Role of Potassium Nutrition in Improving Yield and Quality of Spice Crops in India

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Abstract

Investigations carried out on potassium nutrition in improving yield and quality of spices during the last two decades at IISR on eleven important spice crops, grown in major soils viz., red and laterite, forests, alluvial and black soils under different agro-climate regions of India are discussed. Soil fertility survey carried out in major black pepper growing tracts of Kerala, Karnataka and Tamilnadu in 300 locations showed that the soils are acidic, intensively leached, deficient in soil available K, besides P, Ca, Mg and Zn. The Kaolinite is the predominant clay mineral derived from weathering of schist and granite. An intensive garden to garden survey carried out in 102 locations in one of the major black pepper growing tracts in Kerala (Calicut district) showed that 27% sample are low in available K status, 55% medium and 18% high. Field experiments on the nutritional requirement of hybrid black pepper Panniyur-1 in an ultisoil, poor in major nutrients, showed that application of 270 g K_2O vine^{-1} year^{-1} besides 140 g nitrogen, 55 g P_2O_5 were optimum in increasing availability of nutrients in the soil, yield response and quality. Investigations on nutrient requirements of bush black pepper showed that bi-monthly application of NPK @ 1, 0.5, 2.0 g per pot (10 kg soil) is optimum. Potash requirement of bush black pepper grown in field, is 20 g K_2O per bush. Studies on the source of potassium for pepper showed that K_2SO_4 is a better source than KCl and KNO_3 in optimizing yield and quality. Soil fertility evaluation survey in small cardamom growing tracts of South India revealed that available K status is often low to medium. Investigations on different categories of K in cardamom growing soils showed that exchangeable K is correlated with HNO_3 extractable K, NaOAc extractable K and K index, r values being 0.65*, 0.67** and 0.94** respectively. It was further found that cardamom yield is related to potassium buffer power also. Investigations on nutrient requirements showed that, in cardamom grown in trench systems of high density planting, application of 240 kg K_2O ha^{-1} year^{-1} resulted in maximum productivity. Studies on sustained nutritional requirement for ginger showed that 50 kg K_2O ha^{-1} besides 20 tonnes of FYM as basal, 25 tonnes green leaf mulch together with N at 75 kg ha^{-1}, P_2O_5 at 50 kg ha^{-1} were optimum. Investigations on the nutritional requirement of turmeric showed that application of 120 kg K_2O with 20 tonnes FYM and 25 tonnes green leaves ha^{-1} year –1, besides N and

P were optimum for rhizome yield and curcumin production. Potassium requirement of tree spices viz. clove (210 kg), nutmeg (125 kg) and cinnamon (200 kg) (K_2O) per adult tree ha^{-1} respectively were optimum for sustained productivity. Field experiments proved for optimum productivity of seed spices, potassium application @ 20 kg ha^{-1} was optimum for coriander, fennel and fenugreek respectively. The K requirement of cumin is 50 kg K_2O ha^{-1}. These investigations proved the importance of K in augmenting yield and quality of spices for economical return to the farmers.

Introduction

India, the "land of spices" is the world's largest producer, consumer and exporter of spices. India produces annually 2.9 million tonnes of spices from 2.5million ha valued US $ 5582 million. In 1999-2000, India exported 2.1 lakh tonnes of spices valued US $ 404.5 million (Rs. 1861 crores) (**Table 1**). Export is only around 7% of the total spices production in India. To meet the internal consumption and international export demand, an annual growth rate of eight to ten per cent is envisaged in different spices. To achieve the target, productivity of spices has to be stepped up. One of the critical components in augmenting production is balanced nutrition, and among the nutrients,

Table 1. Area, production and Productivity of spices in India*

Crop	*Area ('000 ha)*	*Production ('000 t)*	*Productivity (kg ha^{-1})*
Pepper	238.32	65.99	276.90
Cardamom (Small)	84.91	8.79	103.52
Cardamom (Large)	26.36	5.27	109.92
Chilies	892.20	921.30	1032.62
Ginger	77.61	263.17	3391.00
Turmeric	155.80	598.40	3840.82
Clove	2.36	2.46	1024.37
Nutmeg	4.78	1.42	297.07
Cinnamon	0.45	0.23	230.00
Coriander	546.50	290.00	530.65
Cumin	288.53	116.27	402.97
Celery	2.94	3.57	1214.29
Fennel	27.44	36.90	1344.75
Fenugreek	38.49	49.97	1298.26
Garlic	114.40	517.70	4525.35
Saffron	5.71	0.016	2.80
Total	2506.68	2881.46	

*(1998-99)

potassium is one of the elements contributing to production and quality of spices.

Annual consumption of K in India is around 4.1 million tonnes (FAI, 2000). The total spices cultivated area in India is 2.5 million hectares. Assuming that at least 25 per cent of spices growing area consume at least 50 per cent of the recommended level of potassium, the rough estimate of the consumption of K by spice crops in India would be around 0.4 million tonnes annually, that signifies the quantum of K used by spice crops.

Sources of potassium in Spices growing soils

Sources of potassium in spices through soils are K Feldspars ($KAlSi_3O_8$), Muscovite [$KAl_3Si_3O_{10}(OH)_2$], Biotite [$K(Mg,Fe)_{3,}AlSi_3O_{10}(OH)_2$], phologopite [$KMg_2A_{l2}Si_3O_{10}(OH)_2$], Clay minerals and organic matter. Major sources of potassium fertilizers are Potassium chloride (60-62% K_2O), Potassium sulphate (50-53%K_2O), Potassium nitrate (44-46%K_2O) Potassium magnesium sulphate (22%K_2O). Of these, potassium chloride (Muriate of potash) accounts for 98%of all potassium used for spice crops. Among the sources of potassium, potassium sulphate is the best source in contributing yield and quality of black pepper (Sadanandan and Hamza, 1996c). Indigenous sources such as crop residues, farmyard manure (FYM), organic cakes, organic manures, wood ash etc., are also utilized as potassium sources from time immemorial (**Table 2**).

Potassium status of major spice growing soils

Spices are grown in India in a variety of soils. Majority of these spices growing soils are Alfisols, laterite, gravelly sandy clay loams to sandy loam. Black pepper is cultivated in 2.38 lakh ha. Soils are mainly lateritic (Alfisols), red loam (Oxisols), forest loam (Mollisols) and alluvium (Entisols). These soils are acidic, low in CEC and K, but high in Fe and Al status. The soil fertility survey carried out in major black pepper growing states of South India in 300 locations showed that the soils are intensively leached (2000-4000mm rain in 120-140 rainy days year^{-1}), acidic, deficient in K, Ca, Mg and Zn. The kaolinite is the predominant clay mineral and exchangeable K is low to medium. In another survey carried out in coconut-black pepper mixed cropping system consisting 102 locations in Kerala (Calicut district) showed that 27% samples are low, 55% medium and 18% high in exchangeable K status.

Table 2. Different sources of K containing inorganic and organic fertilizer with their composition used in growing spices

Sources	*Average composition (%)*		
	N	P_2O_5	K_2O
Manures			
Farm Yard Manure	0.4	0.3	0.3
Goat Manure	3.5	2.0	0.4
Poultry Manure	1.0	3.8	1.0
Pig Manure	3.1	3.2	0.5
Leaf litters (Mixed)	2.0	0.5	2.4
Wood ash	0.2	2.1	7.2
Coconut coir dust	1.2	0.05	2.0
Oil Cakes			
Neemcake	3.0	0.7	1.6
Cotton cake	3.3	1.9	1.6
Brassica cake	2.2	1.2	1.8
Groundnut cake	7.0	1.6	1.6
Gingily cake	5.2	2.1	1.3
Inorganic Fertilizers			
Muriate of Potash			60
Sulphate of Potash			50
Nitrate of Potash	13		44
Potassium Magnesium Sulphate			22
Potassium Orthophosphate		30-50	30-50
Potassium Polyphosphate		40-60	22-48
Potassium Calcium Pyrophosphate		39-54	25-26
Potassium Metaphosphate		55-57	38

Cardamom (small) is grown in around 85 thousand ha. The soil fertility survey in potential cardamom growing tracts in Idukki (Kerala) and Coorg (Karnataka) showed that major soils are Mollisols followed by Alfisols, derived mainly from schists, and granites and are clay loam to sandy clay loam in texture, acidic, with 33% of samples low in K, while 28% medium and 39%high. The soils are very much leached (3000-4000mm rain received in 120-130 days year^{-1}). The clay fraction is predominantly kaolinite and there is very little fixation of K. The soils are low in base exchange capacity and exchangeable K. The soils have high organic matter status which are derived from forest litters and organic matter applied, helped in the retention of soil moisture.

Ginger and turmeric are grown in around 2.33 lakh ha. The survey conducted in major turmeric growing tracts showed that soils are basic in character and medium to high in K status. Soil survey of major ginger growing tracts showed that the soils are acidic in reaction and low to medium in available K status.

The tree spices (Clove, Nutmeg and Cinnamon) are cultivated in around 7,500 ha in South India that are red and laterite soils and are poor to medium in K status. The seed spices (coriander, cumin, fennel, fenugreek and celery) are cultivated in around nine lakh ha, mostly in alluvium that is alkaline in reaction, generally high in CEC, poor in organic matter, medium to high in K and low in micronutrient's status.

The major spices growing soils of South India receive high rainfall. Considerable loss of potassium from soils due to leaching occurs. Hence split application of K fertilizer adjusted to the crop demand and weather conditions are some of the useful measures recommended to improve efficiency of K fertilizers. The spice growing areas in North India receive relatively less rainfall. K application is recommended at a subdued level.

Significance of potassium in Spice Crops

Studies conducted on K nutrition of spices showed that potassium is the second most important nutrient element next to Nitrogen for growth and development of spice crops (Sadanandan *et. al.*, 1998). The growing parts of spice plants contain more K than any other parts. Nutrient removal studies showed that K is the nutrient element largely removed by the spices (**Table 3**). Potassium is necessary in young growing tissues for cell elongation and possibly for cell division. Potassium is very mobile in plants and therefore circulates freely and has vital role in maintenance of turgor pressure. It also helps in several physiological processes and uptake of other nutrient elements. It improves quality and yield of spices (Sadanandan, 1993). Earlier worker report similar results in other crops (Mengel, 1978). Potassium is known to play a vital role in photosynthesis and carbohydrate formation in spices. It has also been shown that K plays a key role in the activation of more than 60 enzyme systems in plants. Contrast to other elements that are involved in the formation of cell structure, K functions in the cell sap. The high mobility of K permits it to move quickly from cell to cell or from older parts to newly developed tissues and storage organs (Sadanandan and Hamza, unpublished), Inadequate K to meet the needs of different plant parts, diminishes growth and subjects the crops to undesirable traits such as increased disease and make susceptible to diseases (Sadanandan *et al.*, 1993a). It has also a role in

Table 3. NPK recommendation and removal by different spice crops (kg ha^{-1} year^{-1})

	Recommendations								Average	Nutrient removal by product		
	Organic		Inorganic			Total			***			
	FYM	Mulch**	N	P	K	N	P	K	Yield	N	P	K
Black pepper	10000	2000	140	55	270	240	105	360	2000	46	10	63
Cardamom	10000	2000	75	75	150	175	125	240	450	8	2	19
Ginger	20000	5000	75	50	50	295	155	255	3800	59	24	111
Turmeric	20000	5000	60	50	120	280	155	325	4700	86	31	194
Clove	2500	1000	85	70	210	120	245	245	900	10	3	8
Nutmeg	2500	1000	60	30	125	95	45	160	750	8	2	4
Cinnamon	1000	500	200	180	200	216	187	217	460	3	1	4
Coriander	1500		20	40	20	29	46	26	476	9	3	9
Cumin	2000		25	20	20	37	28	28	578	19	5	3
Fennel	2000		60	40	20	72	48	28	1300	32	13	18
Fenugreek	2000		25	25	50	40	35	60	1000	35	18	14

*6:4:4 kg NPK/tonne of FYM** 20:5:25 kg NPK/tonne of Mulch (dry)
***For pepper, cardamom, ginger and turmeric, Research Station yield, and for others, National average yield

stomatal respiration, photosynthetic transfer, crop development etc. Studies on the removal of various nutrients during harvest of spice crops showed that all the spice crops remove more amount of K than any other elements (**Table 3**). The magnitude of K by pepper vine and the potash recommendation for the black pepper followed in Malaysia and in India are given in **Table 4**. Investigations on the ratio of elements absorbed in cardamom revealed that the ratio of uptake of nutrients are of the order-N, P, K, Ca, Mg as 8:1:12:3:0.6 (Korikanthimath, 1994)

Among the spices, maximum K removal is by turmeric followed by ginger and pepper (**Table 3**). Sadanandan (1993) reported that K from older leaves are re-distributed to the younger growing tissues, resulting in deficiency symptoms in the older leaves, and K deficiency leads to drastic reduction in crop growth. Further studies using quartz sand with Hoagland solution devoid of K, conducted with different spice crops (pepper, ginger, turmeric, clove and nutmeg) showed that K from the older leaves move to new leaves and hence the characteristic symptoms of chlorosis and burnt appearance of margin of leaves first appear in older leaves and then spread to younger leaves (**Table 8**) (Sadanandan and Hamza, unpublished).

The potassium requirements of spices vary from different spice varieties

Table 4. NPK Utilization by black pepper and fertilizer recommendations**

Sl. No.	*Author/year*	*Country*	*Nutrients removed (kg ha^{-1})*	*Dose recommended (kg ha^{-1} year^{-1})*
1	Waard and Sutton, 1960	Malaysia (Sarawak)	cv. Kuching N 252, P_2O_5 32, K_2O 224	N:P_2O_5:K_2O:MgO 240:120:340:100 and 28g trace elements
2	Sim, 1971	Sarawak	N 233, P_2O_5 39, K_2O 207	
3	Raj, 1972	Sarawak	-	N 340 g (Urea)*, P 113 g (S. Super)*, 454 g (MOP)
4	Azmil and Yau, 1993	Malaysia (Johore)	cv. Kuching	N 250, P_2O_5 100, K_2O 250 (+ 400 gm magnesium lime stone/vine)
5	Pillai and Sasikumaran, 1976	India	Var. Panniyur-1 N 34, P_2O_5 3.5, K_2O 32* (vine^{-1})	N 100, P_2O_5 40, K_2O 140
6	Pillai *et al* 1987	India	N 34, P_2O_5 3.5, K_2O 32* (vine^{-1})	N 50, P_2O_5 50, K_2O 200
7	Sadanandan, 1993	India	N 137, P_2O_5 61, K_2O 330	N140, P_2O_5 55, K_2O 270

*Vine
**Sadanandan, 2000

and locations to locations. Studies showed that it depends on the K status and dynamics of K in the soil, rooting pattern of spice varieties and their productivity. Since K is indispensable for biochemical and biophysical reactions in the tissues, potassium should be supplied and maintained at optimum rates for augmenting production and quality up gradation of spices.

Factors affecting K availability in spice growing soils

Studies on the major soil factors affecting K availability to spice crops showed that, they are soil pH, kind of clay minerals, Cation Exchange Capacity (CEC), amount of exchangeable K, capacity to fix soils K, soil moisture, soil aeration, soil temperature, calcium and magnesium status of soil, relative amount of other nutrient elements, rooting depth of spice plants etc. Studies conducted at IISR showed that split application of K, application of FYM, green leaf etc. increase the K availability in soil, uptake of K and enhance the quality of spices (**Table 5**) (Sadanandan and Hamza, 1998).

Soil testing of K for judicious fertilization

The exchangeable and soil solution potassium are the readily available source and they are usually extracted and measured in soil testing laboratories (Sadanandan *et al.*, 1993). Studies on different categories of K in major cardamom growing soils viz., Idukki district of Kerala and Coorg district of Karnataka, showed that exchangeable K is positively correlated with cardamom yield (r = 0.47**) and which again correlated with HNO_3 extractable K (r = 0.65**), NaOAc extractable K (r = 0.67**) and K index (r = 0.94**) (**Table 6**). This highlights the significance of exchangeable and non-exchangeable K in the mineral nutrition of cardamom crop (Sadanandan *et. al.* 1993a). Srinivasa Rao *et al* (2001) highlighted the significance of non-exchangeable K in crop nutrition. From this, the significance of exchangeable and non-exchangeable K is understood. Soil testing gives directions about fertility levels of soil, which aid for balanced use of fertilizers for sustainable spices production. Application of K fertilizers based on soil test for augmenting production is relevant particularly at context of increased cost of the fertilizers by three folds since 1993. In experiments conducted in farmer's field by adopting integrated nutrient management, it was found that exchangeable K in soil was increased 76% due to integrated nutrient management in which K fertilizer application was one of the components compared to farmer's practice. Using the data collected in the above survey, a study was also conducted on relationship between K buffer power of soil and cardamom yield. It was found that cardamom yield showed a two-fold increase in Coorg soils as compared to Idukki soils. The key to this difference lies in

Table 5. Effect of NPK fertilization on soil available K, tissue K, yield and quality of spices

Crop	*Check/ Fertilizer**	*Soil K (mg kg^{-1})*	*Leaf K (%)*	*Produce K (%)*	*Yield (kg ha^{-1})*	*Production of oleoresin/ curcumin*** (kg ha^{-1})*
Pepper	Check	71	2.1	0.65	837	76
	Fert.	125	2.6	1.80	3,268	307
Bush pepper	Check	101	2.1	0.54	54**	7**
	Fert.	193	3.0	1.82	182**	23**
Cardamom	Check	54	1.3	1.7	200	14
	Fert.	195	2.0	2.4	368	26
Ginger	Check	58	2.0	1.6	2,400	180
	Fert.	80	3.2	3.3	4,200	260
Turmeric	Check	97	3.1	2.9	2,891	165
	Fert.	146	3.4	3.4	5,024	271

*Recommended dose of fertilizers; **g pot^{-1}; ***for turmeric

Table 6. Correlation coefficient (r) among forms of K in soil and leaf content and yield of cardamom in major soils of Coorg and Idukki

Ke	*Ke*	*Kne*	*K (HNO_3)*	*K (NaOAc)*	*Ke/Ca+Mg*	*L-K*
Kne	N.S.					
K (HNO_3)	0.65**	0.86**				
K (NaOAc)	0.65**	0.59**	0.79**			
Ke/Ca+Mg	0.94**	N.S.	0.56**	0.67**		
L-K	N.S.	0.20*	N.S.	N.S.	N.S.	
Yield	0.47**	N.S.	0.22*	0.27*	0.46*	0.23*

Ke – Exchangeable K, Kne – Non-exchangeable K, L-K – Leaf K

their widely varying K buffer power and not the routine soil test K data. Both NH_4OAc extractable and HNO_3 extractable K were much less in Coorg soils when compared to Idukki soils. But Coorg soils showed almost a two-fold increase in their K buffer power as compared to Idukki soils. On the basis of the original K buffer power concept put forth by Mengel and Kirkby (1982), this in effect, would mean that for an identical quantity of K removed from both soils, a similar decrease in K quantity (as represented by HNO_3 extraction in this investigation results) but the consequent reduction in K intensity (as represented by NH_4OAc extractions in this investigation) in Coorg soils would only be half as compared to the Idukki soils, implying that depletion of K in the latter will be at a much faster rate as compared to the former. It is this inherent difference, which results in the Coorg soils sustaining the cardamom yield at a much higher level. This finding, additionally, supports the contention that sound K fertilizer recommendation for cardamom will need to be based on the soil's K buffer power and not exclusively on routine soil test K data (Prabhakaran Nair *et al.,* 1996).

Response of spices to Potassium application

Studies conducted so far showed that the response of spice crops to K fertilizer application depends on several factors like the inherent soil K status, the dynamics of the soil to meet the K requirement, age, growth and yield of crops. Continuous availability of either soil K and/or applied fertilizer K to the plant depends on physical and chemical characteristics of the soil (Schreoder 1974, Van Digest 1978). The typical behaviour of K in soil can be described as non-exchangeable K, exchangeable K, soil solution K and plant K. The exchangeable and soil solution K forms, are readily available to crop (Sadanandan *et al.*, 1993) and they are the one usually extracted and measured in most soil testing procedures as available soil K. Capacity of a soil to supply

K to a crop above an estimated period of time is fundamentally based on K content and the rate of K released by primary minerals and the nature or type and quantity of clay minerals present in the soil. Investigations on nutrient content in different parts such as leaf, stem, root and produce of major spices showed that K content is the highest in all the spices. This evidently shows that K needs of spices are higher than any other elements (**Table 7**).

In addition, mobility of soil solution K to the root zone by mass flow/ diffusion in keeping with crop requirements in different seasons is one of the most important single factors in K nutrition, especially at high yield levels. Sadanandan (1994) reported that the key to devising K fertilizer schedule should be precisely quantification of the "K buffer power" of the soil in which the plant grows. Prabhakaran Nair *et al* (1996) suggested that for those nutrients which are principally absorbed by the plant through diffusion

Table 7. Potassium content of different parts of spice crops

Crop	*K concentration (g 100^{-1}g)*			
	Leaf	*Stem*	*Root*	*Produce*
Pepper	2.6	1.4	2.3	1.80
Cardamom	2.5	3.5	1.7	2.40
Ginger	3.2	2.7	4.1	3.30
Turmeric	3.4	3.2	4.1	3.40
Clove	1.8	1.3	1.0	0.85
Nutmeg	1.6	1.2	0.9	0.40
Cinnamon	1.4	1.2	1.0	0.95

Table 8. Potassium deficiency symptoms, K concentration and indicator leaf* for analysis

Crop	*Deficiency symptoms*	*K Concentration*
Pepper	Necrosis of the older leaves that spread towards leaf margin, delay flowering	1.10
Ginger	Necrosis and burnt appearance starting from leaf tip and spread towards leaf margin	1.00
Turmeric	Chlorotic lesion and drying of leaf tips	1.50
Cardamom	Marginal chlorosis and drying of leaf tips of older leaves	1.00
Nutmeg	Chlorotic margin followed by tip drying of older leaves	0.88
Clove	Tip drying of the older leaves	0.83

*Pepper – Youngest matured leaf (YML) of fruiting laterals from middle 1/3 portion of vine at the crop harvest
*Cardamom-Fifth pair of leaf from panicle bearing tillers during April
*Ginger- Fourth pair of leaf at 90 DAP
*Turmeric – Third pair of leaf at 90 DAP
*Clove/ Nutmeg/ Cinnamon -YML from fruiting branch during March-April

process, the soil buffer power for the nutrient might provide the most accurate clue to plant uptake and help determining precise fertilizer requirements. He further stressed that soil buffer will have a great impact on the replenishment rate in the zones of K depletion nearest to the plant root and consequently on the mean K concentration at the root surface itself.

Crop response studies to K fertilization in different spice crops showed that among the three major nutrients, K requirement is the highest (**Table 9**). It is evident that in all the spice crops, the uptake of K is the highest compared to the any other nutrients. From the table, it can be seen that annually 63, 19, 194, 111, 8, 4, 4,9,3,18 kg ha^{-1} potassium are removed by produce of spice crops viz., black pepper, cardamom, turmeric, ginger, clove, nutmeg, cinnamon, coriander, cumin, fennel and fenugreek respectively through harvested produce.

Nutrient partition studies in different parts of four-year-old pepper vine varieties viz., Karimunda and Panniyur-1 (**Table 9**), showed that in all the parts (stem, leaf root and berry) K content is the highest. It is evident from the above that in order to get sustained growth and yield of spices, K removed annually, should be replenished. In crop response studies (Sadanandan 1993) by fitting response function of hybrid Panniyur-1 pepper variety 270 kg K_2O ha^{-1} was found optimum while in cardamom under high density planting in trench system 150 kg K_2O ha^{-1} $year^{-1}$ was found the best (Korikanthimath 1994). The fertilizer management for sustainable ginger production in Kerala is NPK @ 75:50:50 kg ha^{-1}. In Bihar, recommendation is 100 kg K_2O together with 150 kg N and 50 kg P. Potassium recommendation to improved turmeric varieties is of the order of 100-120 kg K_2O ha^{-1}. And for tree spices potassium requirements are: clove (210 kg) nutmeg (125 kg) and cinnamon (200 kg) K_2O per adult tree ha^{-1}. Critical levels of K and response of major spices to K application are discussed below.

Table 9. Nutrient removal by an adult black pepper vine (kg ha^{-1})*

Variety/Parts	*Panniyur-1*				*Karimunda*			
	Dry matter	*N*	*P*	*K*	*Dry matter*	*N*	*P*	*K*
Stem	6.0	43.8	13.7	100.8	4.4	35.6	8.1	68.6
Leaf	6.0	151.8	28.9	195.6	5.8	98.6	30.5	221.3
Root	2.5	72.3	9.2	76.0	2.2	26.4	5.5	55.4
Berry	1.0	24.2	4.6	32.3	1.0	22.0	5.0	30.2
Total	15.5	292	56	405	13.4	183	49	376

*Sadanandan, 2000

a) Pepper *(Piper nigrum* L)

Integrated nutrient and disease management studies in a mixed cropping system with black pepper conducted in the farmer's fields for four years showed that application of FYM, Neem cake and bone meal @ 5, 1 and half kg vine^{-1} year^{-1} together with NPK fertilizer at a subdued level of 100, 40, 140 g vine^{-1} year^{-1} increased soil available K status by 45%, leaf K status by 13% and pepper yield by 172% (Sadanandan *et. al.* 1993b). For pepper, Pillai *et al* (1987) reported that 200 g K_2O vine^{-1} as optimum whereas Sadanandan, (2000) reported upto 270 g K_2O vine^{-1} as optimum dose by studying response function. Waard (1969) reported critical level of K up to 2% in pepper leaf. For bush pepper growing in pots, application of NPK @ 1, 0.5, 2g pot^{-1} (10 kg soil) was optimum. Further K_2SO_4 was a better source than KNO_3, KCl and wood ash for bush pepper (Sadanandan and Hamza, unpublished). Leaf nutrient norms for black pepper using Diagnostic Recommendation Integration System (DRIS) Sadanandan *et al* (1996) reported that in pepper leaves potassium concentration of 0.33% is deficient. 0.33-1.17 % as low. 1.18 to 2.84 % as optimum, 2.85 to 3.68% as high and more than 3.68% as excessive level.

b) Cardamom *(Elettaria cardamomum)*

Vasantha Kumar and Mohanakumaran (1989) reported that for cardamom, potassium content of leaves and pseudostem was maximum at the flower bud development and peak flowering stages respectively, and thereafter K concentration of rhizome, roots and panicles showed peak values at capsule maturity stage. Sadanandan *et al.* (1993) reported that 150 kg K_2O ha^{-1} year^{-1} is optimum, whereas Korikanthimath (1994) reported that 240 kg K_2O ha^{-1} year $^{-1}$ is needed under high-density trench system of planting. Cardamom being a perennial crop and steady absorption and utilization of K take place throughout its life cycle and it is a heavy feeder of K (Kulkarni *et al.* 1971).

c) Ginger *(Zingiber officinale)*

It was reported that, for optimum productivity, NPK @ 75, 50, 50 kg together with 25 tonnes green leaf and 20 tonnes FYM is required. (Sadanandan *et al*, 1988). Sadanandan and Rohini Iyer (1986) reported that application of two tonns neem cake together with 75, 50, 50 kg NPK has increased ginger yield by 32.8% and restricted rhizome rot disease incidence to 4.7% compared to 14.5% in FYM treated plots.

d) Turmeric *(Curcuma longa)*

Rathinavel (1983) reported significant increase in plant height, tiller production number of leaves, number of mother, primary and secondary rhizomes and ultimately yield of turmeric due to potassium application. Sadanandan and Hamza (1996b & 1998) reported that NPK @ 60, 50, 120 kg ha^{-1} with micronutrients were optimum for varieties Suvarna, Suguna and Alleppey, whereas NPK @ 50, 40, 100 kg ha^{-1} with micronutrients was optimum for Sudarshana.

e) Tree spices: clove *(Zyzigium aromaticum)*, nutmeg (*Myristica fragrans*) and cinnamon *(Cinnamomum veerum)*

Potassium requirement of tree spices viz. clove (210 kg), nutmeg (125 kg) and cinnamon (200 kg) K_2O for adult tree per ha^{-1} respectively were optimum for sustained productivity.

f) Seed spices: Coriander *(Coriandrum sativam)*, Cumin *(Cuminum cyminum)*, Fennel *(Foeniculum vulgare)* and Fenugreek *(Trigonella foenum graecum)*

Fertilizer response studies for seed spices were conducted by several workers. Fageria *et al* (1972) reported good response to K_2O up to 80 kg ha^{-1} for cumin. Pillai and Boominathan (1975) reported response of coriander to potassium upto 20 kg ha^{-1}. Afridi *et al.* (1983) reported response of potash to fennel up to 90 kg ha^{-1}. Studies conducted by All India Coordinated Research Project on Spices at their centers in major seed spices growing belts of Rajasthan and Gujarat showed that for coriander 20 kg K ha^{-1} was optimum (Rethinam and Sadanandan.1994). The requirement of K for cumin is 30 to 45 kg depending upon K status of the soil. For a crop of fenugreek 50 kg K_2O ha^{-1} was adequate (Sadanandan *et al.,* 1998).

Potassium and resistance against water stress, disease and pest incidence

Potassium has many important roles, in the growth, water stress and yield of spice plants. The guard cell on either side of stomata accumulates large amounts of K, if K supply is adequate or sufficient K supply. Under adequate K supply, foliage canopy is increased and soil cover is accelerated thus preventing moisture loss. Potassium usually hastens the rate of crop development at maturity.

Deficiency of K is one of the factors that predisposes the plant to the attack of pests and diseases. It was found that due to the adoption of integrated nutrient (application of organic and inorganics including K@ 140 kg ha^{-1}) and disease management in pepper growing tracts of Calicut district (Kerala) in farmers' field, the incidence of *Phytophthora* foot rot of black pepper was brought down from 6.4 to 1.9 per cent, slow decline incidence from, 6.8 to 2.2 per cent.

Potassium interaction and correlations with other nutrients

Investigations carried out showed that with adequate supply of K, nitrogen utilization by various spice crops are enhanced. Field experiments showed that wherever N : K ratio is 1 : 2, the yields are maximum in black pepper and for cardamom the N : K ratio is 1 : 1.5. For seed spices, the optimum ratio is 1 : 1 (**Table 3**).

The effects of K in relation to major, secondary and micro mutrients were studied by relating correlation in different spices. The correlation studies conducted in black pepper showed that soil K was positively correlated with soil Zn (r = 0.47**) and negatively with soil Fe (r = –0.39**). Root K was correlated with root Fe (r = 0.30*) and with root Cu (r = 0.39*). The leaf K was also correlated with leaf Ca (r = 6.22*) and negatively correlated with leaf Mg (r = –0.21*) and with leaf Al (r = 0.29*). Leaf K was positively correlated with soil Al (r = 0.27**).

Correlation studies in cardamom showed that exchangeable K was correlated with soil Ca (r = 0.25*) and leaf Ca (r = 0.27**), non exchangeable K was correlated with soil Mg (r = 0.29**) and K index (K/Ca+Mg) negatively with leaf Ca (r = 0.29**). Leaf K was found negatively correlated with leaf Fe (r = 0.33**) and with leaf Zn (r = 0.31**).

Potassium is necessary to get significant response to applied P. Wilson *et al* (1975) reported that both P and K are essential to maintain a linear response to N in matured tea. The Ca and Mg content of leaf decrease with increase in leaf K levels (Wettasingh and Watson, 1980). Sivasubramanian and Talibudeen (1971) reported that leaf K content was adversely affected by presence of higher concentrations of Al in the soil solution. The labile K or Al content of the soil did not affect the leaf Al content. The leaf K content is affected by the labile K or Al content of the solution, reveal that below a particular K/Al ratio, any slight change in K/Al ratio will drastically affect the leaf K level. This is particularly important in acidic soils, where availability of Al is high. Under such conditions it will not be possible to predict the real deficiency or sufficiency of K in the soil solution by the mere foliar analysis of K or even Al alone without considering soil analysis and nutrient ratios. The practice of liming for management of soil pH, and resultant reduction of Aluminium and Manganese toxicities, are beneficial both by minimizing their depressive actions on K uptake by plants and/or by liming increases CEC, which increase ability of soil to retain K, and thereby encouraging healthy root system capable of absorbing more K. Raising pH by liming reduces leaching losses of nutrients.

Influence of K on quality

Potassium is often described as a quality element for crop production. It indirectly improves utilization of N and protein formation, size, weight, oil content, colour etc. Experiment conducted at IISR showed that application of K increased the berry size, weight and oleoresin in black pepper. It also increased the yields, size of fingers in ginger and turmeric. It also increases oleoresin in ginger and curcumin recovery in turmeric (**Table 5**).

Economics of K fertilization in spices

The economics of potassium use depend upon yield increase per unit input. Reliance on benefit/cost ratio is not true also, since even high ratio occur with low yield and low rates of application of a nutrient and for this reason economic benefits per unit area also should be calculated. Studies conducted at IISR showed that application of potash @ 270 kg ha^{-1} was economical for pepper and 150 kg ha^{-1} $year^{-1}$ for cardamom and for tree spices K @ 1000 g $plant^{-1}$ was economical. For annual crops like ginger @ 50 kg ha^{-1} $year^{-1}$ was optimum. For improved turmeric varieties K @ 120 kg ha^{-1} $year^{-1}$ was economical (**Table 10**). Mengel and Kirkby (1980) in an exhaustive review of K in crop production emphasized the point that the economics of K fertilization merit increasing attention in the developing countries in the years to come in view of deficiency of K in the soil. The recent decontrol of price of potassium fertilizer in India amply underscores this point. A schematic representation for sustainable management of spice crop with reference to soil and nutrient parameters and the corrective measure to be followed are given in **Table 11**.

Conclusion

Potassium is seemed to be most important element, as it is largely accumulated in different plant parts and is removed with produce of different spice crops. It improves not only quantity, but also quality like oils and oleoresin, size, colour etc. of different spices. Potassium fertilizer will give the plant vigour and ability to resist against drought, disease etc. Major spices growing soils are generally acidic, low to medium in soil exchangeable K, further subject to high rainfall and hence to leaching loss also. Though potassium sulphate was known better sources for pepper, potassium chloride accounts for 98% of potassium applied for spice crops. Potassium fertilizer recommendation for spices should be based on soil test K data. Exchangeable soil K was correlated with yield. Soil K was correlated with Ca, Mg, Fe, Zn, Cu and Al in soil and plant.

Table 10. Nutrient levels and recommendations for sustainable pepper production

Soil nutrients	*Desirable levels mg kg^{-1}*	*Dose recommended kg ha^{-1}*	**Source of fertilizer/ micro nutrients kg ha^{-1}*
Soil pH	6-7		Lime @ 3 t in April-May with 1st week
Organic matter	2.5%	10,000	FYM
Black pepper	NPK	140, 55, 270	N as urea P as phosphate rock K as muriate potash
Cardamom	–do–	75:150:150	–do–
Ginger	–do–	75:50:50	–do–
Turmeric	–do–	50:51:120	–do–
Clove	–do–	100:75:150	–do–
Nutmeg	–do–	–do–	–do–
Cinnamon	–do–	–do–	–do–

Zn, B, Mo, @ 5,2, 1 kg ha^{-1} (Zn sulphate 23 kg, Borax 18 kg, sodium molybdate in September)

Table 11. Sustainable management of spice crops

Soil management problems	***Corrective measures***
Soil erosion	Conservation practices
Loss of soil	Conservation tillage to suit soil types
Loss of nutrients	Appropriate soil management
Depletion of organic matter	Management of crop residue/use of mulch & animal waste, Develop technology for crop residue and animal waste management
Soil fertility	Revalidation of soil fertility, based on soil test values
Low soil fertility (low/high pH, org. matter & nutrient content)	Monitor changes in soil status, develop new soil test methods
Al toxicity	Use lime & organic matter
Accumulation of unused elements	Investigate dynamics and behavior in soil-plant ecosystem
Lone use of fertilizer	New fertilizers
Chemical fertilizer	As per soil test crop response
Based on yield goals	Use of slow release fertilizers, adoption of integrated and nutrient management
Exclusive use leads to pollution	Use bio-fertilizers
	Improve sanitation and phyto sanitary availability (SPS)
Live stock waste	Organic resources recycling
Loss of organic resources	Adoption of mixed farming
Pollution problem	Efficient use of animal waste

Future thrust

The productivity of most of the spices is almost double what the progressive farmers attained. This yield gap can easily be bridged by the adoption of better management of resources like water and nutrients in which K assumes significance in augmenting production and quality of spices. Some of the future prospects and thrust areas with special reference to K nutrition which merit further research are:

- A uniform response to applied K for all spices has been noticed. But cost of K fertilizers increased by three-fold recently. The efficiency of K is, therefore, to be increased by proper balance with other nutrients and/or placement of K with organic manures.
- Potassium use in spices should essentially be on cropping system basis.

Spices based cropping system or spices as mixed crop (in coconut-arecanut-coffee-cardamom plantations) where K application strategy needs to be worked out for different levels of soil fertility and crop rotation.

- Development of critical levels of K in spice growing soils and plant tissues, which are to be validated under field conditions and soil test crop response correlation study for major spice crops to be worked out.
- Nutrient interactions (both synergistic and antagonistic) for their effect on yield, oils and oleoresin of spices. The important ones are N-K, P-K, K-Mg, K-Ca, K-micronutrients.
- Identification of spice varieties which are efficient users/absorbers of both soil and fertilizer K and if they are able to maintain yield and quality, those cultivars can be recommended to farmers, which absorb less K per unit of yield, oil/oleoresin produced.
- K and water use efficiency and cold tolerance.
- Reason for low essential oil content particularly in seed spices and relationship if any between K nutrition and soil climatic conditions.
- Significance of K fertilization against immature tender splitting of nutmeg.
- Dynamics of K and crop quality-colour, size, storage, oils and oleoresins production.
- Potassium in relation to suppressing root-rot, stem-rot disease as wider K/Ca ratio in plant tissue makes the crop comparatively free of diseases.
- Precision farming by fine tuning the application of K fertilizers according to the needs of the farm and soil condition.
- Use of Information Technology in technology transfer

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