

ROLE OF POTASSIUM IN FRUIT CROPS - A REVIEW

A. Ramesh Kumar, N. Kumar and M. Kavino

Department of Fruit Crops, Horticultural College and Research Institute,
Tamil Nadu Agricultural University, Coimbatore - 641 003, India

ABSTRACT

Potassium appears to have profound influence on fruit quality through its influence on size, appearance, colour, soluble solids, acidity and vitamin contents. Potassium deficiency in fruits is often observed even in K-rich soils. Fruits like banana, grapes, peach and passion fruit have high potassium requirement. Although potassium does not form part of the structure of plant constituents, it regulates many vital functions like carbon assimilation, translocation of proteins and sugars, water balance in plants, maintaining turgor pressure in the cell, root development, improving quality of the fruits by maintaining desirable sugar to acid ratio, ripening of fruit and many other processes. Thus, it is the most important nutrient regulating the quality of fruits. Potassium is involved in many aspects of plant physiology viz., activation of more than 60 enzymes, aiding in photosynthesis, favouring high energy status, regulation of stomata opening etc. With the changing cropping pattern, need for potassium nutrition has become pertinent to obtain high yield of quality fruits. In this review paper role of potassium on various physiological processes in improving the yield and quality of major fruit crops has been discussed.

All fruit crops have strict requirement for a balanced fertilizer management. Many horticultural crops are heavy removers of nutrients and high yields can only be sustained through the application of optimal doses in balanced proportion. Among the major nutrients, potassium not only improves yields but also benefits various aspects of quality. Hence, potassium fertilization results in a higher value product and therefore in a greater return to the farmer.

What is Potassium?

Potassium is one of the essential nutrients for plant growth and vital for sustaining high-yield in agriculture. Potassium is often referred as the quality element for crop production (Usherwood, 1985). The crucial importance of potassium in quality formation stems from its role in promoting synthesis of photosynthates and their transport to fruits, grains, tubers, and storage organs and to enhance their conversion into starch, protein, vitamins, oil etc. (Mengel and Kirkby, 1987). With a shortage of potassium many metabolic processes are affected, like the rate of photosynthesis, the rate of translocation and enzyme systems (Marschner, 1995; Mengel,

1997). At the same time, the rate of dark respiration is increased. The result is a reduction in plant growth and in crop quality. K influences on quality can also be indirect as a result of its positive interaction with other nutrients especially with nitrogen and production practices (Usherwood, 1985).

Involvement of potassium in physiological processes

i) Energy

Plants require potassium for the production of high-energy molecules (ATP) which are produced both in photosynthesis and transpiration processes (Willingford, 1980). Potassium maintains the balance of electric charges in chloroplasts, which is required for ATP formation. Hence, K improves the transfer of radiation energy into primary chemical energy in the form of ATP (photophosphorylation) and NADPH (FeIII cyanide reduction in the chloroplasts. This energy transfer is a fundamental process in the plant and an adequate K supply guarantees high levels of energy in the form of ATP and NADPH (Pfluger and Mengal, 1972). This energy is required for all synthetic process in plant metabolism, resulting in production of

carbohydrates, proteins and lipids, which express the quality of the crops. The high-energy status in crops well supplied with K also promotes synthesis of secondary metabolites, like vitamin C (Mengel, 1997).

ii) Photosynthesis

Potassium affects the photosynthesis process in many levels, affecting several processes (Marschner, 1995). Synthesis of ATP is needed for the photosynthesis reaction. Activities and efficiencies of the enzymes involved in photosynthesis (like RuBP carboxylase) CO_2 uptake into the leaves (stomata opening) Balance of electric charges needed for photophosphorylation in chloroplasts, counterion to the light-induced H^+ flux across the thylakoid membranes are purely K dependent processes in any plant system. The rate of photosynthesis is measured as the rate of CO_2 assimilation. Photosynthesis required adequate K levels in leaf tissue. In corn, maximum CO_2 fixation happens when leaf K concentration is 1.7-2%, and decreases very sharply under low K conditions (Smid and Peaslee, 1976).

iii) Enzymes

Potassium is involved in the activation of more than 60 enzymes, including synthetases, oxidoreductases, dehydrogenases, transferases and kinases. These enzymes are necessary for essential plant processes such as energy utilization, starch synthesis, N metabolism and respiration (Wallingford, 1980). The effect of different cations on the activity of starch synthase that catalyzes the incorporation of glucose into long-chain starch molecules (Mengel and Kirkby, 1987). It can be seen that potassium is the most efficient cation stimulating the enzyme. Optimum K nutrition results in higher concentration of starch in the plant. On the contrary, potassium deficiency changes carbohydrate metabolism, with negative consequences, such as accumulation of soluble carbohydrates and in decrease in starch content (Mengel and Kirkby,

1987).

iv) Translocation

Potassium plays an important role in the transport of assimilates and nutrients. The photosynthates must be transported from the leaves (sources) to the site of their use or storage (sinks). Potassium promotes phloem transport of photosynthates - mainly sucrose and aminoacids - to the physiological sinks (fruits) (Mengel, 1997). K plays a positive role in phloem loading with sucrose, in increasing the transport rate of phloem-sap solutes and in phloem unloading (Herlihy, 1989). The role of K is related to its contribution to the osmotic potential in the sieve tubes and to its function in ATP synthesis which provides the energy for the loading of photosynthates. In plants well supplied with K, the concentration of potassium, the osmotic potential of the phloem sap and the volume flow rate, are all higher than in plants supplied with a lower K level. As a result, sucrose concentration in the phloem sap is increased (Marschner, 1995). Potassium not only promotes the translocation of newly synthesized photosynthates but also has a beneficial effect on the mobilization of stored material (Mengel and Kirkby, 1987). Potassium plays also an important role as counter ion for nitrate transport in the xylem. After nitrate reduction in shoot, charge balance has to be maintained by corresponding net increase in organic acid anions. Part of these organic anions (mainly malate) can be retranslocated with K as the accompanying cation through the phloem to the roots (Marschner, 1995).

v) Potassium and nitrogen interaction

The inorganic nitrogen taken up by the plant as nitrate (NO_3^-) or ammonium (NH_4^+) must be converted into organic N compounds which contain the nitrogen primarily as NH_2 groups. The first products in this conversion process are amino acids of quite simple structure. They are the substrates for the synthesis of the more complicated organic

N compounds, such as nucleic acids or proteins. The conversion of inorganic nitrogen and the synthesis of organic N compounds are both energy-consuming processes. It is of little use for the plant to take up much inorganic N unless this can be converted into amino acids and proteins. A high concentration of ammonia or nitrates in the plant would actually be poisonous. Good K nutrition favours the rapid turnover of inorganic nitrogen into proteins and consequently, potassium improves the effect of nitrogen fertilizer. In fact high rates of N can be utilized by the plant and transformed into high yield only in the presence of high K levels (Murray, 1960 and Hewit and Osborne, 1962).

vi) K and water regime of the plant

Potassium improves Water-Use Efficiency. As mentioned earlier, much K is taken up by the plant. Accumulation of potassium in the cells leads to an increase of their osmotic pressure so that water moved into the cell and this, in turn, increases the turgor pressure of the cell. As turgor is essential for cell expansion, it can be concluded that K is involved in the basic process of cell enlargement. Through its contribution to the osmotic pressure and turgidity of cells K has a dominant role in the opening and closing of the stomata, which regulate the transpiration of water and the penetration of atmospheric carbon dioxide into the leaf. In water stress, plants well supplied with K very quickly close their stomata, thus preventing excessive water loss by the plant. If, on the other hand, the plant obtains sufficient water the stomata open wide and CO₂ assimilation is high. Thus K improved water use efficiency (Amberger, 1968 and Mengel and Forster, 1973). According to recent investigations, the involvement in "osmoregulation" i.e. in the adjustment of plant cells to environmental conditions seems to be one of the most important biophysical roles of potassium. Thus it is plausible that K, in addition to its many

biochemical functions, improves the tolerance of the plant to various stress situations, such as drought, low temperature or salinity.

These multiple functions of K in many metabolic processes lead to numerous positive effects of an adequate K nutrition

- Increases root growth
- Improves drought resistance
- Reduces water loss and wilting
- Enhances winter hardiness
- Improves resistance to pests and diseases
- Builds cellulose and reduces stalk lodging

The specific effects of K on quality improvement are

- Increases protein content of plants
- Increases starch content
- Increases vitamin C and soluble solid content
- Improves fruits colour and flavor
- Improves size of fruits
- Increases peel thickness
- Reduces physiological disorders (creasing and cracking in citrus, blotchy ripening complex in tomato etc.)
- Reduces incidence of pests and diseases
- Enhances storage and shipping quality
- Extends shelf life

Effect of K on fruit yield and quality

Banana

Bunch size of banana was significantly increased by soil application of 480 g K₂O per plant in studies conducted by Chattopadhyay and Bose (1986). Mustaffa (1988) recorded largest bunch size (22.69 kg) on application of 300 g K₂O per plant in Hill banana. In Kerala, when a heavy feeder of K like Amorphophallus was intercropped in banana, it caused poor filling which could be reversed by adequate supply of K. Increasing K levels from 0 to 400 g K₂O per plant in Hill banana (Mustaffa, 1988) increased TSS. Sugar content increased from 11 to 13.1 per cent by soil application of 480 g K₂O per plant to Dwarf Cavendish banana (Chattopadhyay and Bose, 1986). Mustaffa (1988) found increase in acid

content of Hill banana with increasing dose of K from 0 to 250 g K_2O per plant and ascorbic acid from 62.2 to 108.6 mg/100 g pulp by 300 g of K_2O .

Banana dwarf most other crops in terms of potassium uptake. Potassium uptake is 18-30 kg K_2O /t whole bunch (Cavendish type varieties) and up to 60 for other varieties (IFA, 1992). A banana plantation yielding 50 t/ha requires approximately 1625 kg K/ha, being K absorption the largest during bunch growth (Von Uexkll, 1985). Yield and quality are strongly influenced by K nutrition. Potassium improves fruit weight and number of fruits per bunch, and increases the content of total soluble solids, sugars and starch (Bhargava *et al.*, 1993). Low potassium nutrition results in thin and fragile bunches with shorter shelf life (Von Uexkll, 1985). In addition, K stimulates earlier bunch shooting and shortens the number of days to fruit maturity. Potassium has also a significant effect in improving resistance to diseases such as leaf spot and banana wilt (Von Uexkll, 1985).

Citrus

Application of 680 g of K_2O per tree to Coorg mandarin increased TSS from 10.63 to 11.02 per cent, acidity from 1.32 to 1.44 per cent and ascorbic acid from 41.4 to 42.7 mg/100 ml juice (Srivastava and Bopaiah, 1977). Desai *et al.* (1986) recorded significantly larger (165 to 178) fruits in sweet orange trees receiving 400 g K_2O . Randhawa and Srivastava (1986) also reported increased fruits size in Coorg mandarin on K application. Information on the effect of potassium on colour development is inadequate. Experience indicates that inadequacy of potassium leads to premature colour development and poor quality. Excessive application of K causes delayed colour break especially in non-climacteric fruits. Juice content in sweet orange is reported to be influenced by K application. Increases in juice content was observed on soil application of 400 g K_2O per tree per year

(Desai *et al.*, 1986). Foliar spray of 1 per cent KNO_3 increased juice content. TSS of mandarin (Srivastava and Bopaiah, 1977) and sweet orange (Desai *et al.*, 1986) fruits also increased significantly on soil application of K in Coorg mandarin, significant correlation between leaf K and TSS content was observed (Anonymous, 1987) suggesting the usefulness of K application to obtain high TSS.

The degree of granulation, characterised by harder and dry juice sacs, was found to be higher in trees deficient in nutrients including potassium (Munshi *et al.*, 1978), which was due to restricted translocation of photosynthates in granulated fruits. Singh and Singh (1981) found that 3 foliar sprays of 1 per cent KNO_3 reduced granulation to 50 per cent from 74 per cent. Potassium spray also improved pulp, juice, TSS, sugars and ascorbic acid contents in fruits and markedly reduced peel, rag, total acidity and starch contents. Application of K was, therefore, beneficial in reducing granulation in mandarins. Chanana and Nijjar (1984) determined K content in citrus leaves at various stages of development of normal fruits and those showing granulation. Plants having granulated fruits had lower leaf K than those with normal fruits although, the concentrations in both cases were in satisfactory range. It appears that granulation can be avoided by raising leaf K to upper limit (1.7 per cent) of the satisfactory range.

Grapes

Larger grape bunches with big berries of Anab-e-shahi were obtained on application of 1.16 kg K_2O per vine in 2 splits in a year, i.e., at pruning time and 60 days later (Gopalaswamy and Rao, 1972). Under K deficient conditions, firmness of grape berry was found to decrease significantly. On foliar feeding with K_2SO_4 at 1 per cent concentration significantly increased juice content in Perlette grape. Gopalaswamy and Rao (1972) reported higher TSS in Anab-e-Shahi cultivar by single application of 4 kg K_2O per vine in year. Acidity

in Anab-e-Shahi berries increased on application of 2.32 kg K₂O per vine in two splits. Higher sugar/acid ratio was obtained in Anab-e-Shahi grape berries on two split applications of 1.16 kg K₂O per vine as compared to a single application of 2.32 kg K₂O.

Guava

Foliar spray of 1 per cent KNO₃ to Allahabad Safeda guava increased fruit size significantly (Singh *et al.*, 1981). Mitra and Bose (1985) and Mitra (1987) reported higher TSS in Lucknow-49 on application of 160 and 320 g K₂O per plant annually than by no K-application. Foliar spray of 1 per cent K₂SO₄ also increased the TSS which was attributed to higher assimilating power of the leaves over a longer period resulting in increased availability of sugars to fruits (Ahlawat and Yamdagni, 1981). Soil application of 320 g K₂O per plant annually increased total and reducing sugars in Lucknow-49 cultivar (Mitra and Bose, 1985). Mitra (1987) also reported significant increases in sugars on soil application of 260 g K₂O per tree. Foliar sprays of 1 per cent K₂SO₄ at weekly intervals improved the sugar content of guava fruits (Ahlawat and Yamdagni, 1981). In cultivar Lucknow-49, foliar spray of 1 and 2 per cent KaSCU increase total and reducing sugars significantly (Singh and Chauhan, 1982), whereas, 1 per cent KNO₃ increased the sugars in Allahabad Safeda (Singh *et al.*, 1981). Mitra and Bose (1985) and Mitra (1987) observed increases in acidity of Lucknow-49 fruits on application of 130 to 320 g K₂O per tree. Mitra and Bose (1986) and Mitra (1987) recorded higher vitamin C in guava cultivar Lucknow-49 on application of K. Foliar spray of 1 and 2 per cent K₂SO₄ also increased ascorbic acid content from 64 to 72.7 mg per 100 g pulp (Singh *et al.*, 1981).

Mango

Singh (1967) observed that 73 : 18 : 68 g of N, P and K per tree per year was

essential for photosynthesis which in turn increased the fruit yield. In cultivar Langra, the fruit remains green even on full maturity and thus size is the only important parameter to determine its quality which is greatly affected by K fertilization. Application of both organic manure and mixture of N,P and K fertilizers enhanced the fruit weight of Dashehari mango (Singh *et al.*, 1984). Foliar spray of 1, 2 and 3 per cent each of N,P and K on Dashehari cultivar improved fruit size by 18 per cent and increased TSS from 16.5 to 17.9 per cent, sugars from 11.3 to 14.7 per cent and acidity from 0.126 to 0.142 per cent in Banarasi Langra. Foliar sprays of KNO₃ (0, 1, 2, 3 and 4 per cent) + NaH₂-PO₄ (0, 0.2, 0.4, 0.6, 0.8, and 1 per cent) increased fruit size from 231.8 to 322.9 g, TSS from 18.5 to 20 per cent, sugars from 14.5 to 15.5 per cent and ascorbic acid from 75.5 to 82 mg per 100 g pulp. Increase in reducing sugars and reduction in acidity were also recorded (Singh and Tripathi, 1978). Experienced, in Ratnagiri district of Maharashtra in soils poor in K (due to high rainfall, 5000 mm per year) clearly brought out the fact that to obtain quality fruits with attractive colour, potassium application is must. In Dashehari mango, application of 100:200:200 of N, P, K per tree per year recorded higher dry matter content and fruit yield (Malhi and Nijjar, 1985). A dose of 1.5 kg of N and K each per tree promoted fruiting and TSS (Abd-EL-AL *et al.*, 1994).

Papaya

Jauhari and Singh (1971) obtained higher TSS on application of K to Coorg Honey Dew papaya. Potassium is known to help in sugar translocation in plants and thus its application increased TSS content (10.1° Brix) in the papaya pulp.

Apple

Potassium application at 1050 g K₂O/tree to Golden Delicious apple increased total soluble solids from 13 to 13.5 per cent (Awasthi and Karkara, 1979). Nutrient

disorders have been found to be one of the important causes of corking and bitter pit in apple. These disorders are caused by calcium and boron deficiency. Hence adequate K favours the uptake of all other elements especially Ca and B in balanced proportion from soil. Further, sufficient K application results in accumulation of high amounts of TSS and sugars. Thus K plays a major role in ameliorating these nutrient disorders.

Peach

Potassium increased total soluble solids and acidity in peach fruits on application of 200 and 400 g K₂O per tree (Yamdagni and Jindal, 1978).

Pomegranate and Strawberry

Investigations carried out by Sen and Chauhan (1983) showed that application of K increased the TSS : acid ratio in pomegranate fruits. Combined application of N (625 g per plant) and K (250g per plant) in Jyothi pomegranate improved the fruit weight and yield (Padmavathamma *et al.*, 1999). Pathak and Pundir (1981) recommended application of N, P and K at 240, 160 and 60 kg per ha for a 12 years old orchard. In a 3 years old plantation, 200, 120 and 60 Kg of N, P and K gave the best results for fruit yield and quality (Pareek, 1981). Application of 175 kg K₂O/ha increased the TSS in strawberry fruits (Singh and Singh, 1979).

FERTILIZER MANAGEMENT

Time of application

Limited information is available regarding the time of application of potassium fertilizers. Potassium is mobile and has high demand during fruit development. It, thus, required judicious application. Studies conducted by Singh *et al.* (1990) on Dwarf Cavendish banana demonstrated that the application of potassium during shooting stage increased fruit weight. Similar results were obtained by Ramesh Kumar (2005) in Robusta banana.

Source of potassium

The consumption of N, P₂O₅ and K₂O fertilizers in India reached 9.07 million tonnes during 1987-88 which, on an average, come to 50 kg nutrients/hectare. A 40 tonne crop of banana removes 100 kg K₂O (Tandon, 1987) but many growers apply little or no K to banana which has resulted in widespread K deficiency. In grapes, application of heavy doses of K induced magnesium deficiency (Bhargava and Wasnik, 1989). There are two major potash fertilizers, potassium chloride or muriate of potash (MOP) and potassium sulphate or sulphate of potash (SOP). Each has a characteristic composition (Table 1) and must be considered to suit a crop. Crops sensitive to chloride toxicity, potassium sulphate is preferred (Anonymous, 1981; Bhandari *et al.*, 1987 and Ramesh Kumar, 2005).

Being less expensive, potassium chloride accounts for 99 per cent of the potash used compared to just 1 per cent of potassium sulphate (Tandon, 1987). If on adverse effects are observed on fruit yield, quality and soil health. MOP will obviously be preferred. However, production of good quality fruits is invariably better by potassium sulphate than by potassium chloride (Tandon, 1987), particularly in case of intensively fertilized grapes (Anonymous, 1989).

Under conditions of low rainfall and high evaporative demand, salt build up takes place and use of chloride containing fertilizers may cause widespread chloride toxicity (Anonymous, 1981). In grapes, it reduced sugars and shelf life of berries and deteriorate their colour and taste when K was supplied in higher doses (more than a kg per vine) (Chadha, 1984). In pineapple also, SOP is superior to MOP with regard to fruit size and TSS.

Table 1. Composition of potassium fertilizers

Component	Potassium chloride (KCl) or muriate of potash	Potassium sulphate (K_2SO_4) or sulphate of potash
K_2O (%)	60	50
S (%)	Nil	18
Chloride (%)	47	-
Salt index	120	45

REFERENCES

- Abd. EL.AL, A.A. *et al.* (1994). *Ann. Agric. Sci.*, **32**: 2029-2038.
- Ahlawat, V.P. and Yamdagni, R. (1981). *Agric. Sci. Digest.*, **1**: 213-14.
- Amberger, A. (1968). *Pot. Rev. Subj.* 327th suite: 1-5.
- Anonymous (1981). Annual Report. Indian Institute of Horticultural Research, Hessaraghatta, Bangalore, pp. 1-220.
- Anonymous (1989). Annual Report. Indian Institute of Horticultural Research, Hessaraghatta, Bangalore, pp. 1-105.
- Anonymous (1987). Annual Report. All India Co-ordinated Research Project on Tropical Fruits, IHR, Bangalore, pp. 1-224.
- Awasthi, R.P. and Karkara, B.K. (1979). *India J. Hort.*, **36**: 413-18.
- Bhandari, D.K. *et al.* (1987). *Farmer Parliament*, **22**: 11-12.
- Bhargava, B.S. and Wasnik, H.M. (1989). *Indian Grape J.*, **3(5)**: 62-66.
- Bhargava, B.S. *et al.* (1993). In: *Advances in Horticulture, Vol. 2 Fruit Crops: Part 2.* (Chadha, K.L. and Pareek, O.P. eds.). Malhotra Publishing House, New Delhi, pp. 947-960.
- Chadha, K.L. (1984). *Indian J. Hort.*, **41**: 145-59.
- Chanana, Y.R. and Nijjar, G.S. (1984). *Indian J. Hort.*, **41**: 240-43.
- Chattopadhyay, P.K. and Bose, T.K. (1986). *Indian Agric.*, **30**: 213-22.
- Desai, U.T. *et al.* (1986). *J. Maharashtra Agric. Univ.*, **11**: 145-47.
- Gopalaswamy, N. and Rao, V.N.M. (1972). *South Indian Hort.*, **20**: 41-49.
- Herlihy, M. (1989). In: *Methods of K Research in Plants. Proceedings of the 21st Colloquium of the International Potash Institute held at Louvain-la-Neuve, Belgium, 19-21 June 1989*, IPI, Bern, Switzerland, pp. 259-270.
- Hewitt, C.W. and Osborne, R.E. (1962). *Emp. J. Exp. Agric.*, **30**: 249-256.
- Jauhari, O.S. and Singh, D.V. (1971). *Prog. Hort.*, **2**: 81-89.
- Malhi, C.S. and Nijjar, G.S. (1985). *Int. Symp. on mango, India, Abst. No. 4*, pp. 29.
- Marschner, H. (1995). *Mineral Nutrition of Higher Plants*. 2nd Ed. Academic Press, London.
- Mengel, K. (1997). In: *Food Security in the WANA region, the essential need for balanced fertilization* (Johnston, A.E. ed.). Proceedings of the Regional Workshop of the International Potash Institute held at Bornova, Izmir, Turkey, 26-30 May 1997, IPI, Bern, Switzerland, pp. 157-174.
- Mengel, K. and Forster, H. (1973). *Pflanzenenerhr Bodenkunde.*, **134**: 148-156.
- Mengel, K. and Kirkby, E.A. (1987). *Principles of Plant Nutrition*. 4th Edition. International Potash Institute, IPI, Bern, Switzerland, pp. 685.
- Mitra, S.K. and Bose, T.K. (1985). *South Indian Hort.*, **33**: 286-92.
- Mitra, S.K. (1987). *J. Potassium Res.*, **3**: 160-63.
- Munshi, S.K. *et al.* (1978). *Indian J. Hort.*, **35**: 85-90.
- Murray, D.B. (1960). *Trop. Agric. Trin.*, **37**: 97-106.
- Mustaffa, M.M. (1988). *J. Potassium Res.*, **4**: 75-80.
- Padmavathamma, A.S. *et al.* (1999). *Karnataka J. Agric. Sci.*, **11**: 1126-1128.
- Pareek, O.P. (1981). Project. Rep. Proc. 1st Natl. workshop on Arid zone fruits research, HAU, Hisar.
- Pathak, S.P. and Pundir, J.P.S. (1981). *Udyanika*, **4**: 7-11.
- Pfluger, R. and Mengel, K. (1972). *Plant and Soil*, **36**: 417-425.
- Ramesh Kumar, A. (2005). Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore-641 003, TN, India.
- Randhawa, G.S. and Srivastava, K.C. (1986). *Citriculture in India*. Hindustan Publishing Co., India, pp. 128-87.
- Sen, N.L. and Chauhan, K.S. (1983). *Punjab Hort. J.*, **23**: 59-63.
- Singh, H. and Singh, R. (1981). *Scientia Hort.*, **14**: 235-44.
- Singh, H. and Singh, R. (1979). *Punjab Hort. J.*, **19**: 71-73.
- Singh, H.P. *et al.* (1990). *J. Potassium Res.*, **47**: 133-39.
- Singh, K. and Chauhan, K.S. (1982). *HAU J. Res.*, **12**: 649-54.

- Singh, K.I. (1984). *Prog. Hort.*, **16**: 120-23.
- Singh, K.K. (1967). *The mango: A Handbook*, ICAR, New Delhi, pp. 70-78.
- Singh, T.P. et al. (1979). *HAU J. Res.*, **9**: 235-240.
- Singh, U.R. and Tripathi, J.S. (1978). *Punjab Hort. J.*, **18**: 39-40.
- Smid, A.E. and Peaslee, D.E. (1976). *Agron. J.*, **68**: 904-908.
- Srivastava, K.C. and Bopaiah, M.G. (1977). *Proc. Inter. Citrus. Symp.*, **1**: 29-34.
- Tandon, H.L.S. (1987). *Fertilizer Recommendations for Horticultural Crops. A Guide Book*. Fert. Dev. Consult. Org, New Delhi, pp: 1-112.
- Usherwood, N.R. (1985). In: *Potassium in Agriculture*. (Munson, R.S. ed.). ASA-CSSA-SSSA, Madison, WI, pp. 489-513.
- Von Uexkll, H.R. (1985). In: *Potassium in Agriculture*. (Munson, R.S. ed.). ASA-CSSA-SSSA, Madison, WI, pp. 929-954.
- Wallingford, W. (1980). In: *Potassium for Agriculture*. Potash and Phosphate Institute, Atlanta, GA, pp. 10-27.
- Yamdagni, R. and Jindal, P.C. (1978). *Prog. Hort.*, **10**: 41-44.