POTASSIUM IN AGRICULTURE AND STRATEGIES TO IMPROVE USE EFFICIENCY

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Potassium (K) is essential for plants, and makes up about 5% of plant dry biomass. Although not a constituent of plant structure, K is vital for the protein and starch synthesis, osmo regulation, turgor generation, cell expansion, regulation of membrane electric potential, pH homeostasis and activates more than 60 enzymes. It improves crop quality and enhances plant's ability to resist biotic and abiotic stresses. Some plants have the ability to absorb K more than its requirement for normal growth, often termed as "luxury consumption" which may act as an "insurance strategy" to make plants survive sudden environmental stresses.

VISUAL DEFICIENCY SYMPTOMS

As K is mobile in plants, deficiency symptoms are first visible in the older leaves. K deficiency interferes with normal metabolic activities resulting in reduced growth and productivity. Distinct visual symptoms include yellowing and necrosis of leaf margins, beginning from the lower and older leaves (Figure1). Under severe deficiency, the fired leaf margin may fall off and progress towards mid rib. K deficient plants are poorly developed and weak, seeds are shrivelled, fruits and vegetables lack normal colour with low keeping quality and short shelf life.

Figure 1. Symptoms of K deficiency in cucurbits

K DYNAMICS IN SOIL

Potassium is the eighth most abundant element, constituting about 2.5% of the earth's crust. Plants acquire K^+ only from the soil solution through root epidermal and cortical cells. In soil, K exist in four principal forms: ionic form in soil solution (0.1-0.2%), exchangeable K (1-2%), fixed or non-exchangeable K (1-10%), and lattice K (90-98%) (Sparks, 1987). All these forms are dynamic in nature (Figure 2). Lattice K consist of K-bearing minerals such as feldspars (orthoclase and plagioclase) and phyllosilicates (micas, chlorite, etc.) which release K^+ in the course of their weathering. Solution K and exchangeable K are considered to be labile and are in dynamic equilibrium to meet the immediate requirements of growing plants, while the latter two forms are considered non-labile K and are responsible for the long-term supply of K to plants. Different K bearing minerals, their composition and percent K_2O are presented in table 1 and figure 3. When soil solution K is inadequate to meet the immediate requirement of plants, it requires external supply of K through fertilizers such as muriate of potash, sulfate of potash or other complex fertilizers.

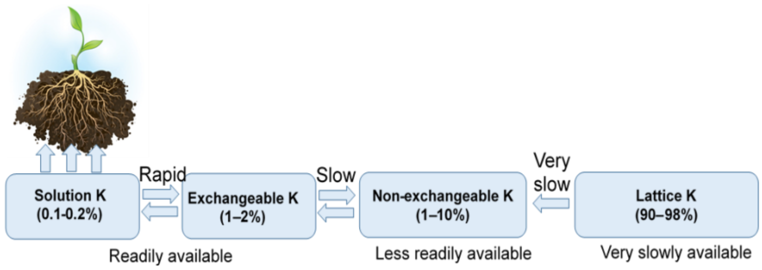

Figure 2. Dynamic equilibrium of different forms of K in soil

Table 1. K bearing silicate minerals, their composition and K_2O %

K bearing Minerals	Chemical Composition	K_2O (%)
Leucite	$KAl(SiO_3)_2$	21.4
Feldspars		
Orthoclase	$KAlSi_3O_8$	16.8
Anorthoclase	$(Na, K)AlSi_3O_8$	2.4–12.1
Microcline	$KAlSi_2O_3$	16.8
Micas		
Muscovite	$H_2KAl_3(SiO4)_3$	11.8
Biotite	$(H,K)_2(Mg,Fe)_2Al_2(SiO_4)_2$	6.2–10.1
Phlogopite	$(H, K, Mg, F)_3(Mg_3Al(SiO_4)_2$	7.8–10.4
Lepidolite	$KLi(Al,OH,F_2)Al(SiO_3)_3$	10.7–12.3

(Source: Sauchelli, 1961)

Figure 3. Different Potassium Minerals *(Source: www.mindat.org)*

STATUS OF K IN INDIAN SOILS AND K FERTILIZER CONSUMPTION

Status of available K in soil is determined by the quantity of K extracted by 1N ammonium acetate (pH 7). Soils containing <120, 120–280 and > 280 kg K ha^{-1} are rated as low, medium and high respectively in available K. In India, recent soil fertility map developed from 500 districts (excluding Northeast states) using Geomatics 9.0 showed that only 13% of the samples are poor in available K while 50% of the samples are rich in available K (Muralidharudu et al., 2011). Omission of K fertilizers in rice, wheat and maize by farmers caused average yield loss of 622, 715 and 700 kg ha^{-1} respectively (Majumdar et al., 2012). In addition to yield loss, continuous omission of K would result in depletion of soil K reserve and net negative K balance. Although consumption of K fertilizer increased from 6 thousand tonnes (1950s) to 3.1 million tonnes (present), our total fertilizer consumption is highly biased towards N fertilizer; while K fertilizer constitute only 10% of the total consumption (Figure 4). Also, the net negative balance among primary nutrients is highest for K (69%) compared with N (19%) and P (12%).

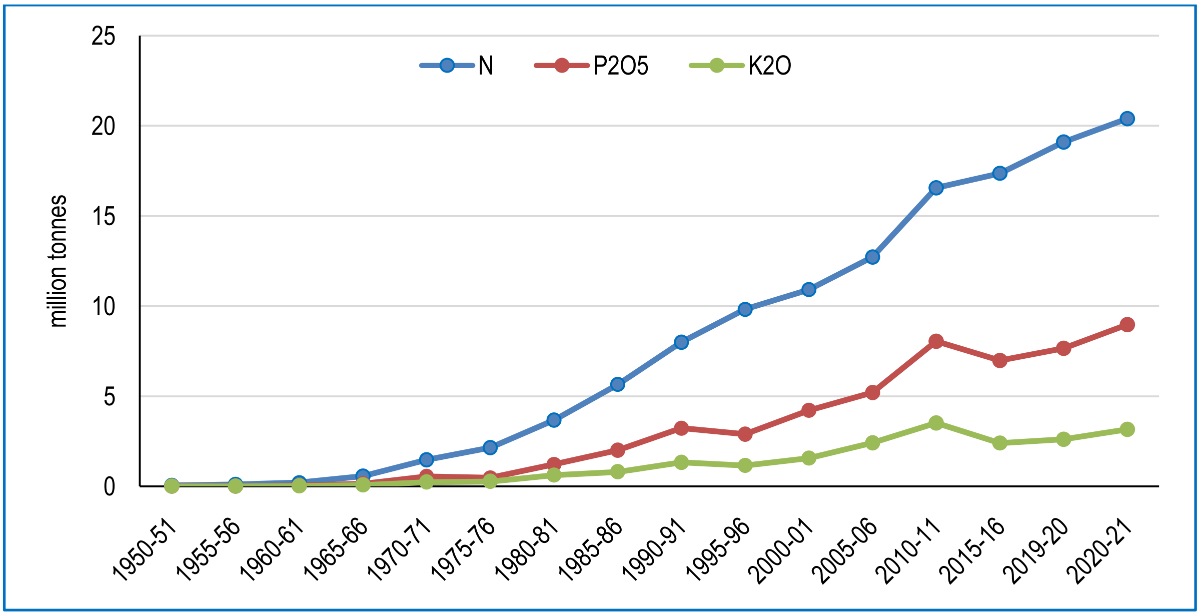

Figure 4. Trends of fertilizers consumption of India (Source: Fertiliser Association of India 2021)

LOSSES OF K FROM SOIL

Potassium (K) losses comprise of removals in harvested crops and losses via leaching, water erosion and wind erosion.

Crop Removal: Modern intensive agriculture leads to significant removal of K from the soil through harvested portion and this constitutes the largest loss of potassium from soil. The total quantity of K lost increased with rise in total K accumulation (uptake) and crop productivity. The biomass yield and total uptake of K of major crops presented in table 2 give an estimate of how much K is lost through this mode.

Table 2. Biomass yield and total uptake of K of major crops

Crop	Biomass Yield (t ha^{-1})	Total Uptake (kg K ha^{-1})
Rice	5.14	180
Wheat	3.90	137
Chickpea	1.50	49
Groundnut	2.54	95
Soybean	2.50	101
Alfalfa	91.9	669
Mustard	2.60	133
Sunflower	2.38	141
Potato	29.5	119
Sugarcane	87.6	270
Banana	38.0	1053
Pineapple	84.0	440

(Source: Tandon 1991)

Water Erosion: According to ICAR-IISWC, water erosion affects 73.3 m ha of our arable land, and this adversely affects agricultural production, water quality, soil fertility, hydrology and environmental sustainability. Water erosion removes the top fertile soil highly concentrated with crop nutrients through surface run-off, drainage water and sediments. A study in Ratnagiri district, Maharashtra estimated nutrient loss of N, P_2O_5, K_2O and organic carbon as 8.9 g kg^{-1} yr^{-1}, 0.13 g kg^{-1} yr^{-1}, 5.8 g kg^{-1} yr^{-1} and 638.94 kg ha^{-1} yr^{-1}, respectively due to water erosion (Salunkhe et al., 2018).

Wind Erosion: Abrasion, burial, dust deposition, etc. during wind erosion damaged crops. Apart from this, detachment of nutrient rich top soil particles removes soil organic matter and nutrients along with it. These soil particles contain a significant portion of the bulk soil's K supply. In hot arid ecosystem of India, average loss of K through wind erosion was estimated to be 14.8, 8.87 and 2.16 kg K_2O $ha^{-1}yr^{-1}$ respectively under very severe, severe and moderate erosion category (Santra et al. 2017).

Leaching: As K^+ is a mobile ion, it can move along with the drained water down the soil profile. Consequently, significant amounts of K can be leached below the rhizosphere volume by percolating water. The quantity of K leached from the soil is a function of soil texture, soil pH, cation exchange capacity, water regime and available K. Sandy soil, soils with low cation exchange capacity, higher the water depth, higher soil available K and larger K rates increased K leaching. During a growing season, leached K may be as high as 42 kg ha^{-1} in sandy loam soil under continuous standing water condition (Islam et al., 2014).

STRATEGIES TO IMPROVE K USE EFFICIENCY IN PLANTS

Given the indispensable nature of K in plant nutrition and India's dependency on imports for its K fertilizer requirement, enhancing K use efficiency (KUE) that seldom exceeds 60% is of particular significance in India. Different strategies to improve KUE may include:

- **Synchrony of K Supply with Plant Demand:** In most annual crops, basal application of the full dose of K fertilizer is a common practice. However, this is often not suited to supply adequate K to the crops during peak demand phases. The timing of K fertilizer application to crops is site and crop-specific. In rice-maize system, split application as basal and at panicle emergence in rice, and as basal and at pre-silking in maize significantly improved K uptake and grain yield compared to a single full basal application (Singh et al., 2021).

- **Balanced Fertilization:** Application of nutrients in optimum rates and adequate amount is necessary for higher KUE. Excess application is wasteful, while inadequate application could not meet plant nutrient demands, and both these processes detrimental for achieving higher production and productivity. Balanced supply of essential nutrients is necessary to maintain higher KUE.

- **Integrated Plant Nutrient System (IPNS):** IPNS enhances crop and soil productivity, maintain soil fertility and improve farm profitability through balanced use of chemical and organic fertilizers along with biological sources of plant nutrients. Use of FYM, biofertilizers, green manure and short duration legumes could substitute up to 25-50% of crop K needs.

- **Crop Residue Management:** As crop residues usually contain more K (>80%) than the harvested seed, it can partially substitute a portion of crop fertilizer requirement and augment soil K content. Residue incorporation reportedly ameliorates the negative K balance and improved soil water-soluble, exchangeable, and non-exchangeable K (Jiang et al., 2018). Incorporation or retention of crop residues can also help mitigate residue burning.

- Alternative source of plant-available K such as biochar, wood ash, waste mica and K solubilizing bacteria like *Bacillus mucilaginosus, Azotobacter chroococcum,* etc. could be used as a source of K in agriculture.

CONCLUSION

There is no doubt about the importance of K fertilization for achieving food security of the country. Given that all K fertilizers are imported, all efforts must be made to improve the KUE, use other alternative sources and reducing the various pathways of losses.

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