Potassium Management of Banana

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Introduction

Banana is one of the most important fruit crops in India. It is being cultivated in four lakh hectares with a total annual production of 13.5 million tonnes. Banana being a heavy feeder of potassium requires nearly 1500 kg of K_2O per hectare. Nearly 6 lakh tonnes of K_2O is required for banana production in India which in terms of K fertilizer comes to be about 10 lakh tonnes of KCl or 12 lakh tonnes of K_2SO_4 per year. Though, the Indian soils in banana growing belts are very rich in potassium minerals, the potassium availability to banana crop is restricted due to various soil factors. Chemical compounds of potassium are highly soluble, but its soil mineral forms (micas and orthoclase feldspars) are slowly soluble. It is the most abundant metal cation in tissues of banana and other crops (often upto 3 or 4% of dry weight), but soil humus furnishes very little potassium during decomposition. Decomposition of fresh plant residues from banana orchards supplies whatever potassium the plant absorbed for its growth. Potassium is required for the activation of over 60 enzymes involved in the formation of carbohydrates, translocation of sugars, various enzyme actions, yield, quality parameters, storage life of banana, the tolerance to certain diseases, mechanisms to overcome the abiotic stress, cell permeability and several other functions.

Weathering of soil primary minerals can be a chief source of nutrients such as potassium, calcium, magnesium, phosphorus and minor elements in low input banana/plantain cropping systems. Nutrient reserves depend on both soil parent rock composition and weathering stage. In Volcanic ash soils of Cameroon, high Ca and Mg reserves (related to the presence of Ca-plagioclases, augite and olivine) influence banana nutrition, particularly the cation balance involving K (Delvaux, 1989). In mica-rich alluvial soils from Madagascar, Godefroy (1988) reported the positive effect of Guatamale grass

(*Tripsicumm laxum*) on K availability for bananas. The grass was planted in sequential cropping with banana, cut off and used as mulch for the next banana planting. The exchangeable K level in the topsoil increased from 0.14 (before planting grass) to 1 meq 100^{-1} g.

Potassium in Banana Plant System

Potassium is a key element in banana nutrition. The earliest reference to analysis of banana plant sap showed a high concentration of potassium in the plant. This observation has since been confirmed for many countries (Twyford, 1967). The most universal symptom of potassium deficiency is the appearance of orange-yellow colour in the oldest leaves and their subsequent rapid desiccation. This is one of the most important expressions of potassium deficiency. This results in reduced total leaf area of the plant and the longevity of the leaf (Lahav, 1972; Murray, 1960). The midrib curves so that the tip of the leaf points towards the base of the plant (Lahav, 1972; Murray, 1959). Other effects of potassium deficiency are choking, delay in flower initiation and reduced fruit size.

A sudden shortage of potassium can occur if the potassium release rates of the soil do not match the seasonal demand for potassium by the plant. In such instances the plant may bunch satisfactorily and then the leaf system may suddenly collapse as potassium is withdrawn from the leaves to supply the needs of the growing fruit (Turner and Bull, 1970).

Studies of the ontogenic course of potassium uptake under field conditions have shown an overall decrease in whole plant concentration of potassium in the dry matter from sucker to fruit harvest. The potassium uptake is proportionally greater than dry matter accumulation early in the life of the plant. Under restricted potassium supply, the highest potassium uptake rate occurs during the first half of the vegetative phase. It is redistributed within the plant (Vorm and Diest, 1982) to allow further accumulation of dry matter. Where potassium supply is abundant, large amounts of potassium is absorbed during the later half of the vegetative phase (Twyford and Walmsley, 1973, 1974a, 1974b, 1974c) and have a special effect on the maturation process (Fox, 1989). Even when potassium supply is abundant, potassium uptake during the life cycle is appropriate to meet the needs of the main plant crop but it is not relevant to ratoons, since in stools the mother plant and followers are present at the same time.

Potassium was found to regulate the transfer of nutrients to the xylem. Where potassium supply is low, the transfer of nitrogen, phosphorus, calcium, magnesium, sodium, manganese, copper and zinc across the xylem is restricted (Turner, 1987); the exception is potassium itself, a constant proportion of which moves to the top of the plant irrespective of potassium supply.

Insufficient potassium supply reduces the total dry matter production of banana plants and the distribution of dry matter within the plant. The bunch is the most drastically affected organ and hence the importance of potassium in banana growing. Turner and Barkus (1980) found that while low potassium supply halved the total dry matter produced, the bunch dry matter was reduced by 80% and the roots were unaffected. It was suggested that of the various organs competing for potassium, those nearest the source of supply is the most successful in obtaining their requirements.

Low potassium supply reduced respiration but produced a large variation in the photosynthesis of leaf discs (Martin-Prevel, 1973). Total dry matter is the balance between gross photosynthesis and respiration. Respiration was lower in potassium deficient plants and therefore the main effect of low potassium supply on dry matter production would be through reduction of photosynthesis. Naturally, the reduced photosynthesis was much aggravated by the reduced total leaf area of the plant. This is proved to have a direct impact on bunch weight (Croucher and Mitchell, 1940; Murray, 1961; Summerville, 1944). Martin-Prevel (1973) suggested a major effect of potassium through stomatal control, with potassium deficiency slowing down stomatal movements.

Potassium deficiency impairs protein synthesis, since free amino acids (Freiberg and Stewart, 1960) and soluble forms of nitrogen (Martin-Prevel, 1973) increase in low-potassium plants. The main amino acid to accumulate was Cysteine-methionine (Lahav, 1975). A parallel decrease of amino acids was found in the sap.

Fruit growth is conspicuously restricted by low potassium supply in two ways. The reduction in translocation of carbohydrates from leaves to fruits and their conversion to starch (Martin-Prevel, 1973). Thus, low potassium supply produces ‘thin’ fruit and fragile bunches, a phenomenon frequently observed in the field as well as in controlled experiments.

Potassium supply affects the fruit quality by affecting the reducing, non-reducing and total sugars. As potassium supply increases, the sugar/ acid ratio increases because of increase in sugars as well as decrease in acidity (Vadivel and Shanmugavelu, 1978).

Availability and Management of K in Banana Soil

Soil potassium exists in four forms in the increasing order of availability, along with estimates of the approximate amounts in each as follows: mineral (5000 to 25000 ppm), non-exchangeable (50 to 750 ppm); exchangeable (40 to 600 ppm); and solution (1 to 10 ppm) K. In general, the relation between exchangeable and solution K^+ is a good measure of availability of K to banana crop. The availability of K to banana and its uptake are affected by various factors. Some of them are discussed hereunder with the proper management of them.

Fixation of K in Soil: Banana being a K-loving crop requires heavy dosage of potassium. As K is highly susceptible to leaching losses in light textured soils, its split application is very essential. The splitting of K application and their frequency of application depends on the texture of the soil. Banana is being cultivated in different districts of Tamil Nadu where the soil texture ranges widely from sandy to clayey and the potassium fixing capacity depends on the texture of the soil (Jeyabaskaran, 1998). As leaching loss of K is low in soil of high K fixing capacity, the soil K fixing capacity can be useful for standardising the splitting of K application for economic and effective K fertiliser utilisation. The soils of South Arcot district recorded the highest K fixing capacity and the soils of Tiruchirappalli district recorded the lowest K fixing capacity (**Table 1**). In general, irrespective of the soil texture and the systems of cultivation, the banana farmers follow 3 splitting of K fertiliser application for banana crop. However, this study suggests that on medium K fixing capacity soils, more number of splitting may be required for efficient use of applied fertiliser.

Soil Salinity and Sodicity: Problems related to salinity arise during dry climate on saline soils and/or because of the use of a poor quality irrigation water. Excessive salinity increases the Na content in roots with a marked depression in K uptake (Lahav, 1973), reduces the growth rate, delays flowering and decreases crop yield (Israeli *et al.*, 1986). In the Canary Islands, the optimal value for the soil K/Na ratio is considered to be 2.5 and banana yield decline

Table 1. Potassium fixing capacity (%) of banana soils of Tamil Nadu

District	Number of Samples	Range	Mean	Sandard Deviation (%)	C.V
Tiruchirappalli	40	10.0-83.3	44.0	23.1	52.6
Salem	20	22.2-72.2	51.8	18.3	35.3
South Arcot	35	38.8-94.4	71.4	18.1	25.4
Coimbatore	30	38.9-61.1	50.0	11.1	22.2
Thanjavur	30	72.2-88.8	67.8	14.4	21.3
Madurai & Virudunagar	25	15.0-98.8	46.0	28.7	62.4

when the Na proportion in over 8% of the sum of exchangeable cations.

In some areas of India, bananas are grown on 'saline sodic' soils. In such soils bananas suffer from salt injury which causes external symptoms of marginal chlorosis of leaves and results in a significant yield reduction. In mostof the saline sodic soils, K/Na ratio are found to be less than one, but for banana K/Na ratios of more than one is essential. The soil and tissue samples were analysed for Na and K concentrations by Jeyabaskaran (2000). The correlation coefficients and linear regression equations were worked out among the parameters studied and are shown in the **Table 2**. In both soil and plant, the increase in Na concentration decreased the yield significantly and the reverse was true in the case of K and K/Na ratio. The yield increased significantly with increasing K concentration of both soil and plant. The critical limits for soil and plant K concentrations for optimum yield in saline sodic soils were fixed at 710 ppm and 2.82 per cent, respectively (**Fig. 1, 2**).

Table 2. Linear correlations among soil and plant K, Na and K/Na and yield

Yield (Y) Vs.		Correlation Coefficient	Regression Equations
Soil (X)	Na	-0.68**	Y = -0.02X + 18.43
	K	+0.88**	Y = 0.02X + 1.41
	K/Na	+0.79**	Y = 7.03X + 2.81
Plant (X)	Na	-0.19	Y = -8.04X + 12.42
	K	+0.87**	Y = 6.95X – 6.89
	K/Na	+0.63**	Y = 2.69X – 4.17

*** Significant at 1 % level.*

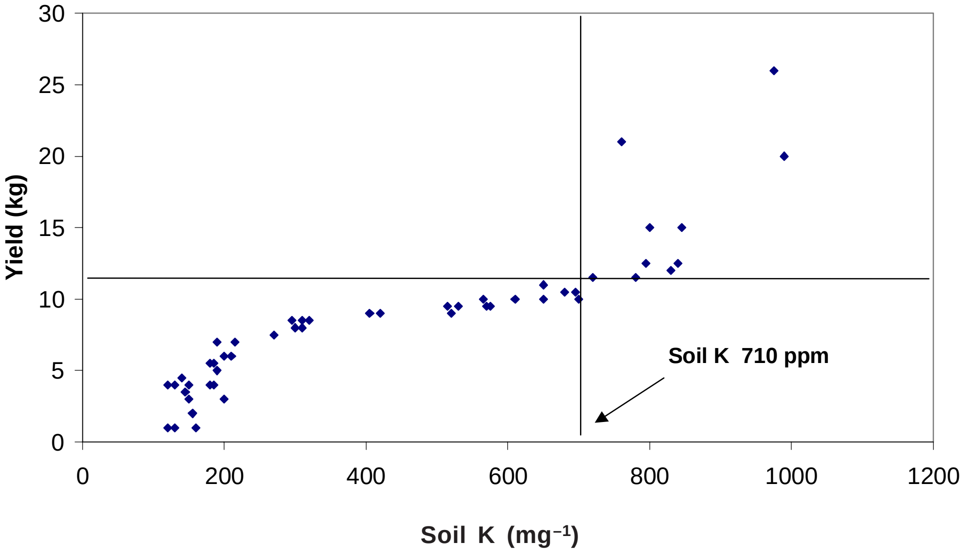

Figure 1. Critical limit of soil K for banana in saline sodic condition.

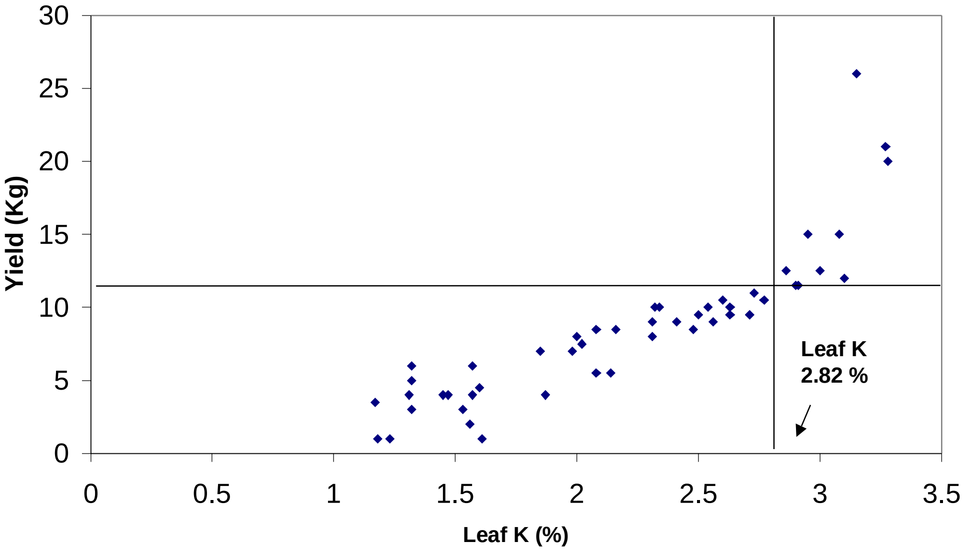

Figure 2. Critical limit of leaf K concentration in banana in saline sodic soil

The crop plants cultivated in saline sodic soils have the tendency to absorb more K to counteract the highly concentrated Na in the soil, as per the thief-watchman theory of Heiman. It is clear that K/Na ratio in soil and plant plays an important role in overcoming the adverse effect of salinity and sodicity. The critical K/Na ratios of soil and banana plant for optimum yield in saline sodic soils were fixed at 1.46 and 5.7, respectively.

Amending Saline Sodic Soil for Banana Cultivation: In an attempt to find out the effects of graded levels of potassium along with gypsum and FYM on the yield of Nendran banana (French Plantain), and on K releasing pattern and Q/I parameters of soil K in sodic soil, Jeyabaskaran *et al.* (2000) found that application of 2 kg plant^{-1} gypsum + 15 kg plant^{-1} FYM + 120% recommended K, exhibited no salt injury symptoms, had highest bunch weight of 10.33 kg and had maximised Potential Buffering Capacity (PBC) of K through out the crop growth period (**Fig. 3, 4**).The effect of amendments and graded levels of K on yield is given in **Table 3**.

Adsorption Isotherms of Soil K (Quantity/Intensity Relationship of Soil K): Exchange data involving K are useful in understanding the contribution of soil K to plant nutrition when they are expressed through Q/I (quantity/Intensity) graphs illustrating Potassium Buffering Capacity (Beckett, 1964). Differing potassium buffering capacities indeed influence K supply to bananas (Delvaux, 1989) as illustrated in **Fig. 5**.

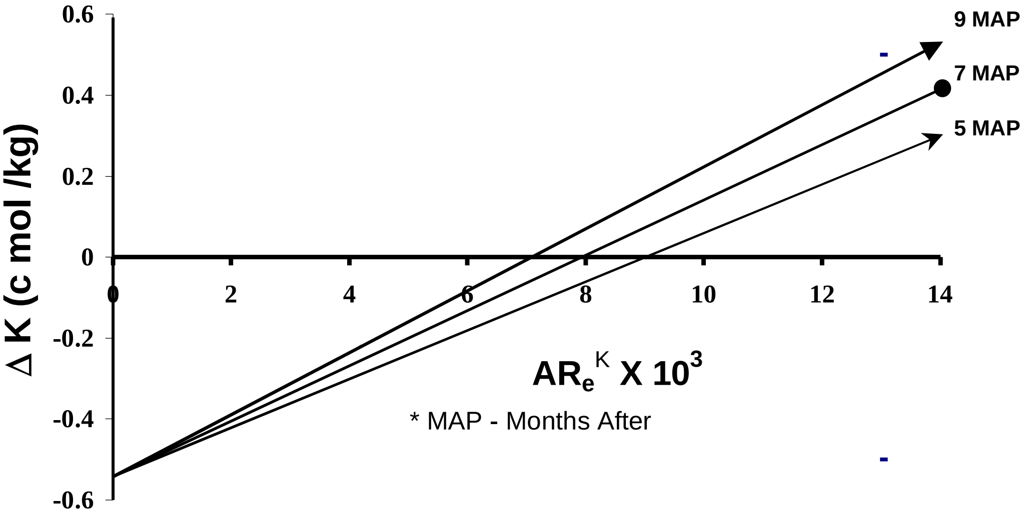

Figure 3. Effect of gypsum and FYM with 120% recommended K on Q/I parameters of soil K at different growth stages of Nendran

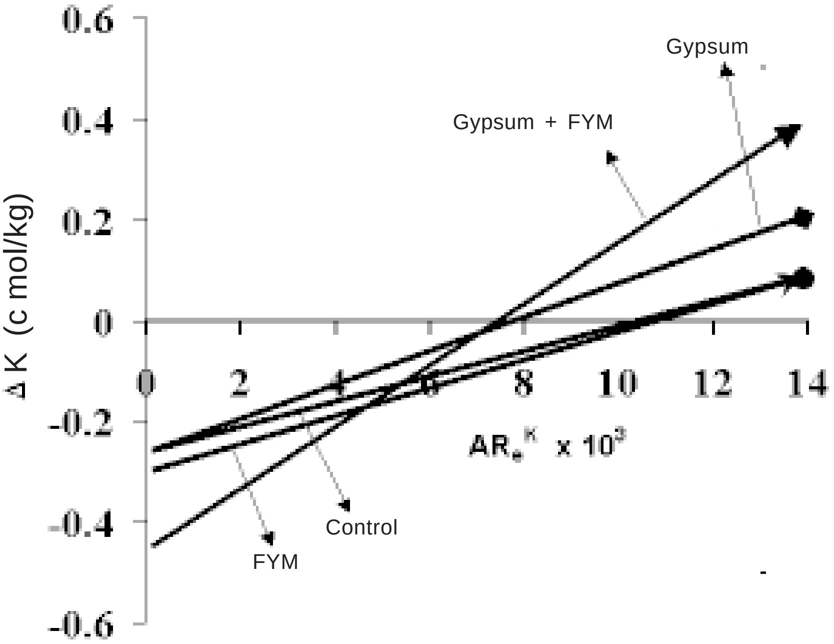

Figure 4. Effect of amendments with 120% recommended K on Q/I parameters of soil K at 8 MAP of Nendran

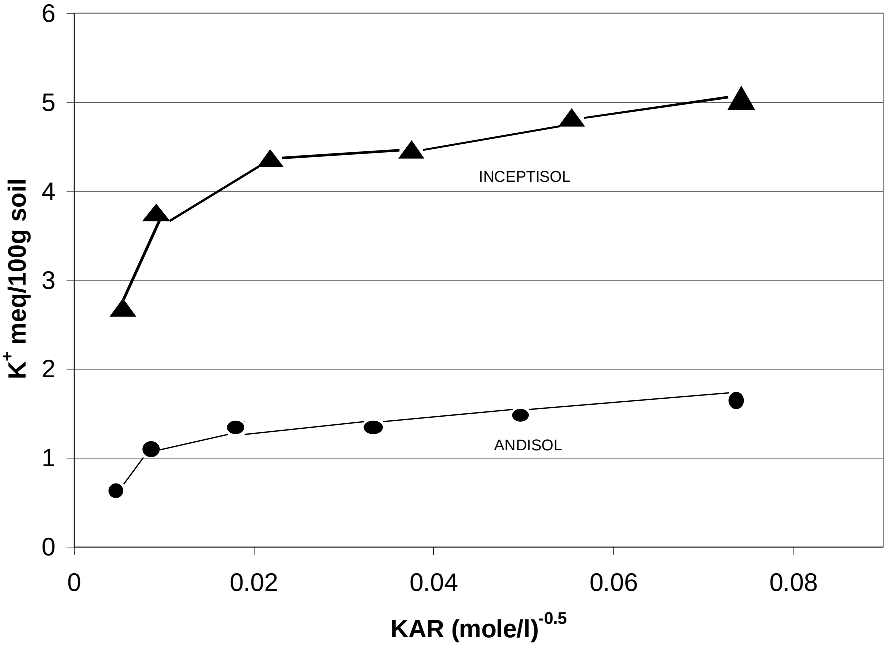

Figure 5. Q/I Relationships of K in Inceptisol and Andisol

Table 3. Effect of amendments and potassium on salt injury and yield of Plantain cv. Nendran.

Treatment	*Salt injury*					*Yield (bunch weight kg plant^{-1})*				
Sub *Main*	K_{90}	K_{100}	K_{110}	K_{120}	*Mean*	K_{90}	K_{100}	K_{110}	K_{120}	*Mean*
Control	55.5	33.8	16.8	5.5	27.9	5.9	5.9	5.9	6.7	6.1
FYM	19.7	12.6	3.1	1.8	9.3	6.1	6.1	6.4	7.1	6.4
Gypsum	15.0	12.4	4.6	0.0	8.0	6.2	6.4	7.4	8.1	7.0
FYM+gyp.	7.3	4.2	2.9	0.0	3.6	7.5	7.8	9.7	10.3	8.8
Mean	24.4	15.7	6.9	1.8		6.47	6.5	7.3	8.1	
CD(P=0.05)	M 4.46	S 3.76	MxS 7.53			M 0.53	S 0.44	MxS 0.89		

In the inceptisol, a reduction in KAR (Potassium Adsorption ratio) due to lixiviation or absorption by roots, will be easily compensated as the soil has a large capacity for stocking potassium and releasing it into the solution. In andisols, however, exchangeable K is invariably below the critical value of 1.5 meq 100^{-1} g estimated for this soil (Delvaux *et al.*, 1987); more splitting potassium supply is required to maintain a regular K nutrition to bananas (**Fig. 6**).

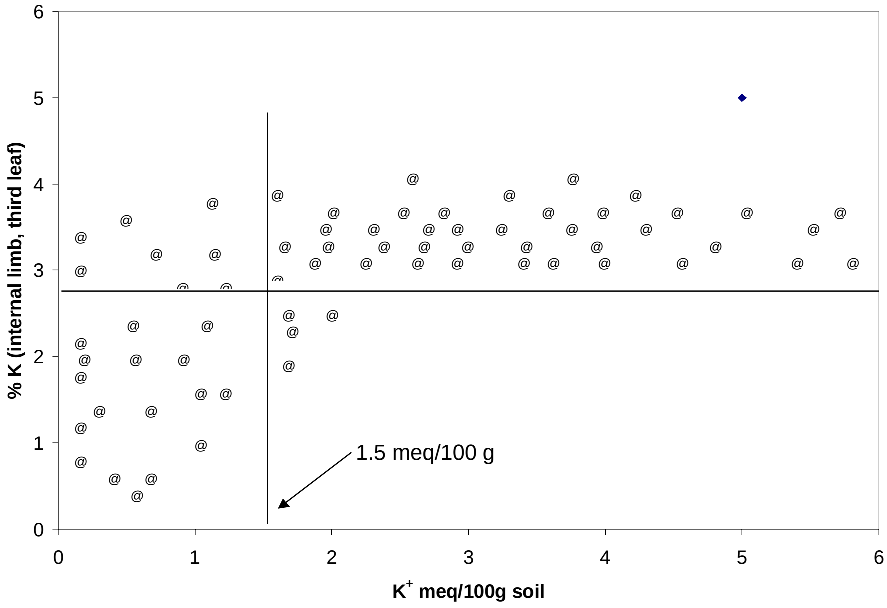

Figure 6. Critical Limit of K in an Andisol in Cameroon (Delvaux *et al.*, 1987)

Interaction of Potassium with Other Nutrient Elments in Soil : Bananas being a high K demanding crop, potassium is the most widely studied nutrient in soils and as it is particularly sensitive to cation balance, the assessment of soil K critical levels is subordinated to K/Ca/Mg balance. The exchangeable potassium critical value varies according to soil saturation in Ca and Mg and the critical level were much lower in low base saturated soils (**Table 4**).

High K/Mg ratios may induce typical mottling of the petiole, called 'blue' with a marked depressive effect on crop yields. Blue and other physiological disorders may appear with K/Mg ratio above 0.6-0.7 (Delvaux, 1988). In acid ultisols of Cameroon K/Mg ratio over 0.7 induces blue only when root depth is poor (<20 cm), and when both exchangeable Mg level and total Mg reserve are below 1.3 and 45 meq 100^{-1} g, respectively (Delvaux, 1988).

Table 4. Critical levels of exchangeable K in some banana soils below which potassium deficiency symptoms are observed on plants.

References	Soil type (area)	Potassium (meq 100^{-1} g)
Dabin and Leneuf (1960)	ferrallitic soils (Ivory coast low base saturated soils derived from ash/pumice.	0.2
Turner *et al.*(1989)	highly Ca, Mg saturated soils (New South Wales)	1.0-1.2
Delvaux *et al.* (1987)	highly Ca, Mg saturated andisols (Cameroon)	1.5

Using soil analysis (or plant analysis) for monitoring K fertilisation requires the determination of a relationship between crop response to the added K and K concentration in soil (or plants). Such relationships were established in the Windward Islands from a 32 site experiment with critical levels in soils of 0.40 meq 100^{-1} g for exchangeable K (Walmsley *et al.*, 1971). From several studies (with no information on crop response), Lahav and Turner (1989) computed asymptotic curves plotting K uptake by bananas against soil K concentrations. Soil critical K content (above which K is not absorbed any more) is in the range of 1.4 meq 100^{-1} g, with a K/Mg ratio of 0.28, close to the optimal value of 0.30 as quoted by Stover and Simmonds (1987). In this case, optimal calcium absorption would require a soil balance K : Mg : Ca of 1 : 3.5 : 10.7 (Turner *et al.*, 1989), unlike the one estimated at 1 : 1.9 : 5.4 from a soil-plant survey covering 151 plots in Cameroon (Delvaux *et al.*, 1987).

Though nutrient concentrations in soils and leaves may be poorly related (Turner *et al.*, 1989), using both soil and plant tests may help in assessing critical values when clear nutritional contents appear (Delvaux *et al.*, 1987). For instance, a typical ‘threshold’ curve relating K contents in soil and leaf for bananas grown in various volcanic ash soils showed that above the critical value estimated at 1.5 meq 100^{-1} g, a lower relative variation in leaf K content is observed.

Interaction of Potassium with other elements within the plant system

Nutrient antagonisms in banana have been widely studied (Lahav *et al.*, 1978). The main cations examined are potassium, calcium and magnesium and many other antagonisms and synergisms have been documented (**Table 5**).

Special attention has been paid to the K/Mg ratio. Mottling of the petiole, called ‘blue’, has been associated with a low K/Mg ratio in the field. In a sand culture study, K : Ca : Mg imbalance was investigated and found that ‘blue’ was caused by potassium deficiency and was not related to high magnesium supply. In the same sand culture experiment a high K/Mg ratio caused a ‘yellow pulp’ condition in the ripe fruit, while yield was unaffected.

Table 5. Effect of deficiencies on the concentration of other nutrients in banana leaves

	Deficient element							
	N	*P*	*K*	*Ca*	*Mg*	*Mn*	*Zn*	*S*
N	-		-		+0			+0
P	+	-	-	+	-	0	+	+
K	+		-	+	+0	0	-	
Ca	-		+	-	+0	+	-	+
Mg	+	-	+	+	-	+		0
Mn			-		+	-		
Cu			+	0				
Zn			0-		0		0	
Fe		-						
Na		-	0					
Cl			+					

+, increase; -, decrease; 0, no effect.

The magnitude of K/Mg antagonism depended greatly on the organ in which concentration changes were measured. Increasing potassium supply had a strong depressive effect on magnesium concentrations in leaves and pseudostem but very little effect on fruit and roots.

The observed K/Mg antagonism in bananas could be a consequence of potassium and magnesium operating independently or of luxury uptake of potassium. This deserves special attention because of the extreme importance of potassium to the banana plant and the increased amounts of potassium being applied in many growing regions of the world. The large uptake of potassium may promote translocation of magnesium towards fruits and storage tissue, or promote growth, thus decreasing whole-plant magnesium concentrations (Turner and Barkus, 1983a).

'Yellow pulp', except for being related to high K/Mg ratio, as mentioned earlier, is associated with high soil calcium and manganese deficiency. However, it can be avoided by a high dosage of sulphur which improves the balance of cations by reducing excess calcium and increasing the absorption of manganese.

Changes in the K/Ca+Mg, P/Zn and N/P ratios were associated with changes in yield in an experiment with KNO_3 and manure in Israel (Lahav *et al.*, 1978). It is necessary to determine whether causal relationships exist between these ratios and yields, since each could have been independently influenced by the treatment. Further work should explore relationships between nutrient uptake and growth, which may account for observed nutrient antagonisms.

The earlier literature on plant nutrition often mentions a synergistic relationship between magnesium and potassium. It was thought that magnesium might have acted as a 'Phosphatic carrier', but this seems unlikely and Martin-Prevel (1978) discounts this mechanism for bananas.

In a factorial sand culture experiment conducted over three crop cycles, the competition between ions was studied in relation to the supply of potassium, magnesium and manganese (Turner and Barkus, 1983b). It was found that potassium and manganese inhibited magnesium uptake, but in a non-competitive way. Increasing potassium supply increased the plant uptake rates of potassium and phosphorus, but decreased the uptake rates of sodium, calcium, magnesium and copper. In such cases the addition of potassium fertilisers may lead to problems of calcium and magnesium deficiency (Turner and Barkus, 1983a).

Effect of Genome and Ploidy Levels of Banana on Potassium Uptake

The diploids differed in the total and pattern of uptake of potassium. The uptake was greater (691.4 g) in Kunnan (AB) than in Anaikomban (630.2 g), which has ‘AA’ genome. The K uptake was continuous and progressive from 4.98 to 630.2 g in Anaikomban and from 9.2 to 691.4 g in Kunnan. The rate of uptake was rapid and the highest at flowering and harvest stages (53.5 per cent) in Anaikomban, whereas it was at 15th leaf and flowering stages (48.5 per cent) in Kunnan. The rate of uptake was slow in the initial stages between 5th leaf and 8th leaf stages.

The pure *acuminata* triploids (AAA) manifested similar pattern of potassium uptake. Wather (AAA) showed a little more requirement of potassium (617.3 g) than Robusta (AAA) (611.3 g). The uptake was linear from 7.9 to 611.3 g in Robusta and from 6.8 to 617.3 g in Wather. The uptake of K was exponential between 15th leaf and flowering stages in Robusta (51.2 per cent), while it was between flowering and harvest in Wather (44.5 per cent). The initial stage of 5th to 8th leaf registered the lowest rate of uptake.

The triploids with *balbisiana* ancestry differed significantly in the uptake of potassium. Monthan (ABB) manifested a greater requirement (1070.69 g), while Poovan (AAB) had a lesser requirement (894.91 g). The uptake showed an upward trend from 8.7 to 894.9 g in Poovan and from 7.9 to 1070.6 g in Monthan. In both the triploids, the K uptake was rapid and the highest at 15th leaf and flowering stages (100.1 per cent in Monthan and 59.1 per cent in Poovan). There was a downward trend in the K uptake between flowering and harvest stages in Monthan (-19.5 per cent). The K uptake was slow at the initial stages for growth at 5th and 8th leaf.

Among the cultivars, the triploid Monthan (ABB) accounted for the highest requirement of potassium (1070.6 g), while Robusta (AAA) for the lowest (611.3 g). In general, the requirement of potassium was the highest in triploids followed by tetraploids. At all the ploidy levels, cultivars having *balbisiana* genome had greater need for potassium than pure acuminata cultivars.

Management of Potassium for Disease Free Banana and Plantain

Some of the nutritional imbalances in the banana may result from diseases and viruses. Such an influence was demonstrated by Nair and George (1966), who emphasized the unique role of Ca and Mg in Bunchy-top virus infection and resistance. After the plants were infected they had higher nitrogen and potassium and lower calcium and magnesium concentrations. The lower Ca and Mg levels were explained as resulting from slow uptake or accelerated translocation from the leaves to other parts of the plant. However, a delay in the incidence of the disease could not be gained by adding Mg or changing the CaO/MgO ratio, as suggested by Nair and Pillai (1966). Hence, the changes in Ca and Mg might have resulted from K/Ca +Mg antagonism.

Severity of *Fusarium* wilt symptoms appeared to be inversely related to potassium uptake (Rishbeth, 1960). This seems to be associated with both inadequate soil aeration as well as with heavily infected corms and roots – major factors in reducing potassium uptake. Differences in soluble-nitrogen content were found between ‘Gross Michel’ (AAA) and the Cavendish subgroup of cultivars, and were attributed to their *Fusarium* wilt sensitivity (Barr, 1963).

It is presumed that nematodes, through their effect on banana roots, may affect nutrient uptake the same way as *Fusarium* does. The relationship between nutrition and nematodes or weevils in plantain is discussed by Obiefuna (1990) and between potassium uptake and Armillaria mellea damage to bananas by Spurling and Spurling (1975).

In Tiruchirappalli district of Tamil Nadu, the ‘Neer Vazhai’ a malady of unknown etiology is very common in Nendran cultivar. The main symptoms of malady is development of small bunches with few hands and fingers failing to fill out. Keeping the hypothesis of nutrient blockages, restricting the finger development in the peduncle of the bunch in the Neer vazhai plant, the segmental analysis of the peduncles of the affected and healthy bunch was done by Jeyabaskaran (1999). The potassium contents of the segments decreased from the base to the tip of the peduncles of both healthy and affected bunch. But the rate of decrease of potassium contents in the segments of affected bunch was more than that of the healthy ones. Very high potassium content at the base of the peduncle of Neer Vazhai bunch clearly indicated the blockage of nutrients for the movement from base to the tip of the peduncles. This blockage may be due to genetical or physiological disorder.

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