005 RY |

RY = Rice yield in q $ha^{-1}$

the crops succeeding the first crop in the cropping system at New Delhi and Coimbatore centers.

*Rice-rice-residual pulse system*

The post-harvest soil test value prediction equations for predicting the soil test values after the harvest of crops in the cropping system were developed making use of the data generated in the first and second test crops of rice at Coimbatore. The prediction equations developed are given in the **Table 19** (Subba Rao and Srivastava, 1998). It is seen that the prediction equations are highly significant for all the three major nutrients for both Kharif and Rabi rice.

Fertiliser rates for the first rice were calculated based on the initial soil test values and fertiliser adjustment equation for that crop. Using prediction equations, the post harvest soil test values after the first crop in the system were predicted from the initial soil test values. Based on initial soil test values, the fertiliser recommendations given for Kharif rice to get the targeted yield of 40, 50 and 60 q $ha^{-1}$ were 57, 106 and 155 kg N $ha^{-1}$, 34, 52 and 71 kg $P_2O_5$ $ha^{-1}$ and 46, 81 and 116 kg $K_2O$ $ha^{-1}$, respectively. Similarly, based on predicted post-harvest soil test values after first crop, the fertiliser doses for Rabi rice to get yield targets of 40, 50 and 60 q $ha^{-1}$ were 70, 114 and 158 kg N $ha^{-1}$, 30, 42 and 54 kg $P_2O_5$ $ha^{-1}$ and 59, 95 and 131 kg $K_2O$ $ha^{-1}$, respectively (**Table 20**). It is desired to generate similar information for different cropping systems in different agro-ecoregions for efficient management of potassic fertilisers in cropping systems.

**Table 20. Fertiliser recommendations for yield targets of rice in rice-rice residual pulse cropping system based on initial soil test values. Year : 1995-96**

| | *First crop (Kharif season)* | | | | | | *Yield target ($q\ ha^{-1}$)* | *Second crop (Rabi season)* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Fertiliser dose ($kg\ ha^{-1}$)* | | | *PHSTV ($kg\ ha^{-1}$)* | | | | *Fertiliser dose ($kg\ ha^{-1}$)* | | | *PHSTV ($kg\ ha^{-1}$)* | | |
| | *N* | *$P_2O_5$* | *$K_2O$* | *N* | *$P_2O_5$* | *$K_2O$* | | *N* | *$P_2O_5$* | *$K_2O$* | *N* | *$P_2O_5$* | *$K_2O$* |
| 40 (L) | 57 | 34 | 46 | 261 | 20.6 | 205 | 40 | 70 | 30 | 59 | 257 | 21.2 | 204 |
| 50 (M) | 106 | 52 | 81 | 271 | 23.9 | 211 | 50 | 114 | 42 | 95 | 279 | 26.1 | 212 |
| 60 (H) | 155 | 71 | 116 | 280 | 27.3 | 217 | 60 | 158 | 54 | 131 | 300 | 31.1 | 219 |

ISTV : Initial soil tst value; PHSTV : Post harvest soil test value; L : Low target: M : Medium target and H : High target

ISTV : $KMnO_4$-N = N = 250 kg $ha^{-1}$; Olsen-P = 15 kg $ha^{-1}$ and $NH_4OAc$-K=200 kg $ha^{-1}$

## Conclusions

The current review clearly thus brought out that (1) the soil fertility in respect of potassium is fast declining. (2) the crop responses to K have increasingly been reported. (3) the fertilizer recommendations do not match the K removals in crops/cropping systems. (4) except for potato-based cropping systems, in all other crops/cropping systems the fertilizer rates recommended are inadequate and do not leave any cumulative or residual effects. (5) and there is an urgent need to work out realistic recommendations matching the crop needs using soil testing as a tool.

## Future Line of Work

The following lines of work are suggested for future researches :

- Potassium application rates, for matching the nutrient requirement and for maintaining adequate available K in different soils under intensive cropping systems, need to worked out.
- The contribution of non-exchangeable K, subsoil K, crop residues need to be worked out in dominant soil-cropping systems.
- Integrated nutrient recommendations involving fertilisers, various organic and non-conventional sources of K need to be worked out for dominant cropping systems.

- Integrated analysis of soil, plant, water and nutrient sources need to be promoted to help work out better nutrient recommendations for crops and cropping systems.

- Nutrient balance sheets need to be worked out for farms, catchments, districts and states. Through this process nutrient transport chains can be established and possibilities for nutrient recycling explored.

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