Research Findings

Fertilization of cassava crop in Malang, Indonesia. IPI-Indonesian Legume and Tuber Crops Research Institute (ILETRI) project. Photo by IPI.

Potassium Nutrition of Cassava

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Introduction

Cassava (*Manihot esculenta* Crantz) is grown throughout the tropics, where it is the fourth most important staple food crop in terms of energy source. It supports approximately 25 percent of farming households in sub-Saharan Africa (about 100 million people) and is a major crop on 35 percent of all agricultural land (about 60 million hectares). In this region, cassava production is increasing mainly due to expansion of cultivation area rather than an increase in productivity which is generally low at around 10 mt ha^{-1}.

Cassava is generally grown in marginal soils because of its minimal requirement for land preparation and its ability to produce reasonably good yields even on eroded and degraded soils (Howeler, 2002). Because of its inherent physiological makeup, cassava can thrive in drought prone acidic soils; the plant readily sheds its leaves and is a calcifuge.

Cassava is preferably grown on light to medium well-drained soils with a pH range of 4.5-7.5 and is adapted to tropical semi-arid conditions. Cassava requires adequate soil moisture from planting to sprouting but is generally not irrigated because it is drought tolerant. However, cassava does respond markedly to irrigation (IFA, 1992).

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Nutrient uptake

Cassava is usually grown by poor farmers in the tropics with minimum inputs. Under continuous cultivation, this can lead to soil nutrient depletion. Cassava takes up substantial amounts of nutrients (mainly potassium (K) and requires large amounts of nitrogen (N) and phosphorous (P)). The quantities of N, P and K that need to be taken up by the plant to attain a fresh root yield from 18 to 45 mt ha^{-1} are presented in Table 1. The harvested roots in particular contain large amounts of K - the NPK ratio in the roots being 5:1:10 in comparison to the typical ratio of 7:1:7 as in other crops (Vanlauwe *et al*., 2008).

Table 1. Nutrient uptake and removal by cassava.

Yield	Plant	N	P_2O_5	K_2O
mt ha^{-1}		------------------------*kg ha^{-1}*------------------------		
45	Fresh roots	62	23	197
	Whole plant	202	73	343
37	Fresh roots	67	38	122
	Whole plant	198	70	220
18	Fresh roots	32	8	41
	Whole plant	95	23	77

Source: IFA, 1992.

Although the plant is well adapted to low levels of available P, it requires fairly high quantities of K, especially when grown continuously for many years on the same site (IFA, 1992). Long-term fertility trials have clearly indicated that sooner or later K deficiency becomes the most limiting nutritional constraint if cassava is grown continuously without adequate K fertilization.

In the past, it has been presumed that as the cassava crop gives reasonable yields under conditions of poor soil fertility, its nutrient requirements are low. This theory came about because, in primitive cultivation systems which still prevail in large parts of the tropics, cassava is often grown on the most exhausted soils at the end of the crop rotation. Extensive research conducted on the nutrition of the crop, however, has shown that in order to realize its full yield potential, nutrient uptake by cassava has to be very high, which in turn requires a well balanced and high rate of fertilizer application (Jansson, 1980).

According to Susan John *et al.* (2010), a crop of cassava yielding 30 mt ha^{-1} of fresh tuber removes 180-200 kg N, 15-22 kg P_2O_5 and 140-160 kg K_2O per ha from the soil. On average, cassava extracts about 4.91, 1.08, and 5.83 kg of N, P, and K respectively per ton of harvested tuber (Howeler, 1981). This clearly indicates the need to restore and maintain soil nutrient status during cultivation through the use of sound nutrient management practices.

Role of potassium

Since cassava is a high carbohydrate producer, it requires a large amount of K which has a special role in carbohydrate synthesis and translocation. Abundant K supply favors the primary processes of photosynthesis. It also regulates the balance between assimilation and respiration in a way that improves net assimilation. This is a prerequisite for vigorous growth and the formation of reserve assimilates (Jansson, 1980).

The translocation of photosynthates from the green parts of the plant (leaf) to the storage root is of utmost importance in the building up of the storage organs (tubers). An abundant supply of K is needed for both short and long distance translocation. This applies to the ‘push’ side of the translocation - the formation of assimilates in the green parts of the plant - as well as the ‘pull’ side - the conversion of the translocates in the building up of storage organs. The osmotic effect of K supply, as well as the more specific effects of the K^+ ions, are involved in the translocation processes (Jansson, 1980).

The role of K in the translocation of carbohydrates was demonstrated in cassava by Malavolta *et al.* (1955) where the tubers of K-deficient plants had lower starch content than those which were sufficiently supplied with K.

Potassium deficiency symptoms

According to Howeler (1996), K-deficient plants may show a variety of symptoms:

- The plants are short, highly branched, with prostrate growth habits.
- The upper internodes are very short and prematurely lignified resulting in a zigzagging of the upper stem.
- In some varieties, upper leaves are small and chlorotic while in others a few lower leaves are yellow with black spots and boarder necrosis.
- During periods of drought, leaf borders may curl upwards, while in wet periods there may be severe die-back due to K deficiency induced anthracnose (*Colletotrichum* sp.).
- In many cases, there are no recognizable symptoms and plants are simply shorter and have smaller leaves than those supplied with K.

Photo 1. Necrosis of the tips and margins of cassava leaves is a symptom of K deficiency. These leaves were taken from mature plants in a treatment where N and P were applied continuously for nine years without any K, as part of a long-term fertilizer experiment at the Central Tuber Crops Research Institute (CTCRI) of the Indian Council of Agricultural Research (ICAR), Thiruvananthapuram, Kerala, India. *Courtesy:* K. Susan John, CTCRI.

Photo 2. K deficiency symptom observed in the plant as stunted growth with drying and shedding of lower leaves. This accession was found sensitive to the low K status of the soil (Ultisol) where it is grown. CTCRI farm, 2006. CTCRI, ICAR, Thiruvananthapuram, Kerala, India. *Courtesy:* K. Susan John, CTCRI.

Plant analytical data

From water culture experiments investigating the nutritional requirements of cassava, Spear *et al*. (1979) concluded that the youngest fully expanded leaf (YFEL) blades without petioles (4^{th} - 5^{th} leaf from top) at 3-4 months after planting provided the best nutritional indicator for K. Petioles, stems and roots have much lower concentrations of N, P, and K. The critical level for K deficiency in the YFEL blades at 3-4 months after planting is about 1.5 percent K, while the sufficiency range is 1.4-1.9 percent K (Howeler, 1996). Adequate K is very important for starch synthesis and translocation and it increases the resistance of the plant to anthracnose (IFA, 1992).

Potassium and cyanogenic glucosides

Cassava roots contain cyanogenic glucosides, which are toxic substances that limit or complicate its use as food and feed. These glucosides give rise to the highly poisonous hydrocyanic acid which must be removed from cassava tubers and leaves prior to consumption.

Inadequate supply of N to the crop often increases the content of these noxious constituents in tubers. The qualitative disadvantages associated with surplus supply of N for obtaining more top (vegetative) yields are reduced if a suitable balance between N, P and K is maintained. An adequate supply of K is especially effective in controlling the qualitative drawbacks of abundant N. It is important to observe the absolute supply of K as well as the N-K relationship, including its interactions, while undertaking nutrient management for the crop (Jansson, 1980).

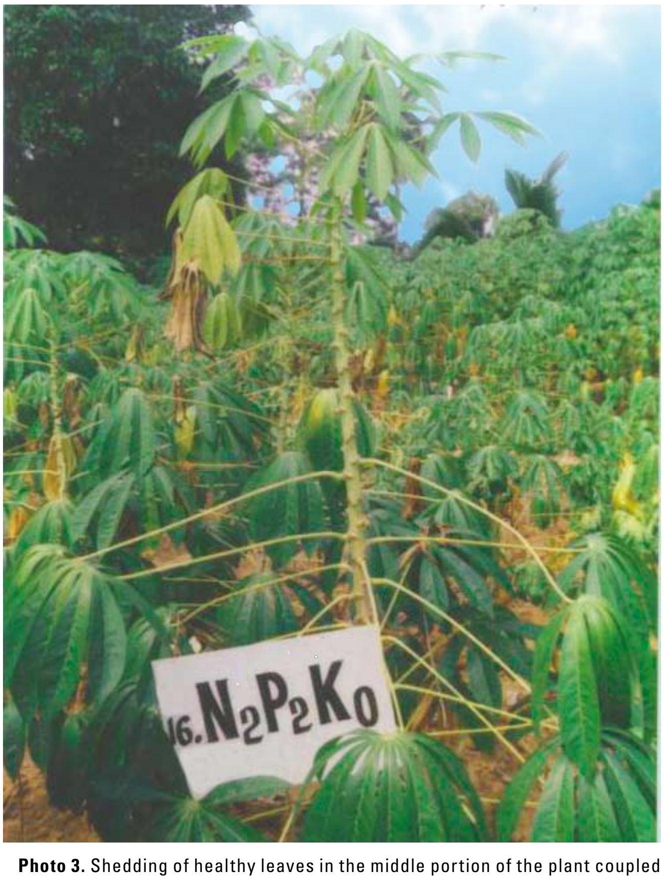

Photo 3. Shedding of healthy leaves in the middle portion of the plant coupled with yellowing and drying of the younger leaves due to imbalanced fertilizer application (N=100 kg ha^{-1}, P=300 kg ha^{-1}, K=0). From field experiment conducted in an Alfisol at Instructional farm, College of Agriculture, Vellayani, Thiruvananthapuran, 2000. CTCRI, ICAR, Thiruvananthapuram, Kerala, India. *Courtesy:* K. Susan John, CTCRI.

Response of cassava to potasssium fertilizers

Studies in Nigeria in the early seventies found that the response of cassava to K fertilizers mainly depended on the cultivars selected. More recently, it has been demonstrated that K fertilizers can enhance the utilization index (ratio of storage root yield to top yield) of cassava cultivars (Obigbesan, 1977). Subsequent studies in Ultisols (acid laterite soils) also in Nigeria indicated a positive response to K application in improving cassava tuber yield after three consecutive croppings (Kang, 1984). In Colombia, previous studies had revealed a higher response to K than N and P on soils with substantially high K contents (Howeler and Spain, 1978).

Fig. 1 shows the long-term effect of continuous application of various levels of nutrients (N, P, and K) annually for eight years in cassava in Colombia. Without fertilizer application, yields declined gradually from about 25 to 14 mt ha^{-1}. Similarly, application of either N or P alone also showed a similar yield decline. However, when K or NPK were applied at sufficiently high rates (100 kg ha^{-1} N, 200 kg ha^{-1} P_2O_5 and 150 kg ha^{-1} K_2O) to maintain the original level of soil exchangeable K, very high yields in the order of 30-40 mt ha^{-1} could be sustained. The high rate of fertilizer application had no beneficial effect on cassava yields, but increased the P and K levels in the soil (Howeler and Cadavid, 1990).

Potassium application not only enhances tuber yield but also improves tuber quality. Nair and Aiyer (1986) found improvement in starch and quality parameters of starch viz., amylose content, granule size, pasting temperature, viscosity and swelling volume, with an increase in the rate of K application. Increased tuber starch content in cassava with an increased rate of K fertilization has also been reported recently in IPI experiments in Indonesia (Table 2, IPI Internal Report).

Nitrogen and potassium interactions

Various investigations have reported that without adequate K supply, cassava does not respond to N fertilizers or it only responds poorly to N at very low rates of K application. These two major mineral nutrients interact with each other in cassava production, with N playing a dominant role in vegetative growth, including leaf development, and K being important in tuber initiation and bulking as described above. Optimal rates of N and P application were studied in a systematic trial in Colombia, where maximum yield was obtained by using 130 kg ha^{-1} N and 160 kg ha^{-1} K, indicating that relatively high rates of both these nutrients are essential to achieve high root yield for cassava (Howeler and Spain, 1978).

In South India, cassava tuber yield was increased by N and K fertilization (Muthuswamy and Rao, 1979), the highest yield being obtained with 50 and 300 kg ha^{-1} N and K_2O respectively (Table 3). From this experiment, it was also observed that the total starch yield was markedly increased by the application of K.

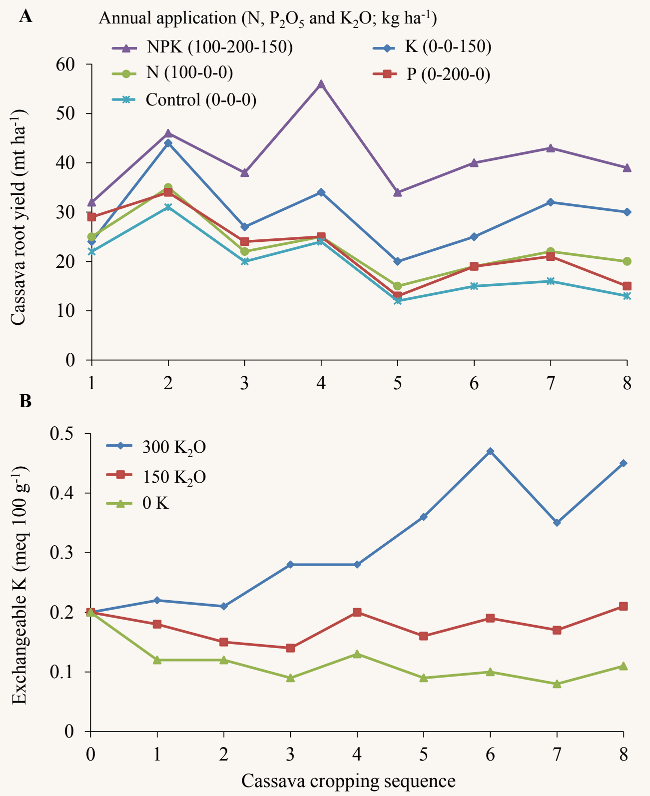

Fig. 1 A+B. (A) Effect of various levels of annual applications of N, P and K on cassava fresh root yield and (B) on the exchangeable K content of the soil, during eight consecutive cropping cycles in a long term NPK trial conducted in CIAT, Quilicao, Colombia. *Source:* Howeler and Cadavid, 1990.

Table 2. Effect of K fertilization on starch content of cassava tuber at harvest in Indonesia.

Fertilizer treatment			Starch content
N	P_2O_5	K_2O	
	kg ha^{-1}		%
30.5[(1)]	7.5	7.5	31.41 c
135	36	0	32.35 cd
135	-	30	32.02 cd
135	36	60	35.47 abc
135	36	90	36.56 ab
135	36	120	32.90 bcb
200	60	180	37.65 a
CV (%)			7.5

Source: IPI Internal Report 2012.
[(1)]Farmers' practice

Table 3. Effect of N and K on cassava tuber yield in India (mt ha^{-1} fresh weight, average of two varieties).

K_2O levels	Nitrogen levels				
	0	50	100	150	Mean
			kg ha^{-1}		
0	28.76	32.40	31.34	32.74	31.31
10	32.35	43.09	36.46	38.62	37.63
200	33.30	39.69	43.12	40.14	39.06
300	32.77	46.94	41.23	37.95	39.72
Mean	31.80	40.53	38.04	37.36	36.93
	S.E.		C.D. at 5%		
Nitrogen	1.03		3.11		
Potash	0.79		2.25		

Source: Muthuswamy and Rao, 1979.

Experiments in Nigeria, in which N and K were supplied, found that although N did not affect cassava tuberization, it significantly increased the numbers of tuberous roots. However, root diameter and weight, storage cell size and number, and dry matter allocation to roots were all significantly higher in plants supplied with either K alone or in combination with N. These were significantly reduced when only N was applied (Kasele *et al.*, 1983).

Potassium fertilizer practice

Potassium deficiency in cassava can be corrected by the application of 50-100 kg ha^{-1} of K as muriate of potash (potassium chloride), with rates being dependent on soil fertility status and expected yield levels. The critical level of soil exchangeable K for cassava was found to be 0.15-0.25 meq 100 g^{-1} (Howeler, 1996). Potassium can be applied as chloride or sulphate, but the former is generally cheaper (IFA, 1992). KCl should be applied in bands near the stake within the first two months after planting. In light textured soils, KCl should be applied in two split doses to prevent losses by leaching (Howeler, 1996).

Compound fertilizers are most convenient, if available, but they should be either high in N and K_2O or supplemented by top dressing with urea and KCl. In soils adequately supplied with P, compound fertilizers with an N-P_2O_5-K_2O ratio of about 2:1:3 or 2:1:4 are recommended in order to supply enough K to prevent K exhaustion of the soil through cassava cultivation (Howeler, 1996).

In India, Susan John *et al.* (2010) recommended applying K by split application (2-3 splits) as K is prone to leaching under humid tropical conditions. Normally, half the recommended dose of K is to be applied as basal at the time of planting and the remaining quantity has to be applied in two splits within 45-60 days of planting. The general recommendation for cassava in South India is 12.5 mt ha^{-1} of farmyard manure along with N:P_2O_5:K_2O at 100:50:100 kg ha^{-1}.

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