NUTRIENT USE EFFICIENCY OF CASSAVA DIFFERS WITH GENOTYPE ARCHITECTURE

Mabrou A. El-Sharkawy [1] - Luis F. Cadavid [2] -
Sara M. de Tafur [3]

ABSTRACT

Five cultivars each from tall, medium and short-stemmed cassava germplasm at CIAT were grown under rainfed conditions in Inceptisols with adequate N, P and K fertilizer. Sequential harvests were made at 2, 4, 6 and 10 months after planting to determine LAI, top and root biomass production. At final harvest, N, P, K, Ca and Mg uptake in top and root biomass was determined. In both medium and short-stemmed cultivars, LAI and top biomass were significantly lower than in the tall cultivars. Differences in root yield were less pronounced due to higher harvest indices in medium and short-stemmed cultivars. Total nutrient uptake was also smaller in medium and short-stemmed cultivars due to lower top biomass. Nutrient use efficiency for root production was significantly greater in medium and short-stemmed cultivars as compared to the tall ones. It would be beneficial, therefore, to breed for short-stemmed cassava in order to reduce soil nutrient depletion and hence conserve soil fertility without sacrificing yield potential. Moreover, due to the feasibility to increase population density with short-stemmed cassava, soil erosion in cassava-based cropping systems could be minimized because of early ground cover.

Keywords: Cassava, Manihot esculenta, Leaf area index, Root yield, Nutrient uptake

COMPENDIO

EFICIENCIA EN EL USO DE NUTRIENTES DE GENOTIPOS DE YUCA DE DIFERENTE ARQUITECTURA

En un Inceptisol de la estación experimental del CIAT, Santander de Quilichao, Cauca, Colombia se sembraron tres tipos de yuca así: alta, media y baja de cada tipo se escogieron cinco cultivares. Los cultivares de porte medio y bajo presentaron IAF y una producción de biomasa en la parte aérea significativamente menor que los de porte alto. Las diferencias en la producción de raíces fue menos pronunciada debido al alto índice de cosecha de los cultivares de porte medio y bajo. La absorción total de nutrientes fue también menor en los cultivares de porte medio y bajo debido a la menor producción de biomasa en la parte aérea. El uso eficiente de los nutrientes para la producción de raíces fue significativamente mayor en los cultivares de pote medio y bajo que en los cultivares altos.

Palabras claves: Yuca; Manihot esculenta; Indice de área foliar; Rendimiento de raíces; Absorción de nutrientes

INTRODUCCION

Concerns have been raised about high-input-technology agriculture's potentially negative side effects, such as environmental pollution (Greenwood, 1990; Davis, 1994; Matson et al., 1998), high levels of soil degradation (Lal, 1989) and particularly the environmental and economic impacts of soil erosion (Pimentel et al., 1995). To minimize these environmental impacts and, at the same time, sustain reasonable crop productivity needed to meet the increasing demands for agricultural products, the judicious uses of agricultural inputs, such as agrochemicals, and the development of improved cultivars tolerant to biotic and abiotic stresses are good strategies (Sanchez and Salinas, 1981; Matson et al., 1998). In contrast with the capital-intensive Green Revolution technology for cereal crops production, cassava (*Manihot esculenta*, Crantz) is produced mainly

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[1] *A.A. 26360, Cali, Valle, Colombia; email: elsharkawy@telesat.com.co;* [2] Centro Internacional de Agricultura Tropical (CIAT), A.A. 6713, Cali, Colombia; [3] *Profesora Asociada. Universidad Nacional de Colombia, Sede Palmira, A.A 237*

by small farmers on low-fertility soils in the tropics with virtually no purchased inputs (El-Sharkawy, 1993). Moreover, due to pressures on land resources and to the inherent tolerance of cassava to poor acid soils (Cock and Howeler, 1978; Howler, 1991a), increasingly more marginal lands are being used for its production in Africa, Asia and South America (Romanoff and Lynam, 1992; El-Sharkawy, 1993; Howeler, 1994). Under these conditions, cultivars that produce more biomass of roots per unit of nutrient extracted would be advantageous (Hershey and Jennings, 1992).

Advances have been made in breeding improved cultivars with high yield potential under favorable environments (Kawano et al., 1978; Hahn et al., 1979) with the improved cultivars having higher harvest indices as compared to traditional landraces (Kawano, 1990). Under abiotic stresses (i.e. low-fertility soils and prolonged water stress), however, cassava plant tends to further increase its harvest index due to lower reduction in root yield as compared to top biomass (Cock and Howeler, 1978; Connor et al., 1981; El-Sharkawy et al., 1992). Total nutrient uptake was also found to be significantly smaller in water-stressed cassava as compared to unstressed crops, thus resulting in higher nutrient use efficiency in terms of root production (El-Sharkawy et al., 1998). The enhancement of nutrient use efficiency was due mainly to a larger reduction in top biomass, and hence, a smaller nutrient uptake in water-stressed crops. These findings implied that reducing top biomass in cassava could be beneficial in minimizing soil nutrient depletion, and hence soil degradation, particularly when cassava is grown continuously in poor soils without fertilizer application. Although, there were many reports on cassava response to fertilizer and on nutrient uptake (Spear et al., 1979; Howeler and Cadavid, 1983, 1990; Howeler, 1991b; Hicks et al., 1991; Pellet and El-Sharkawy, 1993a, b, 1997; Cadavid et al., 1998), no information exists on nutrient uptake and use efficiency as affected by cassava architecture. Therefore, the objectives of this study were to (1) evaluate the productivity of a group of genotypes selected from the cassava germplasm at CIAT having different plant heights and (2) determine their nutrients uptake and use efficiency.

MATERIALS AND METHODS

Plant materials, experimental site and experimental design

Fifteen cassava cultivars with different heights ranging from 230 to 260 cm (tall), from 170 to 200 cm (medium) and from 120 to 150 cm (short) at maturity, were selected from the cassava germplasm at CIAT and were grown in two consecutive cycles at the CIAT Experimental Station at Santander de Quilichao, Cauca, Colombia (lat. 3°06'N, long. 76°31W, altitude 990 m, mean annual temperature 24°C). The soil Inceptisol (FAO) with clayey texture (about 71% clay, 25% silt and 4% sand), pH (H_2O) of 4.5, 2.8 mol C kg^{-1} (dry soil) and 0.41, 0.18, 0.40, 1.80, 9.50, 3.70 and 9.59 mmol kg^{-1} (dry soil) of NH_4, NO_3, P, K, Ca, Mg and Al, respectively. The experimental site had been planted with cassava during the two preceding years. Before planting, the land was prepared by a disc plough in two directions and then was ridged at 1 m distance.

Mature stem cuttings, 20 cm long, were selected in the 1994/1995 season from the cassava germplasm at CIAT Station, Palmira, Valle, Colombia, which was grown on very fertile soil (Vertisol). The lower one-third of woody mature stems (10 months) was used for cuttings which were soaked for 10 min in a fungicide-insecticide Zinc-sulfate solution before planting (Veltkamp, 1985). On October 1994, the cuttings were planted vertically on ridges at 1 m x 1 m to give a population density of 10,000 plants ha^{-1}. In the second cropping cycle (1995/1996), due to shortages of planting materials, particularly of the short cassava cultivars from the Palmira Station, the crop of the preceding year (1994/1995) of the trial was used as a source for planting materials. The cuttings were treated similarly as in the first cycle and were planted on September, 1995, at the same site and density. One month after planting in both years, 50 N, 44 P, 84 K kg ha^{-1} were band-applied in the form of a compound N, P and K fertilizer at 10:8.7:16.7. The experiment was laid out in a split-plot design with four replications. The main plots were assigned to groups of plant architecture and the sub-plots to cultivars within each group. The size of the sub-plot was 60 m^2. During the first growing cycle (1994/1995), the total rainfall from October, 1994, to July, 1995, was 1461 mm and the pan evaporation was 1365 mm. There was a water deficit from December, 1994, to February, 1995, when rainfall ranged from 16 to 70 mm per month. In the second cropping cycle (1995/1996), the total rainfall from September, 1995, to July, 1996, was 1927 mm and the pan evaporation was 1192 mm. Except with the last two months before harvest (June, July, 1996), rainfall was greater than pan evaporation, particularly in December, 1995 (with 300 mm) and in March, 1996 (with 420 mm). No irrigation was applied in either cycles.

Biomass and nutrient uptake determination

Four sequential harvests of 6 protected plants per plot were made at 2, 4, 6 and 10 months after planting in both cropping cycles. Harvested plants were separated into leaves, petiols, stems and storage roots. Samples of the various plant parts (excluding fallen leaves which were not collected) were chopped into small pieces and oven-dried at 75°C at a constant weight to determine dry matter. Subsamples of the dry matter of the different plant parts were ground through a 40-mesh screen Wiley laboratory mil. The nutrient contents of samples were determined according to Salinas and Garcia (1985) and Thomas et al., (1967). Subsamples were digested in sulfuric acid and the contents of N and P in solution were determined colorimetrically on an autoanalyzer; K, Ca and Mg were determined by atomic absorption spectrometry. The nutrient uptake was calculated on basis of unit dry matter of harvested biomass and then converted to kg nutrient ha^{-1}.

Leaf area index (LAI) was determined at each harvest using a 20-leaf sample from different canopy levels; its area was determined and then oven-dried to obtain specific leaf dry weight. The total dry weight of leaves from each harvest was converted to leaf area using the sample specific leaf weight (Veltkamp, 1985).

RESULTS AND DISCUSSION

Leaf area index (LAI) and biomass production

At all harvests in both cycles (except the short group at 4 months in 1994/1995), LAI varied significantly among cultivars within each height group (Table 1). In all cultivars, LAI peaked at 4-6 months and then declined greatly at 10 months. In both cropping cycles, the tall group had significantly greater LAI than the short group with intermediate values in the medium one indicating that LAI in cassava is directly related to plant height, regardless of branching habit. In general, LAI is affected by both the time and levels of reproductive branching, with greater values often observed with early branching cultivars as well as with greater levels of branching (Hunt et al., 1997; Cock et al., 1979). Nevertheless, in this trial there were different branching habits among cultivars, and groups (eye observation).

The low LAI in the short group indicates that light interception at this plant density was much lower throughout the growth cycle as compared with the two other groups. Thus, higher plant population density would have been advantageous in terms of light interception in short cassava. Even in tall cultivars, LAI did not reach the optimum values for root production as predicted by the simulation model developed by Cock et al., (1979). In the first cycle, rainfall was much less than pan evaporation from 3 to 5 months after planting, hence leaf formation might have been reduced. On the other hand, excess rainfall from 3 to 7 months after planting in the second cycle might have enhanced leaf fall, particularly in the tall cultivars.

Top biomass varied significantly among cultivars within each group at all harvests and in both cycles (Table 2). Tall cultivars had significantly greater top biomass than short and medium ones at 6 and 10 months after planting in both cropping cycles. The smallest top biomass was observed in the short cultivars at all harvests in both years. In the second cycle, however, top biomass was greater than those in the first cycle in all cultivars, indicating the favorable effect of higher precipitation in the second cycle. As in LAI, mid-season water deficit in the first cycle might have adversely affected top growth. This observation confirms earlier reports on the effects of early and mid-season water stress on top growth of cassava (El-Sharkawy et al., 1992, 1998).

Root yield varied significantly among cultivars within each group at all harvests in both cycles (Table 3). There were no significant differences in root yield at 6 and 10 months among groups of plant height in the first cycle, whereas differences were significant at 4 and 10 months after planting in the second cycle. The tall cultivars had the largest average root yield at 10 months in the second cycle and the short cultivars had the smallest yield. The medium cultivars had intermediate average root yield. In the second cycle, final yields were higher than those in the first cycle in the tall cultivars. On the other hand, yields of the short cultivars were lower in the second cycle as compared to yields in the first cycle. It appears that the higher precipitation in the second season favored root production in the tall cultivars, whereas it adversely affected short cultivars. There were no mayor changes in average final root yield in the medium cultivars in the two cycles. It is noteworthy that both medium and short cultivars tended to have earlier root bulking as indicated by the higher root yield at 4 months as compared to the tall cultivars.

Differences in root yield among genotype groups were much less than differences in top biomass (compare data of Tables 2 and 3), indicating a higher partitioning ratio of photoassimilates towards roots in the medium and short groups as compared to the tall one. This observation was further substantiated by differences in harvest index (root yield/total biomass) among groups of cultivars. As an average of both cropping cycles, the harvest indices at 10 months after planting were 0.78, 0.74 and 0.66 for the short, medium and tall groups, respectively. These findings point to the advantage of breeding cassava cultivars with shorter stems without large reductions in root yield. Furthermore, increasing population density in medium and short-stemmed cultivars could be beneficial in terms of light interception and hence productivity. Using higher population density should also increase ground cover early in the growing season and thus reduces soil erosion in cassava-based

TABLE 1. Leaf area index (LAI) of tall, medium and short cassava. Harvests were made at 2, 4, 6 and 10 months after planting

Cultivar	1994/1995				1995/1996			
	2	4	6	10	2	4	6	10
Tall								
CG 402-11	0.4	1.8	3.2	2.4	0.3	2.4	2.7	2.4
CM 4574-7	0.6	1.5	2.1	1.2	0.4	2.1	1.3	0.6
M Bra 110	0.5	1.4	1.9	1.7	0.5	2.1	1.5	2.2
M Mal 48	0.6	1.9	1.6	1.4	0.6	3.4	1.8	0.8
M Pan 51	0.3	1.2	1.6	0.3	0.4	1.9	1.0	0.2
Avg.	0.5	1.6	2.1	1.4	0.4	2.4	1.7	1.2
LSD 5% (Duncan) for cultivars	0.2	0.7	0.5	0.4	0.1	0.8	0.7	0.6
Medium								
CM 507-37	0.3	2.0	2.0	0.4	0.4	2.7	2.2	0.7
CM 2766-5	0.3	1.2	1.2	0.1	0.2	2.1	0.5	0.4
CM 4729-4	0.6	1.2	1.6	0.2	0.5	2.7	1.4	0.4
CM 3299-4	0.3	1.6	1.5	0.4	0.2	1.5	1.6	0.3
SG 107-35	0.3	0.9	1.3	0.3	0.4	2.0	0.6	0.3
Avg.	0.4	1.4	1.5	0.3	0.3	2.2	1.3	0.4
LSD 5% (Duncan) for cultivars	0.1	0.5	0.5	9.1	0.1	0.5	0.4	0.3
Short								
CG 1141-1	0.3	1.2	2.0	0.7	0.3	1.6	1.4	0.3
CG 1420-1	0.3	1.5	1.3	0.3	0.2	2.4	1.6	0.2
M Col 22	0.2	1.4	1.0	0.4	0.2	1.7	0.6	0.2
M Bra 900	0.2	1.1	1.1	0.2	0.3	1.6	0.6	0.3
SG 536-1	0.2	1.3	1.5	0.3	0.2	2.0	1.6	0.4
Avg.	0.2	1.3	1.4	0.4	0.2	1.9	1.2	0.3
LSD 5% (Duncan) for cultivars	0.1	NS	0.4	0.1	0.1	0.6	0.5	0.2
LSD 5% (Duncan) for groups of cultivars	0.1	NS	0.5	0.3	0.1	NS	0.5	0.4

NS = Not significant at 5%

cropping systems (Howeler, 1994; Ruppenthal et al., 1997). However, further research is warranted to study the response of short-stemmed cassava to prolonged water stress as well as to soil fertility and to determine their potential for drought-prone areas such as northeastern Brazil and sub-Saharan Africa (El-Sharkawy, 1993). Moreover, potential production of planting materials with good quality and sufficient quantity should be also assessed, especially for short-stemmed cultivars.

Nutrient uptake

Table 4 summarizes data on nutrient uptake in top biomass at final harvest (10 months) in the two cropping cycles. In both cycles, there were significant differences in uptake of all nutrients among cultivars within plant height groups. Differences in uptake among groups were also significant for all nutrients in both years with the largest uptake in the tall cultivars and the smallest uptake in the short ones. The medium cultivars had intermediate uptake. This pattern in nutrient uptake coincided with patterns in top biomass production (Table 2). With the exception of the short cultivars, nutrient uptake was greater in the second cycle than in the first one indicating again differences in top biomass production between the two cycles. The largest uptake in top biomass was in N followed by K, Ca, Mg and P, in a decreasing order.

Nutrient uptake in roots at final harvest also differed significantly among cultivars within groups in both cycles (Table 5). Differences among groups were significant only in the second cycle for all nutrients except N. The largest uptake in the second cycle were in the tall cultivars and the smallest in the short cultivars due to differences in root yield (Table 3). The medium cultivars had intermediate uptake. In the first cycle the largest uptake was in N, whereas in the second cycle the largest

TABLE 2. Top biomass (t ha^{-1} dry weight) of tall, medium and short cassava. Harvests were made at 2, 4, 6 and 10 months after planting

Cultivar	1994/1995				1995/1996			
	2	4	6	10	2	4	6	10
Tall								
CG 402-11	0.3	2.3	3.6	7.1	0.2	2.3	5.5	8.8
CM 4574-7	0.4	2.2	2.7	6.0	0.3	2.4	2.4	5.6
M Bra 110	0.3	2.0	3.2	5.7	0.3	2.3	2.8	9.5
M Mal 48	0.4	2.2	2.3	5.5	0.4	2.9	3.4	9.0
M Pan 51	0.3	1.8	4.9	4.7	0.3	2.5	3.4	5.0
Avg.	0.3	2.1	3.3	5.8	0.3	2.5	3.3	7.6
LSD 5% (Duncan) for cultivars	0.1	0.4	1.2	1.0	0.1	0.5	1.1	2.0
Medium								
CM 507-37	0.2	2.4	2.6	3.7	0.3	2.6	3.2	5.6
CM 2766-5	0.2	1.3	1.5	2.9	0.1	1.8	1.4	3.4
CM 4729-4	0.4	1.7	2.4	4.9	0.4	3.2	3.9	6.0
CM 3299-4	0.2	1.3	1.7	2.0	0.1	1.4	2.3	4.5
SG 107-35	0.3	1.3	1.7	3.2	0.3	2.3	2.3	4.9
Avg.	0.2	1.6	2.0	3.3	0.3	2.3	2.6	4.9
LSD 5% (Duncan) for cultivars	0.1	0.8	0.6	0.8	0.1	0.6	0.5	1.1
Short								
CG 1141-1	0.2	1.2	1.8	2.6	0.2	1.4	1.8	2.1
CG 1420-1	0.2	1.3	1.3	2.1	0.2	1.9	2.1	2.3
M Col 22	0.2	1.4	1.2	3.0	0.2	1.5	1.3	2.0
M Bra 900	0.2	1.5	1.4	2.1	0.2	1.8	1.8	3.3
SG 536-1	0.1	1.4	1.7	3.2	0.1	2.0	2.8	4.2
Avg.	0.2	1.4	1.5	2.6	0.2	1.7	2.0	2.8
LSD 5% (Duncan) for cultivars	NS	0.3	0.4	0.8	0.1	0.5	0.7	0.7
LSD 5% (Duncan) for groups of cultivars	0.1	0.6	0.9	0.9	0.1	0.5	0.7	1.5

NS = Not significant at 5%

uptake was in K. It appears, therefore, that the water deficit that occurred from 3 to 5 months after planting in the first cycle favored N accumulation in roots, thus confirming similar findings by El-Sharkawy et al., (1998).

Nutrient use efficiency

There were significant differences among cultivars within groups for root nutrient use efficiency of all elements in both cropping cycles (Table 6). Differences among genotype groups were also significant for all elements with the lowest values in the tall cultivars. These findings indicate that in terms of root production, medium to short cultivars are advantageous due to their higher nutrient use efficiency as compared to the tall ones. This was mainly due to the much lower top biomass in short-stemmed cassava, and hence lesser nutrient uptake (Table 4). Moreover, differences in nutrient use efficiency could also be partly attributed to the higher harvest indices in the short-stemmed cultivars as compared to the tall ones.

There were significant differences among cultivars within groups in total biomass nutrient use efficiency of all elements in both cropping cycles (Table 7). However, differences among groups were significant only for Ca in the first cycle and for N in the second cycle. In both elements, the tall cultivars had the lowest values. Thus, the large top biomass in tall cultivars did not result in better nutrient use efficiency as compared with short-stemmed cultivars.

TABLE 3. Root yield (t ha^{-1} dry weight) of tall, medium and short cassava. Harvests were made at 2, 4, 6 and 10 months after planting

Cultivar	1994/1995				1995/1996			
	2	4	6	10	2	4	6	10
Tall								
CG 402-11	0.01	0.9	1.5	9.2	0.01	0.6	5.4	14.5
CM 4574-7	0.01	1.9	3.0	13.8	0.01	1.6	5.9	15.2
M Bra 110	0.01	1.6	2.3	10.5	0.01	0.9	4.1	12.3
M Mal 48	0.02	2.2	4.1	14.4	0.02	2.1	7.1	19.9
M Pan 51	0.01	1.6	2.4	8.7	0.01	1.2	5.0	8.6
Avg.	0.01	1.6	2.7	11.3	0.01	1.3	5.5	14.1
LSD 5% (Duncan) for cultivars	0.01	0.4	0.6	1.8	0.01	0.4	1.9	2.7
Medium								
CM 507-37	0.01	1.7	2.6	11.6	0.02	1.4	5.8	13.2
CM 2766-5	0.01	1.7	2.0	10.1	0.01	1.3	4.9	10.0
CM 4729-4	0.03	3.5	3.8	13.3	0.03	2.7	9.3	12.6
CM 3299-4	0.01	2.3	3.3	10.4	0.01	1.4	5.8	1.3
SG 107-35	0.02	2.6	3.1	9.8	0.04	2.9	6.6	12.5
Avg.	0.02	2.3	2.9	11.0	0.02	1.9	6.5	11.7
LSD 5% (Duncan) for cultivars	0.01	0.5	0.9	2.0	0.01	0.4	1.9	2.8
Short								
CG 1141-1	0.01	2.6	4.0	15.0	0.01	1.6	6.2	10.3
CG 1420-1	0.01	2.2	2.6	9.6	0.01	1.8	6.6	8.3
M Col 22	0.01	2.2	2.7	9.7	0.01	1.9	5.4	7.3
M Bra 900	0.01	2.3	2.6	8.3	0.01	1.4	5.5	8.6
SG 536-1	0.01	1.8	2.6	8.7	0.01	0.6	4.3	9.6
Avg.	0.01	2.2	2.9	10.3	0.01	1.5	5.6	8.8
LSD 5% (Duncan) for cultivars	NS	0.6	0.9	1.5	NS	0.8	1.7	2.0
LSD 5% (Duncan) for groups of cultivars	0.01	0.50	NS	NS	0.01	0.6	NS	2.7

NS = Not significant at 5%

TABLE 4. Nutrient uptake (kg ha^{-1}) in top biomass at 10 months after planting of tall, medium and short cassava

Cultivar	1994/1995					1995/1996				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Tall										
CG 402-11	80	8	39	29	13	106	13	64	41	19
CM 4574-7	65	7	41	25	12	53	8	37	20	11
M Bra 110	75	6	46	25	13	111	14	68	45	22
M Mal 48	69	6	31	23	12	88	12	60	36	19
M Pan 51	45	4	31	19	8	43	6	32	20	10
Avg.	67	6	38	24	12	80	11	52	32	16
LSD 5% (Duncan) for cultivars	14.9	1.3	11.5	5.9	2.9	23.5	2.9	14.3	9.2	4.5
Medium										
CM 507-37	44	4	17	15	10	49	7	39	22	12
CM 2766-5	33	3	16	13	7	31	4	20	14	7
CM 4729-4	49	5	31	17	10	57	8	39	30	15
CM 3299-4	30	2	23	11	5	45	6	32	23	12
SG 107-35	43	4	20	13	7	45	6	31	22	11
Avg.	40	4	21	14	8	45	6	32	22	11
LSD 5% (Duncan) for cultivars	10.0	0.9	8.2	3.3	1.3	9.5	1.4	7.7	4.6	2.5
Short										
CG 1141-1	40	3	19	16	8	22	3	14	11	5
CG 1420-1	27	2	17	11	6	23	3	14	10	5
M Col 22	33	3	15	15	7	21	3	13	10	5
M Bra 900	35	3	17	13	6	31	4	21	18	8
SG 536-1	35	3	23	15	5	43	5	27	24	11
Avg.	34	3	18	14	6	28	4	18	15	7
LSD 5% (Duncan) for cultivars	10.4	0.9	5.2	3.3	1.3	7.9	0.9	4.6	3.9	1.7
LSD 5% (Duncan) for groups of cultivars	11.2	1.1	11.4	4.5	2.0	15.9	2.0	10.2	6.6	3.3

TABLE 5. Nutrient uptake (kg ha^{-1}) in root biomass at 10 months after planting of tall, medium and short cassava

Cultivar	1994/1995					1995/1996				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Tall										
CG 402-11	33	6	35	7	5	43	13	61	9	10
CM 4574-7	41	9	51	12	8	41	12	62	11	11
M Bra 110	51	9	44	8	6	37	10	53	7	9
M Mal 48	74	11	59	12	9	58	16	85	12	14
M Pan 51	51	7	33	7	5	24	7	38	7	7
Avg.	50	8	44	9	7	41	12	60	9	10
LSD 5% (Duncan) for cultivars	12.6	1.8	8.5	3.7	2.1	7.7	2.2	11.5	1.8	1.9
Medium										
CM 507-37	43	8	47	12	9	38	11	55	9	9
CM 2766-5	55	7	52	9	6	28	8	42	7	7
CM 4729-4	67	11	64	10	8	38	10	53	8	9
CM 3299-4	66	9	48	9	7	29	8	43	8	7
SG 107-35	48	8	54	8	8	36	11	51	6	9
Avg.	56	9	53	10	7	34	10	49	8	8
LSD 5% (Duncan) for cultivars	11.3	1.9	16.6	3.9	2.3	10.9	3.0	15.7	2.4	2.6
Short										
CG 1141-1	78	10	56	13	10	28	8	45	8	8
CG 1420-1	60	8	47	9	6	25	7	35	5	6
M Col 22	53	7	32	12	8	33	7	34	6	6
M Bra 900	58	7	49	8	7	40	8	41	9	8
SG 536-1	45	6	36	12	7	46	9	45	8	8
Avg.	59	8	44	11	7	34	8	40	7	7
LSD 5% (Duncan) for cultivars	18.8	2.0	12.4	2.8	2.5	7.3	1.7	9.1	1.6	1.6
LSD 5% (Duncan) for groups of cultivars	NS	NS	NS	NS	NS	NS	2.2	11.3	1.8	1.9

NS = Not significant at 5%

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TABLE 6. Nutrient use efficiency for root production at 10 months after planting (kg dry wt kg^{-1} total nutrient uptake) of tall, medium and short cassava

Cultivar	1994/1995					1995/1996				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Tall										
CG 402-11	82	694	124	258	504	97	556	116	293	501
CM 4574-7	130	933	150	385	710	161	765	153	492	696
M Bra 110	84	652	118	319	568	84	528	102	235	406
M Mal 48	101	837	159	412	691	139	714	137	423	620
M Pan 51	91	788	139	333	686	128	685	123	324	503
Avg.	98	781	138	341	632	122	650	126	353	545
LSD 5% (Duncan) for cultivars	16	88	26	89	90	16	66	12	61	74
Medium										
CM 507-37	134	971	187	436	632	151	750	139	428	616
CM 2766-5	116	1007	150	455	853	169	817	159	466	712
CM 4729-4	115	846	143	491	769	131	711	136	337	528
CM 3299-4	110	948	157	519	905	140	741	137	335	550
SG 107-35	109	860	134	477	665	151	722	152	422	631
Avg.	117	926	154	476	765	148	748	143	402	607
LSD 5% (Duncan) for cultivars	14	118	36	86	120	20	77	15	73	91
Short										
CG 1141-1	127	1102	203	523	821	206	938	171	532	768
CG 1420-1	112	944	152	485	834	176	876	171	535	768
M Col 22	115	1019	206	371	681	135	794	154	458	684
M Bra 900	91	819	127	410	657	123	728	138	317	547
SG 536-1	109	934	153	331	703	108	688	133	307	520
Avg.	111	964	168	424	679	150	805	153	435	659
LSD 5% (Duncan) for cultivars	20	105	40	82	101	18	54	10	65	65
LSD 5% (Duncan) for groups of cultivars	17	103	33	85	106	19	67	12	69	78

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TABLE 7. Nutrient use efficiency for total biomass production at 10 months after planting (kg dry wt kg^{-1} total nutrient uptake) of tall, medium and short cassava

Cultivar	1994/1995					1995/1996				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Tall										
CG 402-11	144	1228	220	457	894	157	896	187	471	807
CM 4574-7	186	1337	215	552	1017	221	1051	210	675	956
M Bra 110	130	1003	180	489	871	148	934	181	416	718
M Mal 48	139	1155	220	570	954	200	1029	198	608	893
M Pan 51	140	1218	212	511	1055	203	1087	195	513	798
Avg.	148	1188	209	516	958	186	999	194	537	834
LSD 5% (Duncan) for cultivars	18	105	28	112	149	11	80	24	98	66
Medium										
CM 507-37	177	1282	247	574	835	214	1066	198	607	873
CM 2766-5	148	1290	193	582	1091	227	1097	214	624	955
CM 4729-4	156	1155	194	667	1048	195	1056	202	500	784
CM 3299-4	131	1126	186	616	1072	200	1064	197	480	789
SG 107-35	144	1138	177	631	881	213	1006	212	615	879
Avg.	151	1198	199	614	985	210	1058	205	565	856
LSD 5% (Duncan) for cultivars	17	152	46	98	180	13	91	25	88	61
Short										
CG 1141-1	148	1290	237	612	960	247	1128	206	637	922
CG 1420-1	138	1155	186	591	1023	223	1113	217	713	985
M Col 22	150	1334	269	482	889	172	1013	197	583	872
M Bra 900	114	1025	159	514	822	169	1002	189	436	754
SG 536-1	149	1269	207	447	964	155	989	191	439	748
Avg.	140	1215	212	529	932	193	1049	200	562	856
LSD 5% (Duncan) for cultivars	27	145	142	71	24	15	85	17	61	47
LSD 5% (Duncan) for groups of cultivars	NS	NS	NS	90	NS	15	NS	NS	NS	NS

NS = Not significant at 5%

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