IPI International Potash Institute

Potassium – the Quality Element in Crop Production




INTERNATIONAL POTASH INSTITUTE

Compiled by P. Imas.

ISBN 978-3-905887-07-5
DOI 10.3235/978-3-905887-07-5

Table of Contents

POTASSIUM
THE QUALITY ELEMENT IN CROP PRODUCTION

INTRODUCTION

Potassium (K), along with nitrogen (N) and phosphorus (P), is an essential plant macronutrient that is taken up by crops from soils in relatively large amounts. Potassium increases both the yield and quality of agricultural produce, and enhances the ability of plants to resist diseases, insect attacks, cold and drought stresses and other adverse conditions. It helps in the development of a strong and healthy root system and increases the efficiency of the uptake and use of N and other nutrients. In addition, K has an important role in livestock nutrition.

Potassium has been described as the 'quality element', ensuring optimum quality of agricultural produce. Potassium has two main functions in the plant. First, it has an irreplaceable role in the activation of enzymes that are fundamental to metabolic processes, especially the production of proteins and sugars. Only small amounts of K are required for this biochemical function. Second, K maintains the water content and thus the turgor of cells – a biophysical role. Turgid cells maintain the leaf's vigor so that photosynthesis proceeds efficiently. The relationship between the water and nutrient content of the cell controls the movement of both through the plant, as well as the transport of sugars produced by photosynthesis to storage organs like grains, beet roots, tubers and fruits. Much larger quantities of K are needed for this physiological function than for its biochemical role in plants.

Consumers increasingly require high quality products and are willing to pay more for them. Fertilization with K is critical to achieving the required quality standard. A great deal of research has established the beneficial effect of balanced nutrient supply, including adequate K, on the quality of the harvested produce. This is especially so for nutritional properties, such as the content of protein, oil, vitamins, and for functional aspects (such as taste). Crops with an adequate supply of K have a better appearance, taste and flavor, and also produce food free of the signs of pests and diseases. Potassium fertilization increases yields and improves N fertilizer use-efficiency, which results in less residual nitrate (NO_3) in soils and therefore less environmental pollution.

Numerous on-farm trials within IPI projects have proved that balanced fertilization with K helps the farmer to produce food which meets the various quality criteria. Of course K is not the only nutrient that affects quality, but its balanced supply with other nutrients increases resistance, lowers production costs, improves the product's appearance and reduces the risk of rejection when the produce is offered for sale. Balanced fertilization also safeguards natural resources and contributes to environmental protection. Quality starts in the field!

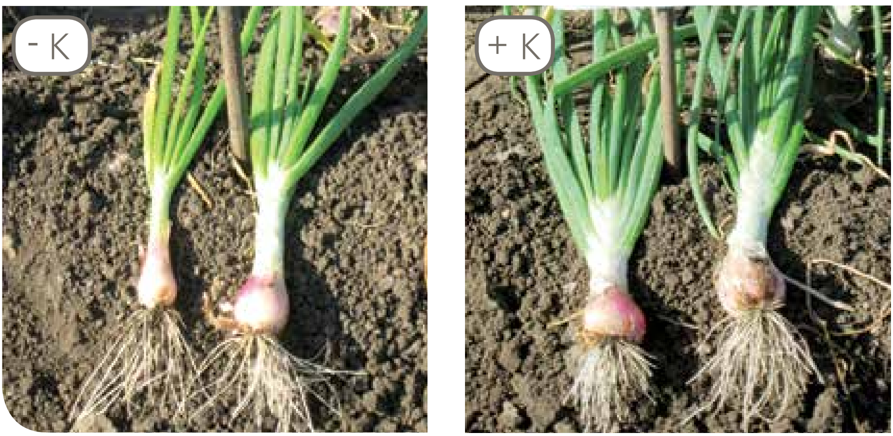


Plate 1. *Effect of K on onion size. IPI-MPKV project, Rahuri, Ahmednagar, Maharashtra, India. 2008-2009. Source: IPI Coordination India.*

CROP **QUALITY**

Quality in agricultural products comprises many characteristics, such as nutritional, organoleptic (taste, color, odor and feel), hygienic and functional properties. Often the amount of K required for optimum yield is also sufficient to secure good quality. However, the need to enhance fruit quality is sometimes more critical than other aspects of yield production, especially when high quality secures the best economic return. In such cases, more K is required to ensure quality than is needed for maximum yield, for example as has been shown to be required for bananas, cotton, potatoes, tobacco, turf grasses, ornamentals and some other food crops.

Potassium has been widely proven to have a crucial role in many crop quality parameters:

- In grain and oilseeds, K improves the nutritive value by increasing the content of protein and oil in cereals and oilseeds, respectively.
- In tubers and oilseeds, K increases starch and size of tubers.
- In cereals, K produces plumper grains and stronger straws.

- In fruit and vegetables, K increases size, vitamin C and sugar content, and improves flavor and color.

- In fiber crops, K improves fiber quality in cotton and flax.

- In addition, K helps maintain quality during storage and transportation, thus extending shelf life.

The term 'quality' refers to several aspects that affect the marketability of the product, including:

- Attractiveness: uniform and large size, good shape and attractive color, freedom from blemishes, markings, mechanical injuries and signs of disease.
- Organoleptic attributes: enhanced flavor and aroma.
- Nutritional value: higher content of proteins and vitamin C.
- Longer shelf life.
- Adequate processing quality for industry.

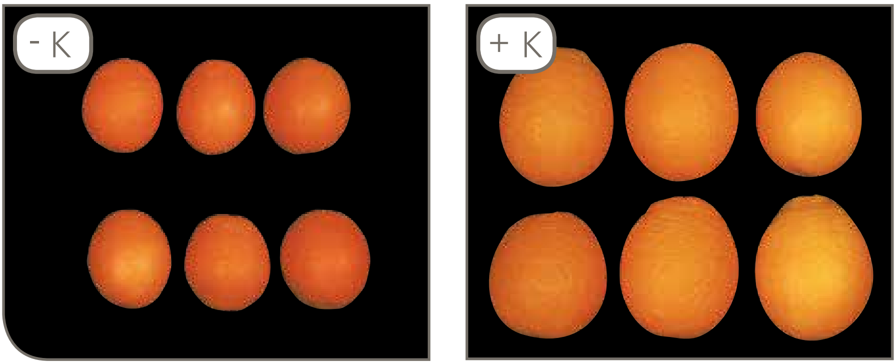


Plate 2. *Effect of K on citrus fruit size. Volcani Center, Israel, 1995. Courtesy: A.R.O., Israel.*

NUTRITIONAL VALUE OF CROPS

The nutritional value refers to the content of certain constituents, such as protein, oil and fat, starch, mineral components and vitamins. The fiber content, as well as the energy content, are widely used parameters in assessing the value of food stuffs in the human diet. The content of nutritive elements, like protein or oil, is used in many countries as a basis for procurement systems and thus is an economic factor.

Potassium has a function in cycling nutrients for growth, i.e. N from the roots to the shoot, and carbon from the source (shoot) to the sink (roots, fruits and other storage organs). Potassium travels as a counter-ion, together with nitrate (NO_3), in the xylem to the shoot. Experiments with the N isotope (^{15}N) showed that plants well supplied with K were able to take up more N, and moreover, convert the N more rapidly into protein. Nitrate in the plant is reduced first to amines and then incorporated into amino acids to ultimately form proteins. A low K supply restricts adequate NO_3 transport and inhibits protein formation, leading to an accumulation in the plant of nitrate-N and soluble amino-N (Fig. 1).

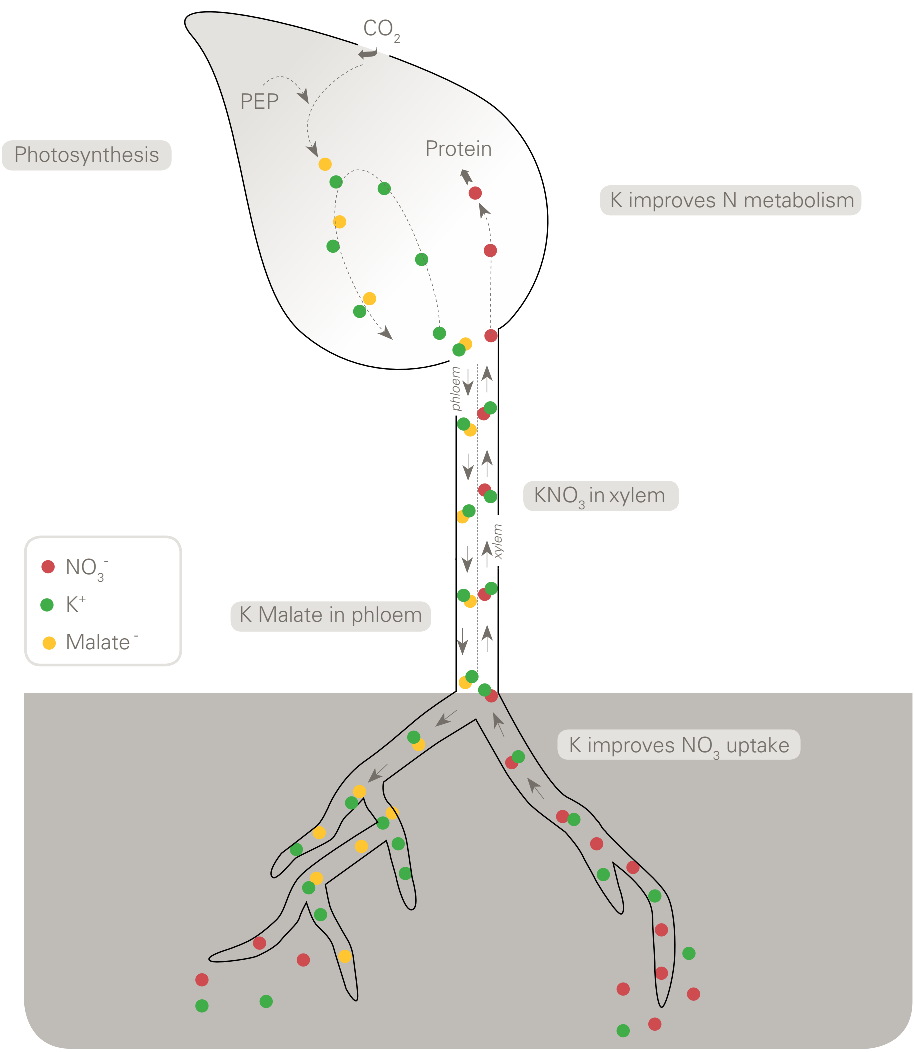


Fig. 1. A simplified schematics for the circulation of potassium between root and shoot in relation to nitrate and malate transport (PEP, phosphoenol pyruvate). After Marschner et al.,1996 (based on Ben-Zioni et al., 1971 and Kirkby and Knight, 1977).

Results from experiments

In India, IPI experiments showed that applying K increased both oil content and oil yield of sunflower (Fig. 2). An oil yield of 696 kg/ha was obtained with 90 kg K_2O/ha application as against 392 kg/ha with imbalanced fertilization (NP only).

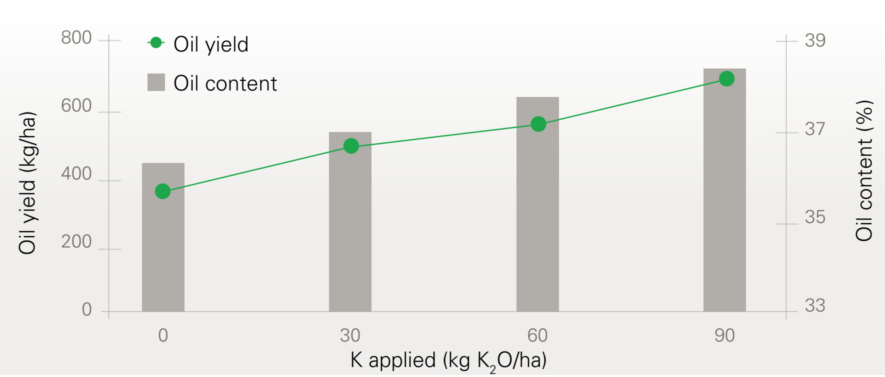


Fig. 2. Effect of K application on oil content and oil yield (oil yield = oil content X crop yield) of sunflower.IPI-PAU project. Punjab, India. 2004. Source: IPI Coordination India.

In papaya, in addition to large yield increase, K fertilization improved major quality parameters of fruits: (i) pulp thickness, i.e. edible part of papaya fruits, was increased; (ii) the sweetness of papaya, the prime fruit quality parameter, mainly judged by the Total Soluble Solids (TSS), was improved; (iii) the acidity content was decreased (Table 1).

***Table 1.** Effect of K application on fruit yield and quality of papaya (11 months after planting). IPI-TNAU project. Theni District, Tamil Nadu, India. 2004-05. Source: IPI Coordination India.*

Treatment	Fruit weight	Pulp thickness	TSS	Acidity
(kg/plant/year)	kg	cm	° Brix	%
$N_{300}P_{300}$	1.14	1.67	10.93	0.51
$+K_{150}$	1.21	2.40	12.03	0.34
$+K_{300}$	1.77	2.60	11.43	0.47

Vitamin C (commonly referred to as ascorbic acid), is perhaps the most popular vitamin. Soil and foliar application of K has been shown to increase the level of vitamin C in many crops, like cucurbits, cauliflower, onion, banana, guava and papaya. In an experiment at the Zhejiang Agricultural University in China, applying K increased the vitamin C content of sweet pepper (Fig. 3).

In citrus, K improves both the citric and ascorbic acid content of the juice, as well as other juice characteristics, like the acid/sugar ratio and soluble solids content.

With proper K nutrition, tomato fruit generally contains more total solids, sugars, acids, carotene and lycopene.

Potassium application increased the protein content of maize, as shown by IPI experiments in India (Fig. 4, page 12). It is also known that K increases protein N and decreases non-protein N, producing more digestible dry matter and protein in maize silage, thus improving the feeding value of the forage for livestock.

Root starch content in cassava increased with K fertilization, as shown in IPI experiments in Indonesia (Table 2, page 12).

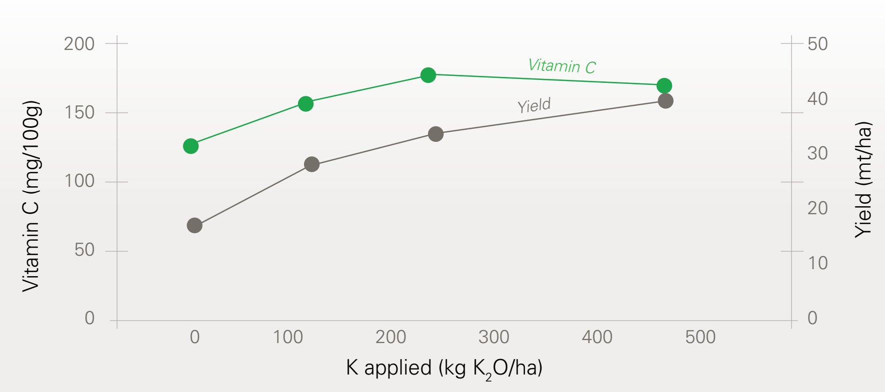


Fig. 3. *Effect of K application on yield and vitamin C content of sweet pepper. Zhejiang Agricultural University, China. Source: Wu-Zhong et al., 2001.*

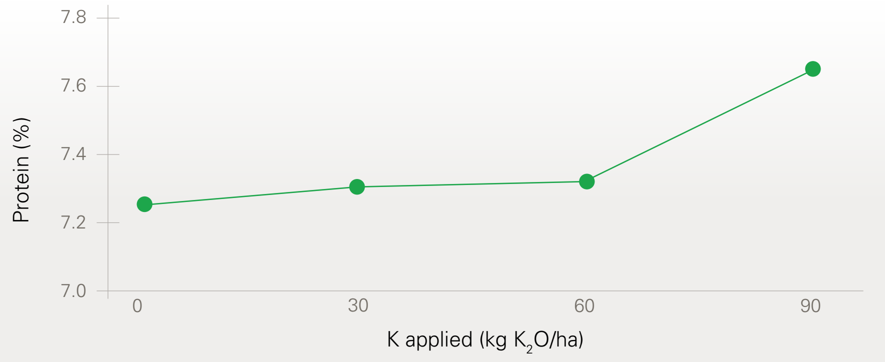


Fig. 4. Effect of K application on protein content in maize. IPI-PAU project. Punjab, India. 2004. Source: IPI Coordination India.

Table 2. Effect of K fertilization on starch content of cassava tubers at harvest. IPI-ILETRI project. Tulungagung, Indonesia. 2012. Source: IPI Coordination SEAP.

Fertilizer treatment (kg/ha)			Starch content (%)
N	P_2O_5	K_2O	(Fresh basis)
135	36	0	31.41 c
135	36	30	32.35 cd
135	36	60	35.47 abc
135	36	90	36.56 ab
135	36	120	32.90 bcb
200	60	180	37.65 a
CV (%)			7.5

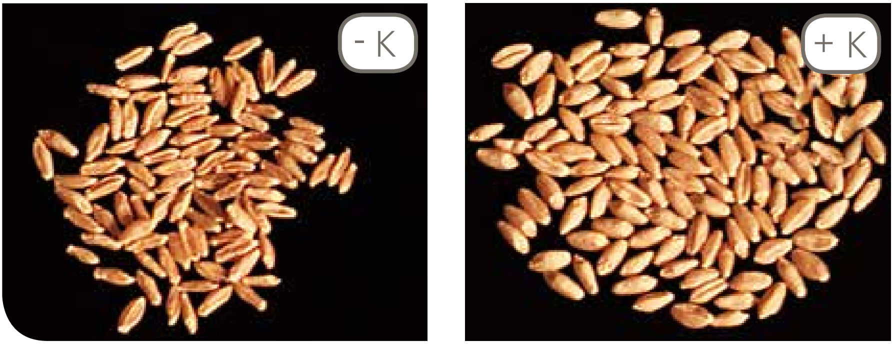


Plate 3. *Effect of K on grain size and appearance of wheat. Potash Research Institute of India (PRII), Gurgaon, Haryana. 2004. Courtesy of PRII, India.*

FOOD **APPEARANCE**

An adequate supply of K promotes the formation of larger grains through a more intensive and longer period of photosynthesis. In Orissa (India), rice yielded more with K, because of a longer period of grain filling and hence larger seeds (larger thousand-grain weight). Wheat grains from K trials in Haryana (India) received a bonus price because of better appearance, i.e. more bold and shiny than seeds from control plots (Plate 3).

With potatoes, K application increases the yield of large and medium-sized tubers and decreases weight loss from the tubers after harvest (Plate 4, page 14). In citrus, K nutrition positively influences the size of fruit (Plate 2, page 7), thickness of the rind and fruit color. The improved yield is due, in part, to reduced fruit fall from the tree and larger fruit size.

By applying K, the incidence of some physiological disorders of tomatoes (such as gold specks, puffiness, blotchy ripening complex, grey wall and greenback or yellow shoulder), can be reduced by applying K. In a survey of 140 fields of tomatoes for food processing in central California, the incidence of two color disorders (yellow shoulder and internal white tissue) was negatively correlated with the K status of both soil and plant.

Physiological disorders of citrus fruits, like plugging and creasing, are associated with high N and low K availability. Potassium deficiency, which results in small, thin-skinned fruit, promotes fruit splitting, although extra K will not always prevent normal splitting in susceptible cultivars.

Plants adequately supplied with K show fewer incidences of pests and diseases. Fissures, cracks and lesions observed on K-deficient fruits and leaves not only offer easy access to invading pathogens but are less appealing to potential consumers at the market. When the appearance, and thus the quality are poor, the farmer cannot sell their produce for the best possible price.

Plate 4. *Effect of K on number and size of potato tubers. IPI-PRII-CPRI project. Jalandhar, Punjab, India. 1997. Source: IPI Coordination India.*

PROCESSING QUALITY

Potassium promotes N absorption, stimulating amino acid translocation from the vegetative parts to the grain, and thus favors the synthesis of gluten and prolamine, as well as the formation of proteins that improve baking quality. Potassium application increases the starch content of rice, wheat, maize, soybean, sesame and some forage crops. The positive effect of K on the oil content of crops has been reported for sesame, soybean, oilseed rape, groundnut and cotton seeds.

Potassium application increases boll size of cotton, improves micronaire value, fiber strength and length, and increases the percentage of mature fibers. Potassium supply to cotton, through its effect on assimilation capacity, is an important determinant of fiber quality under field conditions. The K requirement for producing a high lint yield of acceptable quality can differ among genotypes.

Potassium fertilization improves the quality of potatoes for processing. Insufficient K leads to decreased tuber dry matter through reduced photosynthesis, and hence lower starch production. Potassium deficiency also causes the accumulation of reducing sugars, thus producing undesirable, dark colored chips. Internal blackening of potato tubers may be related to an excess of tyrosine caused by K deficiency. Evidence also exists that bruising and hollow heart can be reduced by K application.

Sugar beet receiving adequate K gives a larger root yield with increased sugar content and consequently a much larger sugar yield. The lower sugar content in beet receiving inadequate K derives from reduced translocation of assimilates from the leaves into the storage organ, due to restricted phloem loading. In addition to less sugar translocation, beet grown with high N and inadequate K has a larger content of amino N, which reduces the extractability of sugar from the beet. Amino N accumulates because synthesis of protein is restricted by K deficiency.

SHELF **LIFE**

The effects of K on shelf life are predominantly favorable, both through slowing senescence and through a decrease of numerous physiological diseases. Potassium increases firmness and strengthens the skin of fruits, thus they are not damaged easily during transport, resist decay for a longer period and stay fresh longer. Increased K application reduces the postharvest moisture loss by increasing the weight of the harvested organs and maintaining tissue integrity. Potassium also can reduce the incidence of some fungal storage diseases that may cause considerable losses, given that fruits, tubers or roots showing even minor damage must be discarded before marketing.

Storage compounds accumulating in the harvested produce during growth and maturation are consumed in the course of metabolic activities during storage. Respiration includes the oxidative breakdown of sugars, starch and organic acids into carbon dioxide and water, with the concurrent production of energy, heat and intermediary compounds to be used in biochemical reactions. With a shortage of K,

EXTERNAL

+ IMPROVES APPEARANCE ATTRIBUTES
size, shape, gloss, color

+ IMPROVES FEEL ATTRIBUTES
firmness, texture, peel thickness

– REDUCES DEFECTS
cracks, creases, marks, flaws (caused by physiological disorders, pests and diseases)

INTERNAL

IMPROVES TASTE ATTRIBUTES

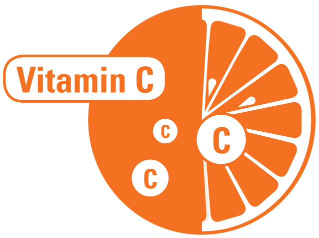
sweetness, bitterness, sourness, saltiness, juice content

IMPROVES TEXTURE ATTRIBUTES

tenderness, firmness, crispness, crunchiness, chewiness, fibrousness

HIDDEN

IMPROVES PROCESSING QUALITY



IMPROVES NUTRITIVE VALUE

content of sugars, proteins, starch, vitamins, soluble solids, minerals

IMPROVES STORAGE AND SHELF LIFE

water loss and decay, discoloration, bruising and other mechanical injury, wilting, texture changes

HIDDEN

IMPROVES PROCESSING QUALITY

IMPROVES NUTRITIVE VALUE

content of sugars, proteins, starch, vitamins, soluble solids, minerals

IMPROVES STORAGE AND SHELF LIFE

water loss and decay, discoloration, bruising and other mechanical injury, wilting, texture changes the rate of respiration is increased and more energy is required for this function; thus fruits that have received low K application do not last as long in storage.

Potassium enhances storage and shipping quality of bananas, tomatoes, potatoes, onions and many other crops, and also extends their shelf life. Some examples are:

- Poor K nutrition of bananas results in thin and fragile bunches with a shorter shelf life.

- Quality of citrus fruits during storage is influenced by the K nutrition of the tree: the incidence of stem-end rot and green mold decreases as K application increases, therefore fruit loss during transport is reduced and supermarket shelf life increases.

- For the orange cultivar 'Shamouti', K reduces the incidence of superficial rind-pitting, a physiological disease that develops in the packing house within 3-5 weeks after harvest, and also during shipment and storage.

- For potatoes, applying K reduces storage losses, related to a reduction in the activity of catalase and peroxidase enzymes.

- In carrots, K enhances keeping quality after harvest; wilting is retarded.

- In pineapple, the incidence of endogenous brown rot (the most important physiological postharvest disorder) can be reduced by supplying larger amounts of K, which increases the level of ascorbic acid in the fruit, preventing the oxidation of phenolic compounds, and thus avoiding the development of the disorder.

SUPPRESSION OF **DISEASES AND INSECTS**

It has been recognized for decades that K enhances a plant's ability to resist pest and diseases. This is not isolated to a few crop species, but includes a wide range of both plants and pathogens. The role of K in crop resistance to diseases was extensively examined in an IPI review of 2,450 literature references. The results showed that adequate amounts of K decrease the incidence of fungal diseases by 70%, of bacterial diseases by 69%, of insect and mite damage by 63%, and of viruses by 41% (Fig. 5, page 24).

Adequate K fertilization produces a strong, vigorously growing plant, which can tolerate disease and insects much more effectively than those suffering stress. By its favorable action in regulating plant metabolism and counteracting the harmful effects of excessive N, K normalizes plant development and ensures proportionate growth. This guarantees the health and hardiness of the plant tissues, providing resistance to damage by pests and diseases.

Although pest damage cannot be avoided by adequate nutrition alone, it can be significantly reduced with K fertilization. Potassium fertilization is an important management tool in the arsenal of plant protection. Including K nutrition as a part of integrated pest management (IPM) lowers the need for other chemical pest and disease control measures and reduces the risk of unwanted pesticide residues. By adopting balanced fertilization, the farmer can reduce the input of agrochemicals and prove that he produces food in a 'natural' way.

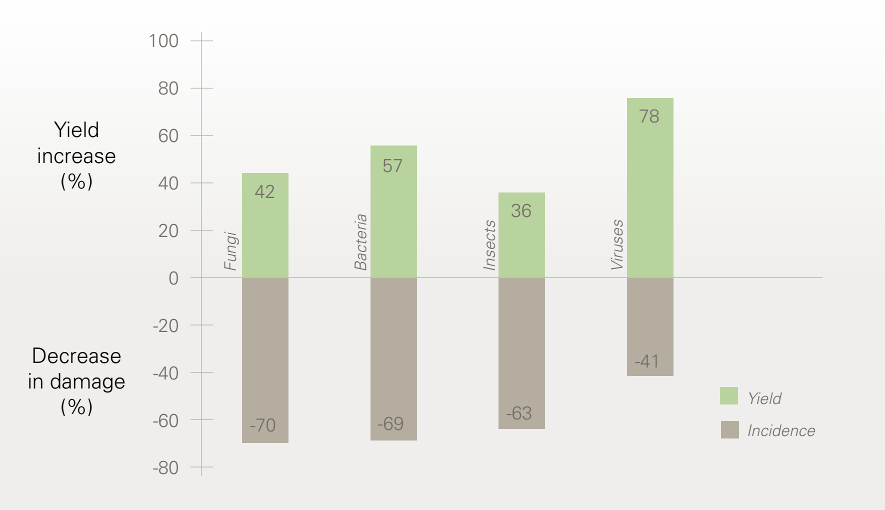


Fig. 5. Reduction of pest damage/disease incidence and corresponding yield increase by K application (n=2,450). Source: Perrenoud, 1990.

Plate 5. Effect of K application on red rot disease (Colletotrichum falcatum) in sugarcane. Meerut, Uttar Pradesh, India. 2002.

Diseases

In general, an inverse relationship is found between available soil K and the severity of disease. It is a common practice to add K fertilizers to reduce certain diseases. Leaf spot in cotton is related to low soil K, low plant tissue K and/or low petiole K. Different K fertilizers, applied as foliar sprays, are highly effective as inducers of systemic protection against powdery mildew in cucumbers. Potassium deficiency in late-season soybeans can lead to reduced yields and poor seed quality, caused by pod and stem blight and purple seed stain. With potatoes, K fertilization has been found to decrease the incidence of several diseases, such as late blight, dry rot, powdery scab and early blight (Plate 6, page 26).

Potassium exerts its greatest effect on diseases by influencing tissue cell structures and biochemical and metabolic functions. Potassium-deficient plants have a larger concentration of soluble sugars, which are a suitable substrate for the growth of many pathogens. Inorganic N accumulates in the sap of K-deficient maize plants through the impairment of N metabolism, which provides a more favorable environment for bacterial growth and subsequent susceptibility to wilt. Potassium also increases the production of disease-inhibitory compounds, such as phenols, phytoalexins and auxins, which increase the resistance of plants to pests and diseases.

The increased resistance to disease because of K has been attributed to various mechanisms, e.g. decreased cell permeability and decreased susceptibility of tissue to maceration and penetration by pathogens. Moreover, K in combination with P induces the development of thicker cuticles and cell walls, which function as mechanical barriers to invasion and infection by pathogens.

Where there is an over-supply of N with inadequate supply of K, the cell walls of plant stems can be thinner because of rapid growth, and lodging occurs. Lodging of cereals exposes plants to diseases with the extra humidity that develops in the lodged crop giving an ideal microclimate for germinating fungal spores. Therefore it is important to ensure that N application is balanced with adequate K.

Physical resistance to diseases is enhanced because an adequate K supply ensures full closure of plant stomata and increases the lignification of vascular tissue. Cracks, fissures and lesions that develop with K deficiency on the surface of leaves and fruits provide easy access to pathogens.

Plate 6. *Effect of K application on the incidence of late blight disease (Phytophthora infestans) in potato. IPI-PRII-CPRI project. Jalandhar, Punjab, India. 1998. Source: IPI Coordination India.*

Plate 7. Effect of K on worm attack in maize. Chengdu, China, 2001. Source: IPI Coordination China.

Insects

The role of K in mitigating crop damage due to insects has been well documented. Plants excessively supplied with N and little K have soft tissue with little resistance to sucking and chewing insects. The yellowish discoloration of plants suffering from K deficiency acts as a signal to attract aphids. The soft surface of tissues with excessive N assists aphids to penetrate the leaf surface and not only compete for assimilates but transmit viruses at the same time. Wilting, which is another indicator of K deficiency, also appears to attract pests.

An excessive N supply with unbalanced fertilization requires carbon (C) to metabolize it and this leaves little C from the Krebs cycle for synthesis of secondary compounds, such as phenols and quinones. Those phenolic compounds play an important role in the host/pathogen relationship, being the basis for many defense mechanisms. They

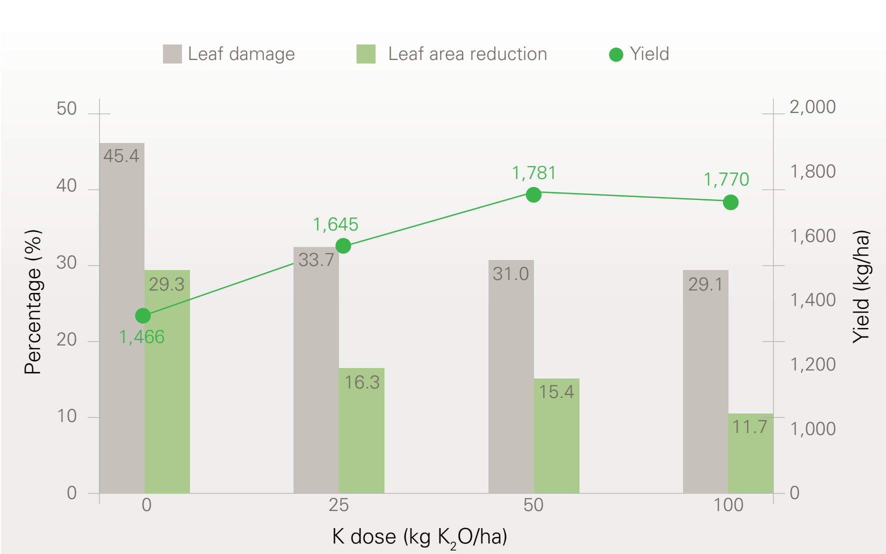


Fig. 6. Effect of K application on soybean yield and leaf damage by blue beetle (Cheorane sp.). IPI-PRII-RAK project. Sehore, Madhya Pradesh, India. 2001. Source: IPI Coordination India.

act as phytoalexins or as precursors of lignin and suberin, which act as mechanical barriers in leaves and stems against pest and insect attack.

During a long-term IPI experiment in India with soybean, the attacks of insects like blue beetle, grey semilooper, girdle beetle and stem fly were clearly reduced with K applications, and consequently yield increased (Fig. 6, Plate 8).

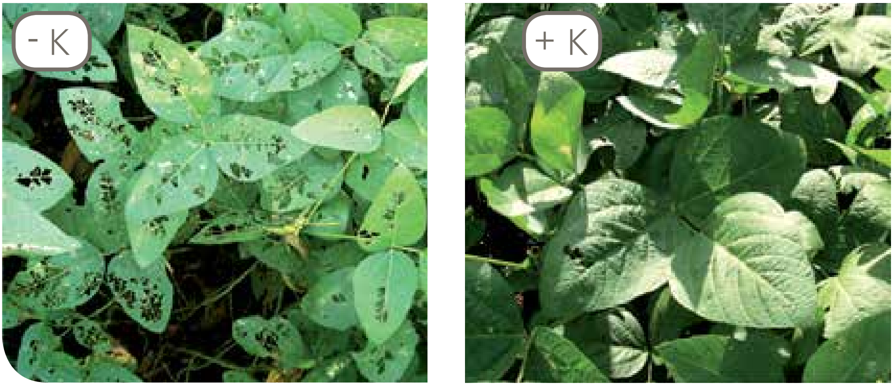


Plate 8. *Effect of K on pest infestation in soybean, IPI-PRII-RAK project. Sehore, Madhya Pradesh, India. 1999. Source: IPI Coordination India.*

HUMAN **HEALTH**

Potassium has long been recognized as an essential element in animal and human nutrition. It is the third most abundant mineral in the human body, after calcium and phosphorus, comprising 5% of the total mineral content of the human body.

Potassium has long been known as a health factor for humans and livestock. It plays a vital role in the transmission of electrical impulses through the central nervous system, and in regulating the smooth, natural rhythms of the beating heart. It mediates important cellular chemical reactions required for nutrients to pass into cells, and it helps to maintain the body's water balance. Potassium stimulates water exchange in the tissue and its release through the kidneys; it stimulates the metabolism by activating the enzyme systems that regulate the digestion of food and fat. It also assists in protein synthesis from amino acids and in carbohydrate metabolism.

Potassium has no harmful effects in humans. It helps regulate blood pressure at stable levels and may help in the prevention of strokes. Humans with an adequate intake of K show fewer cases of hypertension, and when K-rich foods are consumed, blood pressure drops. Potassium has no known deleterious effect on the quality of drinking water. Potassium in drinking water and/or food is no hazard for human health, provided renal function is normal. The limits for K in EU regulations for drinking water have been withdrawn, reflecting the benign nature of this element to human health.

Potassium is absolutely essential for life. Young animals will fail to grow, and may die within a few days when the diet is totally deficient in K. A deficiency of K in the human body can cause muscle weakness, fatigue, constipation, mental apathy, etc. The recommended daily intake of K increases, with age, from 3,000 to 4,700 mg per day. However, research shows that the K levels found in modern diets are far below those found in more traditional diets based on unprocessed foods (Karppanen *et al.*, 2005).

Humans and animals need to obtain an adequate supply of K from their food and feed to be healthy and grow normally. The source of this K is plants. Foods considered rich in K are potatoes, dried fruits, strawberries, avocado, meats, fish, legumes, bananas and whole grains (Table 3).

Table 3. *Potassium content of selected foods. From USDA Nutrient Database for Standard Reference. www.ars.usda.gov/SP2UserFiles/Place/12354500/Data/SR25/nutrlist/sr25a306.pdf*

Food	Serving size	K content	Supply to suggested daily intake*
		(mg K)	(%)
Raisins	1 cup (145 g)	1,086	23%
Avocado	1 medium (201 g)	1,021	22%
Spinach (boiled)	1 cup (180 g)	839	18%
Peas (boiled)	1 cup (196 g)	710	15%
Salmon fish	1/2 fillet (155 g)	632	13%
Potato (baked)	1 medium (156 g)	610	13%
Orange juice	1 cup (248 g)	496	11%
Banana	1 medium (118 g)	422	9%
Whole milk	1 cup (244 g)	322	7%
Sirloin steak beef	85 g	320	7%
Bread, whole-wheat	2 slices (56 g)	138	3%

** FDA daily reference value is 4,700 mg K per day.*

FUNCTIONAL FOODS

Consumers today are seeking benefits from foods that contain natural compounds beneficial to health (functional foods). For example, phytochemicals with medicinal value are defined as bio-active ingredients in food and are thought to support health and fitness. Lycopene in tomatoes, allicin in garlic, or isoflavones in soybean belong to this group. They are associated with prevention of cancer, diabetes, hypertension and heart disease.

Potassium may enhance, for instance, the content of lycopene in tomato. A report in the *Journal of Agricultural and Food Chemistry* confirmed a positive link between K fertilization of soybeans and their isoflavone content. The work showed that, particularly in low fertility soils, K fertilizer increased the major isoflavones - genistein, daidzein, and glycitein - by up to 16%.

Curcumin is a phytochemical extracted from the popular Indian spice turmeric and may be useful for the prevention and treatment of several diseases. The turmeric's rhizome quality is judged on how much curcumin it contains. This important quality parameter of the rhizome has been shown to increase significantly in response to K application. IPI experiments in India confirmed this finding with significantly increased concentrations of curcumin as a consequence of K application (Table 4).

It is not known whether K plays a specific role in the synthesis of phytochemicals, but it may be because K is an important enzyme cofactor for many plant metabolic reactions.

Potassium has also been shown to reduce the contents of toxic phytochemicals. For example, cassava contains potentially toxic, cyanogenic glycoside compounds, which can cause poisoning and death in human beings. Many authors have reported significant reduction in the hydrocyanic acid (HCN) content of cassava tubers in response to K fertilization.

Table 4. *Effect of K application on the yield and quality of turmeric cv. Erode local. IPI-Annamalai University project. Erode, Tamil Nadu, India. 2006. Source: IPI Coordination India.*

Potassium application	Fresh turmeric yield	Curcumin content
kg K_2O/ha	mt/ha	%
0	18.0	2.90
40	24.3	3.30
120	28.3	3.63
200	31.4	3.93
260	34.4	4.47
CD (P=0.05)	1.68	0.15

NITRATE CONTENT IN FOOD

Unbalanced fertilization with an inadequate K supply may lead to NO_3 accumulation in plants. Potassium helps to keep the NO_3 content in fruits and vegetables within the limits established by the public health authorities. EU legislation has defined maximum levels of permitted nitrates in green leafy vegetables such as lettuce and spinach.

The involvement of K in the N cycle can be seen in its role as an enzyme activator in N metabolism. It has been shown by Koch and Mengel (1974), that K-deficient tobacco plants not only absorb 26% less NO_3 than plants receiving adequate K, but of the NO_3 taken up, only 15% is incorporated into protein and 45% still remains as NO_3 in the K-deficient plants. In contrast, plants well fed with K converted 40% of the NO_3 into protein and only 30% remained as NO_3. Less NO_3 remaining in the tissue with the higher conversion rate complies with the consumer's concern for 'safe' food, and the larger NO_3 uptake with an adequate K supply matches the requirement for environmentally-friendly crop production.

IPI on-farm trials in China show that celery receiving adequate K has a NO_3 content of 427 ppm, which is 27% lower than that with unbalanced nutrition (Fig. 7). Potassium helps to keep the NO_3 content of celery within the limits laid down by the public health authority.

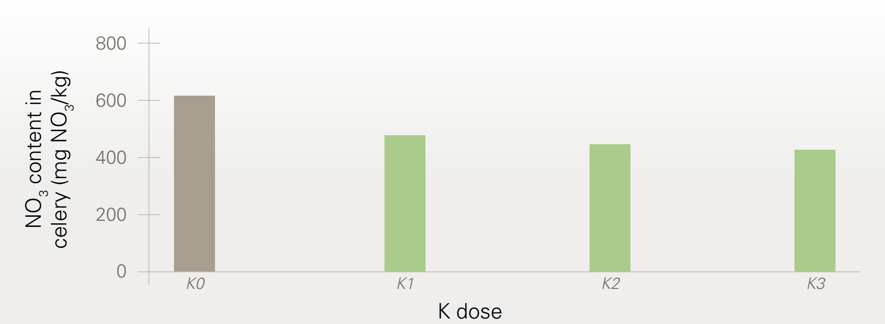


Fig. 7. *Nitrate content in celery as affected by K application in China. Härdter and Krauss, 1999.*

ADDITIONAL READING

1. Various articles on the International Potash Institute (IPI) website: www.ipipotash.org.
2. Potassium and Chloride in Crops and Soils: The Role of Potassium Chloride Fertilizer in Crop Nutrition. Kafkafi, U., G. Xu, P. Imas, H. Magen, and J. Tarchitzky. 2001. IPI-Research Topics 22. International Potash Institute, Switzerland.
3. Potassium Sulphate and Potassium Chloride. Zehler, E., H. Kreipe, and P.A. Gething. 1981. IPI-Research Topics 9. International Potash Institute, Switzerland.
4. Mineral Nutrition of Higher Plants. Marschner, H. 1995. 2nd edition. Academic Press, San Diego, NY.
5. Impact of Potassium on Crop Yield and Quality with regard to Economical and Ecological Aspects. Mengel, K. 1977. *In*: Food Security in the WANA Region, the Essential Need for Balanced Fertilization (Johnston, A.E., ed.) p. 157-174. International Potash Institute, Switzerland.
6. The Role of Potassium in Crop Quality. Usherwood, N.R. 1985. *In*: Potassium in Agriculture (Munson, R.D., ed.) p. 489-514. ASA/CSSA/SSSA, Madison, WI.
7. Potassium and Plant Health. Perrenoud, S. 1990. 2nd edition. IPI Research Topics 3. International Potash Institute, Switzerland.
8. Potassium Fertilization Effects on Isoflavone Concentrations in Soybean. Vyn, T.J., X. Yin, T.W. Brunlsema, C.C. Jackson, I. Rajcan, and S.M. Brouder. 2002. J. Agric. Food Chem. 50:3501-3506.
9. Effect of Mineral Nutritional Status on Shoot-Root Partitioning of Photo-Assimilates and Cycling of Mineral Nutrients. Marschner, H., E.A. Kirkby, and I. Cakmak. 1996. J. Exp. Botany 47:1255-1263.
10. Balanced Fertilization and Crop Quality. Härdter, R., and A. Krauss. 1999. IFA Agric. Conference on Managing Plant Nutrition. Barcelona, Spain, June 29-July 2.
11. The Influence of the Level of Potassium Supply to Young Tobacco Plants (*Nicotiana tabacum* L.) on Short-Term Uptake and Utilization of Nitrate Nitrogen (^{15}N). Koch, K., and K. Mengel. 1974. J. Sci. Fd. Agric. 25:465-471.
12. Yield and Quality Responses of Selected Solanaceous Vegetable Crops to Potassium Fertilization. Wu-Zhong, N., J.S. Liang, and R. Härdter. 2001. Pedosphere 11:251-255.
13. Potassium Requirements for Maximum Yield and Fruit Quality of Processing Tomato. Hartz, T.K., G. Miyao, R.J. Mullen, M.D. Cahn, J. Valencia, and K.L. Brittan. 1999. J. Amer. Soc. Hort. Sci. 124:199-204.
14. Influence of N, K and Irrigation on Citrus Fruit Quality. Koo, R.C.J., and R.L. Reese. 1977. Proc. Int. Soc. Citricul. 1:34-38.
15. Why and How to Implement Sodium, Potassium, Calcium, and Magnesium Changes in Food Items and Diets? Karppanen, H., P. Karppanen, and E. Mervaala. 2005. Journal of Human Hypertension 19, S10-S19.

INTERNATIONAL
POTASH INSTITUTE

Baumgärtlistrasse 17, P.O. Box 260
CH-8810 Horgen, Switzerland
T +41 43 810 49 22, F +41 43 810 49 25
ipi@ipipotash.org; www.ipipotash.org
twitter.com/IPI_potash; facebook.com/IPIpotash
flickr.com/photos/ipi_potash/sets/