academicJournals

Vol. 6(6), pp. 64-72, June 2014
DOI: 10.5897/JPBCS2013.0452
Article Number: 7B7F2BE45505
ISSN 2006-9758

http://www.academicjournals.org/JPBCS

Journal of Plant Breeding and Crop Science

Full Length Research Paper

Effect of initial stem nodal cutting strength on dry matter production and accumulation in cassava (*Manihot esculenta* Crantz)

Puran Bridgemohan* and Ronell S. H. Bridgemohan

Department of Crop Science, Waterloo Research Campus, The University of Trinidad and Tobago, Waterloo Estates, Trinidad and Tobago.

Received 24 March, 2014; Accepted 2 June, 2014

This study was done to determine the effect of initial node strength on dry matter yield of cassava. Studies were conducted at the Waterloo Research Campus, University of Trinidad and Tobago using the sets of Mexican variety (Mx) at 6 months with 1 to 3 nodes, 4 to 9 cm, and dry matter of 6 to 15 g/set. The crop was established at 60 × 80 cm and treated with a compound NPK fertilizer. Growth analysis (functional approach) was carried from 20 to 340 Days after emergence (DAE), and the best fit polynomial regression applied. The results indicated that tuberization started after 120 DAE and tuber dry weight increased with increasing set size ($Y_{TDW} = -1177 + 9.90D - 1.26^{-2} D^2 + 37.7N^2$). The 3 node sets produced ($P > 0.05$) the highest tuber yield. The leaf area ratio (LAR) showed ($P > 0.001$) a quadratic response ($Y_{lar} = 12.8 - 1.94 H - 2.39 N + 0.08 H^2 + 0.18 N{*}H$), peaked at 2 $g/cm^2/day^1$, and declined at harvest. Both the net assimilation rate (NAR) and the relative growth rate (RGR) were not affected by the number of nodes, however, the NAR peaked 0.046 $g/m^2/day$ at 60 DAE. The initial strength of 3 nodes sets proved to be superior to the single node sets.

Key words: Cassava, growth analysis, tuberization, nodes, sets.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) which is considered a traditional subsistence crop in the Caribbean and Latin America has emerged as a global cash crop for food and fuel. The crop can produce more edible energy per hectare per day than any other crop, and the capacity to generate high yields under conditions where other crops might fail (Sousa and Nassar, 2007). It represents the fourth greatest source of calories in the world after rice (*Oryza sativa*), sugarcane (*Saccharum officinarum*) and maize (*Zea mays*) (Medina et al., 2007).

The crop is easily propagated by stem cuttings, drought tolerant, and establishes well on marginal soils with satisfactory yield. It has low exigency for sophisticated cultural requirements; potential pest and disease resistance, high root starch contents and good mechanization prospect (Cereda and Vilpoux, 2003).

*Corresponding author. E-mail: puran.bridgemohan@utt.edu.tt.

The cassava stem cuttings are used as planting materials and these produce two adventitious root types which are used for absorption and storage. The fibrous roots absorb water and minerals and provide support; storage roots accumulate starch (Dominguez et al., 1982).

The quality of cassava planting material or set depends on the stem age, the thickness, number of nodes per cutting and size (Lozano et al., 1977). The control of these factors is essential for the development of vigorous plants capable of producing good number of commercial (storage) roots. Stems older than 8 months are highly lignified and should not be used as planting material. These stems have fewer nutrient reserves, produce weak shoots and only a few storage roots. Toro et al. (1976) found that green stem cuttings and cuttings with 1 to 3 nodes have low germination capability in the field, and are susceptible to dehydration and pathogen invasion. However, long cuttings with more than 10 nodes have a better chance of conserving their viability. It is recommended that stem cuttings of 5 to 7 nodes and minimum length of 20 cm to be used to obtain optimum yield (Carvahlo et al., 1993).

Onwueme (1978) observed that cuttings with 4 to 7 nodes did not differ with respect to mean storage root length, radius of storage root tip, or the number of major stems per plant. However, Lahai et al. (1999) noted that longer cuttings produced a fast growing canopy. Unlike many other crops, foliage and storage roots of cassava grow simultaneously, resulting in competition for assimilate, dry matter production, and phasic development. Gray (2000) proposed two models for the growth and development of cassava, based on the assimilate allocation to storage roots. The spill-over hypothesis for assimilate allocation to storage root governs storage root growth. He found that the number of nodes defined the limits of the load bearing capacity of the shoot, and that the growth demands of the stem, fibrous roots and storage roots are related to leaf demand rates.

San Jose and Maybore (1982) observed that the plant maintained a good canopy high leaf area index (LAI) and net rate of photosynthesis. During tuberization, the cassava plants produced a progressively higher proportion of new leaves and maintained throughout the season a relatively high net assimilation rate (NAR) and LAI.

Storage root number and root yield were shown to be affected by cutting size and root yield was associated with the number of storage roots (Didier and El-Sharkawy, 1994). Furthermore, harvest index and sink-source ratio (root numbers/LAI) were correlated with root number (Carvahlo et al., 1993). Dry matter partitioning followed a simple allometric pattern with the proportionality between the relative growth rate (RGR) of shoots and the RGR of storage roots remaining constant with time but being altered by photoperiod (Keating et al., 1985).

The normal farmer practice in the Caribbean is to use cuttings between 15 to 40 cm from 6 to 8 months old plants with a minimum of 3 to 5 nodes in order to achieve better germination and survival. The assumption is that a larger cutting has a higher opportunity for sprouting and developing due to the presence of more nodes and higher carbohydrate reserves. However, the new recommended approach in Trinidad and Tobago is to use single node cuttings that are excised from 3 months old plants that are disease free. It was observed that the germination was often low, and the subsequent growth, development and yield were variable, and may have been influenced by the low dry matter stored in the initial sets.

The objective of this study was to determine the relative effect of initial stem cutting node size on dry matter production and accumulation of cassava.

MATERIALS AND METHODS

Two field and two pot trials were conducted at the Centre Bioscience, Agriculture and Food Technology, Waterloo Research Campus, University of Trinidad and Tobago, from 2008 to 2011. The pot trials were established on the same soil type as that of the field station. For this purpose, the soil was pulverized and sieved to remove all debris, and solarized to kill weed seeds. The soil type was the Mc. Bean Estate sandy loam with an average CEC of 4.8 meq/100 g; a pH (water soil solution) of 5.7; sand, silt, and clay content of 61.0, 14.5, and 24.5%, respectively, in the upper 0.5 m soil.

The cassava variety used in all trials was the improved high-yielding Mexican variety (Mx) which was introduced in the early 1980's to the island. The planting material or sets were taken from 6 months old healthy cassava plants. The sett sizes treatments were 1, 2, 3, and 4 nodes (N) which varied from 4 to 9 cm in length and ranged in dry matter content from 6 to 15 g/set (Table 1). The sets were cut with a sharp blade sterilized in alcohol (90%) and treated with a fungicidal dip of Alliete [aluminum tris (O-ethyl phosphonate)] against soil-borne fungal pathogens.

The pot trials were conducted under full sunlight conditions. The cassava sets were established in plastic drums filled with 50 L of the solarized soil. At the time of planting, 500 kg/ha of P_2O_5 (triple calcium superphosphate) equivalent was incorporated into the soil as a basal application. Compound NPK fertilizer (13% N : 23% P_2O_5 : 13% K_2O) was top-dressed at the rate of 56.25 g/pl 40 days after planting (DAP), and 47.25 g/plant at 80 DAP.

The pots were placed 60 × 80 cm apart, and the pots lay out to give an effective density of 20.8 thousands plants per hectare (tph). The field trials were conducted on ridges with a similar spacing. The field was weed-free before planting and all subsequent weed control was done manually. No pesticides were used in the experiments. The trial was manually irrigated with 1000 to 1500 ml of water per pot daily to supplement rainfall

Plants were harvested for biomass measurements starting from 20 days after emergence (DAE) at intervals of 20 days until 340 DAE. Plant height and stem diameter were measured at each harvest (D) in four plants from each of the four treatments (Ekanayake, 1996). At each harvest, plants were separated into leaf laminae, petioles, stems, fibrous and tuberous roots and dried in a forced-air oven at 65°C for 72 h (to constant weight) for dry matter determination. Best fit polynomial regression curves were used for growth analysis (Hunt et al., 2002). RGR, NAR, specific leaf area (SLA), leaf area (LA), leaf area ratio (LAR), leaf weight fraction (LWF), shoot dry weight (SDW), and tuber dry weight (TDW) were determined as described by Hunt et al. (2002). Air temperature,

Table 1. Characteristics of the various set sizes before planting.

Sett type	Number of nodes	Node length (cm)	Node diameter (cm)	Pith diameter (cm)	Dry matter (g)
N1	1	4.3	2.1	1.2	6.71
N2	2	6.1	2.1	1.2	8.29
N3	3	8.0	2.2	1.2	11.93
N4	4	9.3	2.2	1.2	15.31
SE		2.21	0.096	0.015	4.241

rainfall, and solar radiation during the experiments were calculated with an automated weather station (Davis Instruments, California) located within the station compound.

Light interception was determined during the morning (10.00 to 11.00 am) hours by measuring the radiation above the canopy, and at soil level using an integrated quantum sensor (Model LJ - 185B Quantum Radiometer/Photometer, LICOR, Inc, Lincoln, NE 68504). LA was measured using an area meter (Type AAM - 5 Hayashi Denko Co. Ltd. Japan). The crop was harvested every 10 days after sowing for dry matter determination and final tuber harvested when most of the shoots and leaves were in senescence. The effect of set size on the production and partitioning of assimilates was monitored in the pot trials only, while tuber yield was calculated in the field study. Treatments in field and pot trials were laid out as a completely randomized design with four replicates. The experimental plots were bordered by two guard rows and the data analyzed using MINITAB 15.

RESULTS AND DISCUSSION

The effect of the initial stem nodal cutting strength was evaluated based on: 1) the production and accumulation of assimilates (in various plant parts and organs); 2) the partitioning of assimilates (using growth analysis techniques); and 3) dry matter accumulation (prior to and during tuberization).

Production and accumulation of dry matter

Production of dry matter was monitored from 20 DAE to harvest at 340 DAE. The pith area occupied 58% of the total stem area for all sett types, but the initial dry matter before planting differed (Table 1).

At 120 DAE, the set sizes attained their optimum leaf dry weight (LDW) at 21.5, 49.7, 60.2, and 72.5 g/dm^2/plant, respectively. The general trend of LDW was quadratic over the harvesting period (D) (Figure 1). The three-node sett produced a significantly higher ($P < 0.005$) LDW than the others continually throughout the crop growth. During the period of tuberization, the LDW varied between 11.8 to 14.8, 12.6 to 16, and 16 to 21 g/plant for N1, N2, and N3 node sets, respectively.

The cassava LAI provided a generalized view of the photosynthetic primary production of assimilates, and was not affected by sett size (Figure 2). During the 90 to 180 DAE, plants maintained a high LAI of above 6.5 and declined afterwards to an average of 1.5 for the remainder of their growth cycle which was characterized by a significant amount of senescence and leaf fall.

The SDW exhibited a quadratic growth pattern over time for all three types of setts (Figure 3). There was a general linear increase in SDW with increasing node number. This trend is similar to tuber dry matter production. After 200 DAE, the SDW remained constant until harvest. The SDW for N1 and N2 were similar, but the SDW for N3 doubled. The increase started as early as 60 DAE and continued until harvest.

The root dry weight (RDW) was not influenced by sett size or number of nodes (Figure 4). However, it increased over the harvesting intervals and peaked at 90 to 120 DAE, and then leveled off and remained fairly constant through the growth cycle. The process of tuberization started at about 120 DAE. The TDW increased with increasing set size, and at harvest, the 3-node setts produced significantly ($P < 0.05$) higher tuber yield (Figure 5). The increment in TDW continued over time.

Partitioning of assimilates

Values for LAR, SLA, and LWF for the varying cassava set sizes are presented in Figures 6, 7, and 8, respectively. The mean LAR over the 15 harvesting periods showed a significant ($P > 0.001$) quadratic response (Figure 6) and decreased linearly with increasing number of nodes. The LAR reflected the total photosynthetic capacity of the cassava plant to respiration and assimilates balance available for growth, development, and subsequent partitioning and storage in the roots or tubers.

The SLA of the cassava leaf is a good estimate of the productive capacity of the plant and is usually influenced by agro-ecological conditions as light and humidity. It is a measure of the foliage thickness of the crop and photosynthetic capability for assimilates. The SLA (Figure 7) displayed a similar quadratic response to that of the LAR and LWF (Figure 8) over harvest periods.

The RGRs of the three cassava set sizes over the different harvest intervals displayed a significant ($P < 0.001$) quadratic response (Figure 9), and was not influenced by number of nodes. The RGR of the cassava crop measures the productivity as the increase of dry matter per unit above ground plant biomass over a specific period of time. The results indicated an increase of the RGR to maximum of 0.0236 g/day between 60 to 220 DAE, and subsequently declined.

$$Y_{LDW} = -9.31 + 8.34N + 0.18D - 0.49^{-3}D^2 : \quad R^2 = 96.41\%.$$

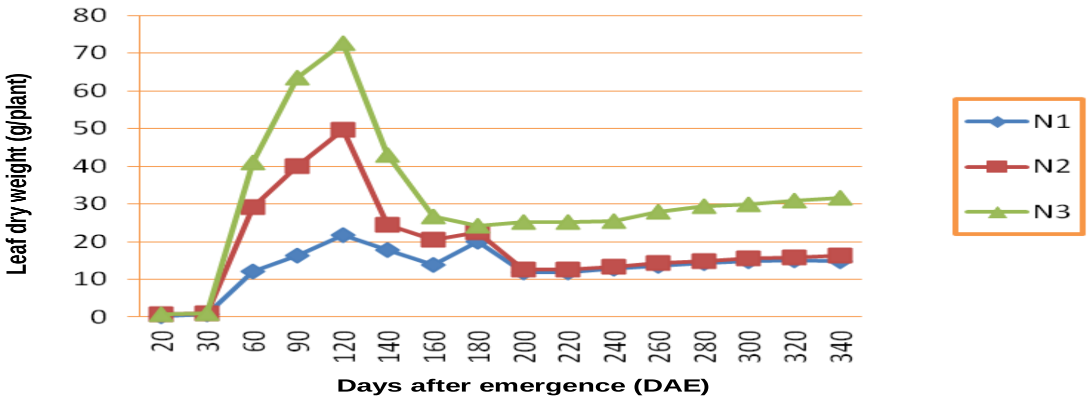

Figure 1. The effects of initial cassava sett nodes on the leaf dry weight (LDW) throughout the crop growth period.

$$Y_{LAI} = 1.54 + 0.03\,D - 0.11^{-3}\,D^2 : R^2 = 83\ \%$$

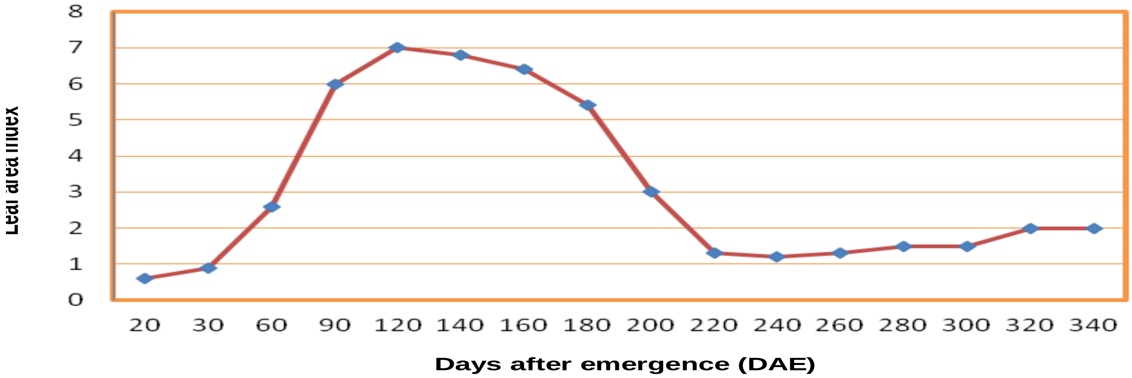

Figure 2. The effects of initial cassava sett nodes on the leaf area index (LAI) throughout the crop growth period.

$$Y_{SDW} = -134 + 1.11D - 1.6^{-3}D^2 + 53.8N \;:\; R^2 = 65.4\%$$

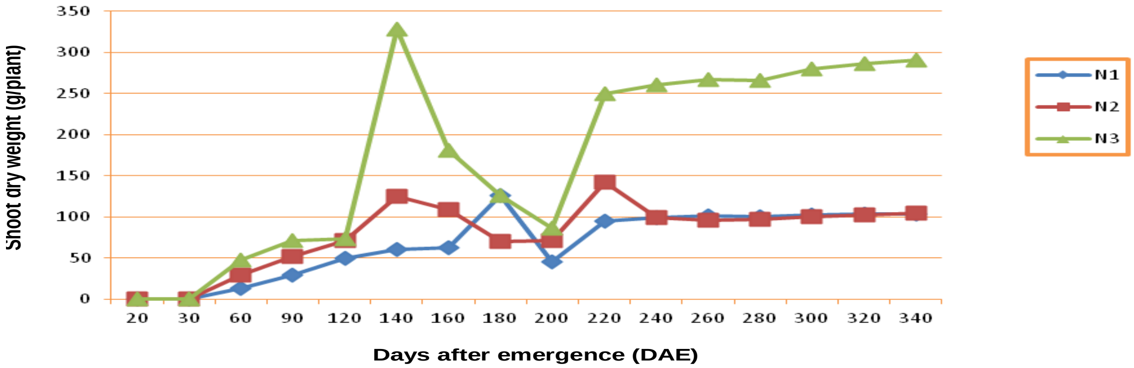

Figure 3. The effects of initial cassava set nodes on the shoot dry weight (SDW) throughout the crop growth period.

$$Y_{RDW} = 15.6 + 0.28D - 0.681^{-3}D^{2} \quad : \quad R^{2} = 96.41\%$$

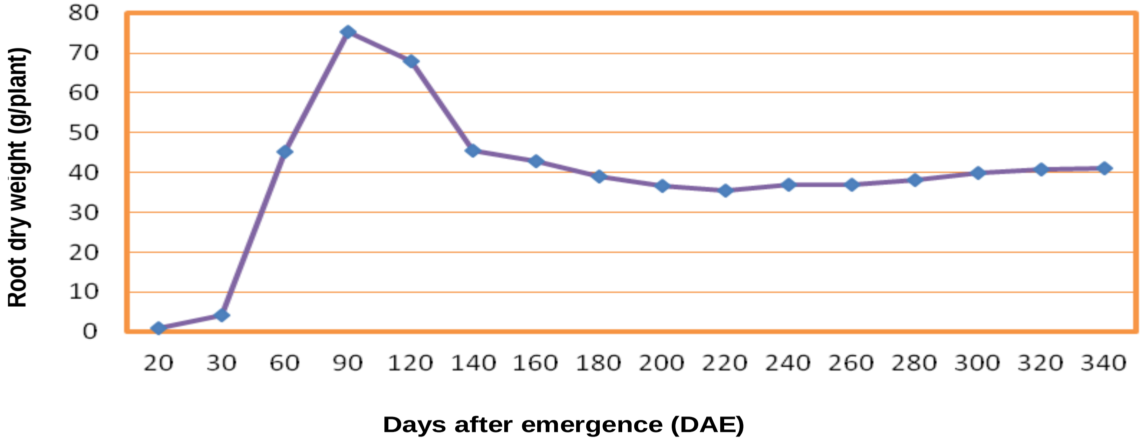

Figure 4. The effects of initial cassava set nodes on the root dry weight (RDW) throughout the crop growth period.

$$Y_{TDW} = -1177 + 9.90D - 1.26^{-2}\,D^{2} + 37.7N^{2}: \quad R^{2} = 84.2\%$$

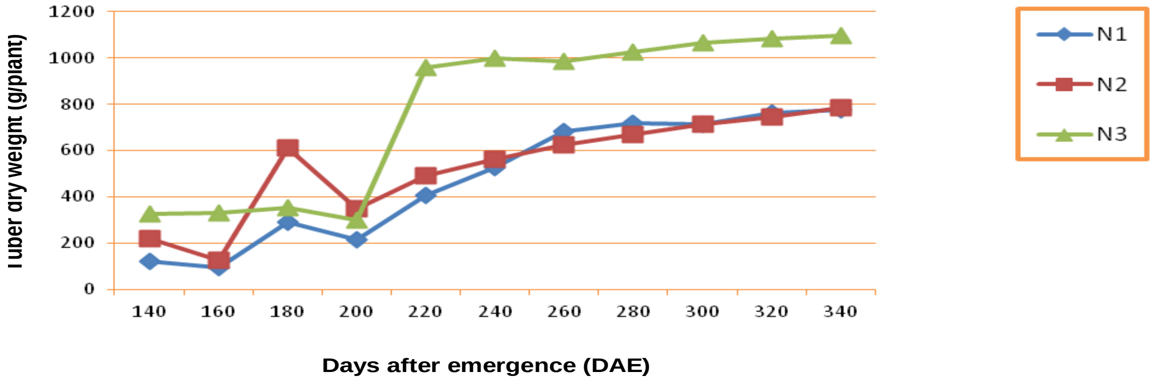

Figure 5. The effects of initial cassava set nodes on the tuber dry weight (TDW) throughout the crop growth period.

$$Y_{lar} = 12.8 - 1.94\,H - 2.39\,N + 0.08\,H^{2} + 0.18\,N{*}H \quad : \quad R2 = 67.6\%.$$

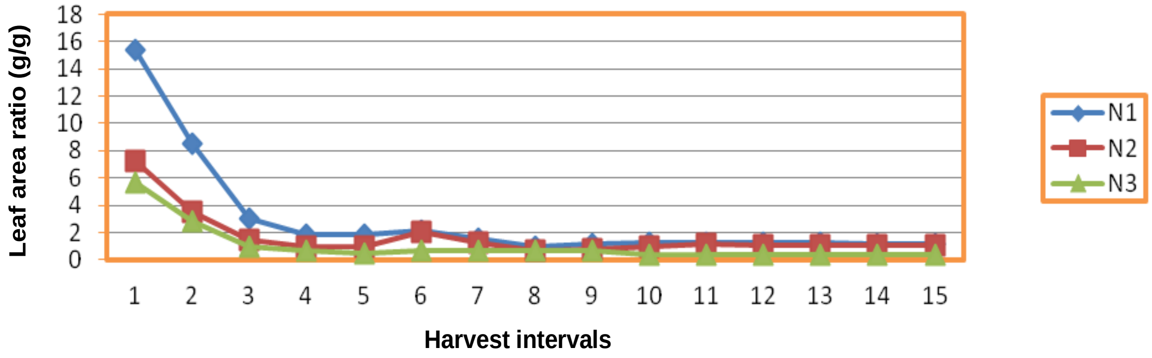

Figure 6. The effect of initial cassava nodes dry matter on the leaf area ratio (LAR) at varying harvest intervals.

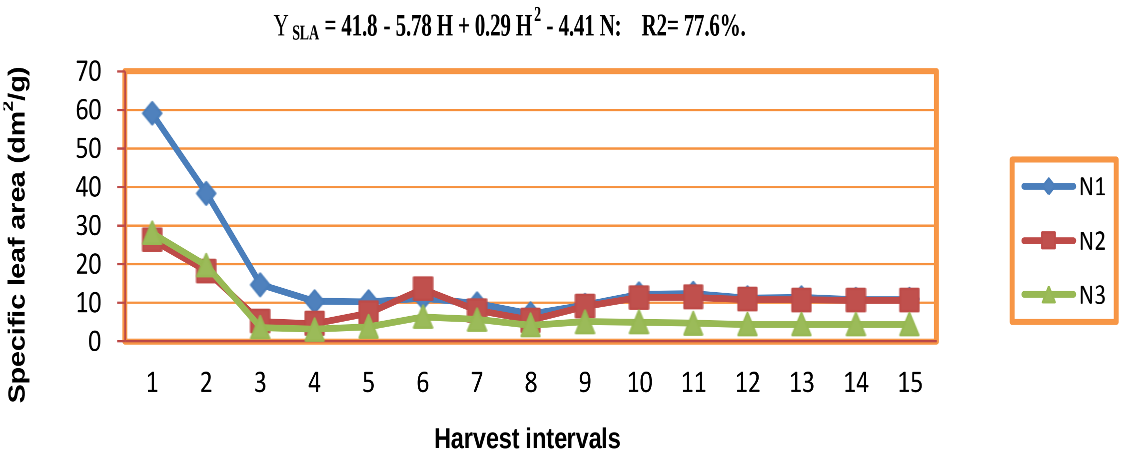

Figure 7. The effect of initial cassava nodes dry matter on the specific leaf area (SLA) at varying harvest intervals.

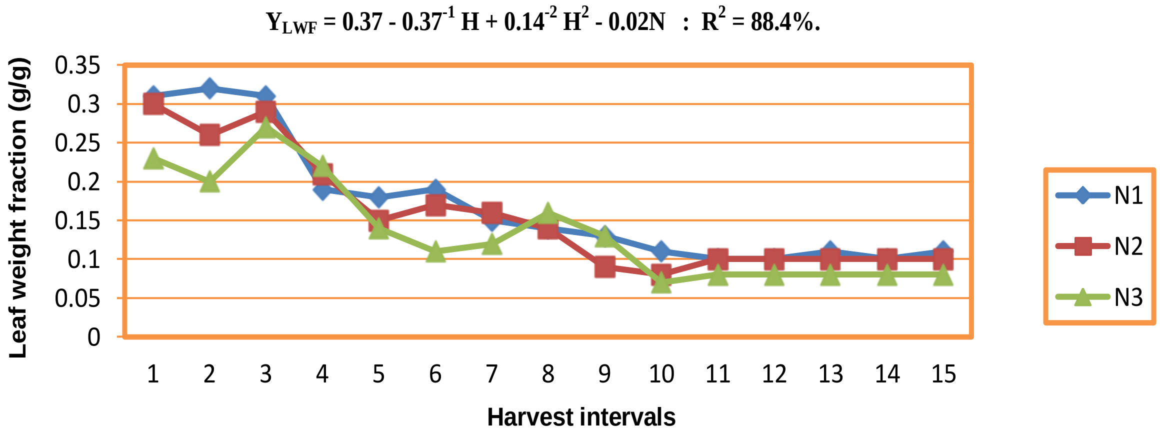

Figure 8. The effect of initial cassava nodes dry matter on the leaf weight fraction (LWF) at varying harvest intervals.

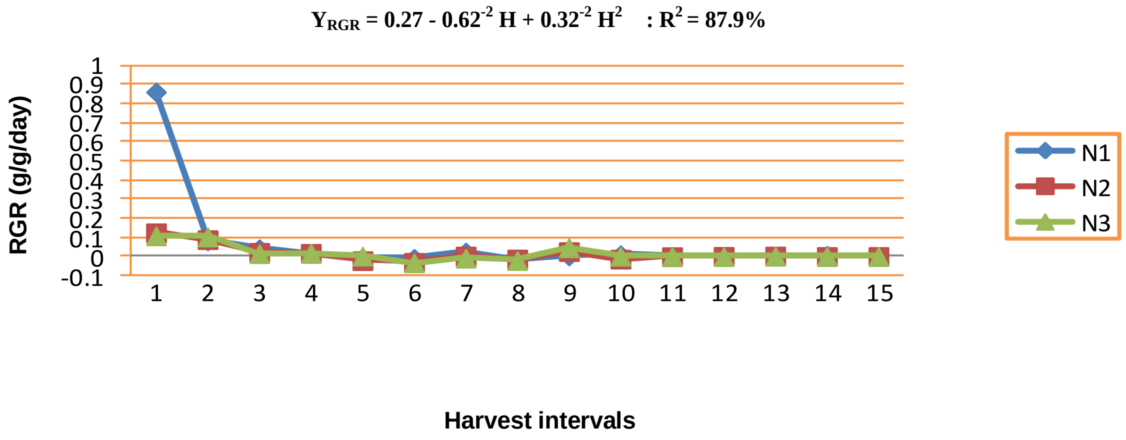

Figure 9. The effect of initial cassava nodes dry matter on the relative growth rate (RGR) at varying harvest intervals.

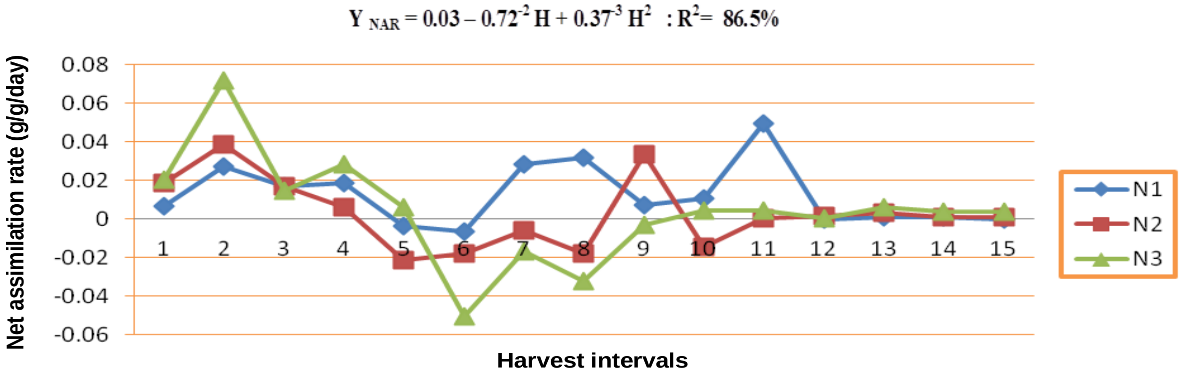

Figure 10. The effect of initial cassava nodes dry matter on the net assimilation rate (NAR) at varying harvest intervals.

Table 2. Growth parameters of the different cassava set sizes at 240 days after planting.

Nodes	Leaf area (cm^2)	Leaf dry weight (g/plant)	Shoot dry weight (g/plant)	Root dry weight (g/plant)
1	158.1	40.2	902.2	78.5
2	153.1	44.2	955.2	133.6
3	165.6	84.4	1092.1	101.3
4	104.5	95.7	596.6	57.95
Y =	7.73 + 0.75D + 2.39N	- 2.7 + 0.1D + 0.4N	-1.68 + 0.10D + 0.42N	- 4. 9 + 0.11D + 0.46N
R^2 (%)	90.1	3.3	96.2	91.2

The trend of the NAR response (Figure 10) followed a similar pattern to that of the RGR, and was not influenced by sett size. The NAR of the cassava crop relates the plant productivity to plant size and the increase in dry weight by leaf size and area. The NAR peaked early at 0.046 g/dm^2/day at 60 DAE, and maintained a steady NAR of 0.0156 to 0.018 g/dm^2/day, and then declined after 260 DAE. Generally, a low NAR will result in a low yields and vice-versa. The reduced NAR at this period of rapid growth could be related to the enhancement of rapid leaf production and expansion rather than biomass production and hence the leaves could be the preferred sink at this stage. Akparobi et al. (1998) suggested that NAR and RGR of cassava exhibited an irregular pattern and decreased with age. The high NAR could be expected with rapid growth.

Dry matter accumulation

The dry matter accumulation prior to tuberization for the varying node sizes are presented in Table 2 and Figure 11. The results indicated that LDW, SDW and LA increased linearly with increasing node number. Similarly, the RDW displayed a similar response up to 120 DAP and up to the initial tuberization.

The effect of node size to dry matter accumulation at the end of tuberization is presented in Figure 11. The entire crop was harvested at 240 days and plants part partitioned for dry matter yield accordingly. The LA was not significant, but the LDW increased linearly with increasing number of nodes. The N3 setts attained the highest shoot dry matter yield (1,092 g/plant). The total dry matter yield of

N1 and N2 treatment were not significantly different and was lower than N3. This variability manifested in a similar pattern with N3 producing the highest tuber yield (1,878 g/plant).

Increasing the nodal length or number of nodes beyond 3 did not enhance tuber fresh yield, and decreased dry matter yield was decreased by 100%. Sagrilo et al. (2008) reported that LDW yield influenced the storage root yield, and that the performance of the storage root dry matter yield followed the same yield pattern as the stem dry matter, and the values of the first were always superior to those of the latter. In this study, the storage root dry matter yield was higher than the stem dry matter yield for some periods.

A cassava growth model, described by Cock et al. (1979) assumed that the storage roots received only the assimilates that remained after meeting all the growth needs of the plant canopy. This assumption results in potential solutions to improve the storage root dry matter production × total dry matter production ratio, as mentioned by Keating et al. (1985). The 3-node sets appeared to give the head start over the 1- and 2-node

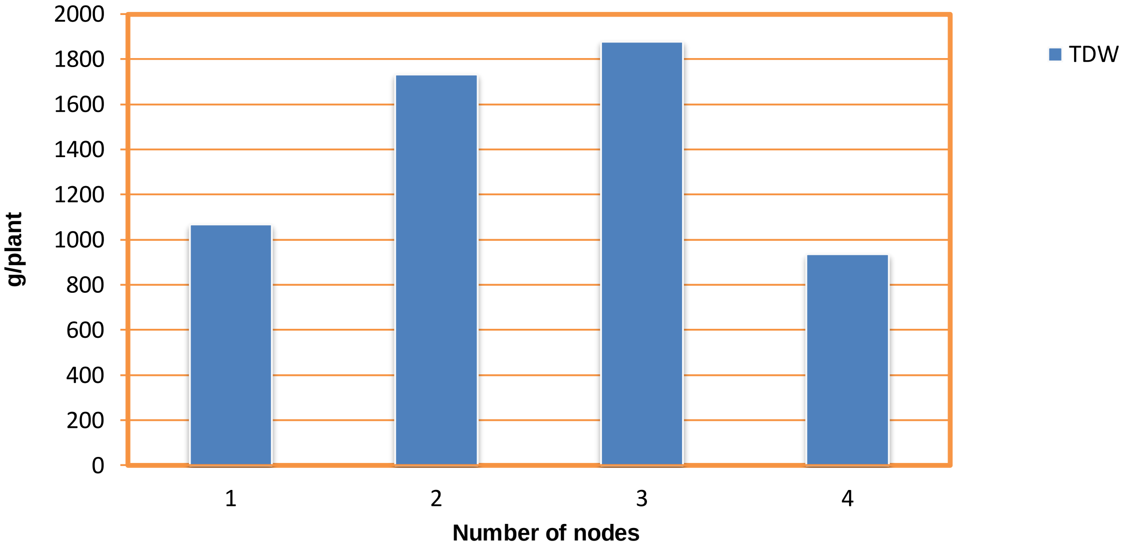

Figure 11. The effect of initial cassava nodes on tuber dry yield (TDY) at harvest.

and were more efficient in allocating the dry matter produced for storage.

Conclusions

The study set out to assess the effect of the initial stem nodal cutting on assimilates production and demand, and its subsequent effect on crop storage roots yield. The study demonstrated that the initial dry matter content of the nodes significantly influenced the growth and development of the crop through the production and subsequent partitioning of assimilates. Increasing dry matter content by increasing the length or the number of nodes up to three influenced each of the RDW, SDW, LDW, and TDW.

The results confirm that the NAR is not a good indicator of productivity or partitioning of assimilates of cassava. It is possible that sink capacity influenced RGR as most sinks, like cassava roots and leaves having an optimum capacity. The use of functional growth analysis did not show any effect on node or set size response unlike the analysis of dry matter production. This suggests that the method was insensitive to changes that occurred due to partition of assimilates, where ‘negative growth’ is common. The study confirmed that the initial strength of three nodes of fully matured cassava stems was superior to single-node sets as it had adequate dry matter. This significantly influenced the final dry matter accumulation in storage roots and final harvestable crop yield.

Conflict of Interests

The author(s) have not declared any conflict of interests.

ACKNOWLEDGEMENT

The author is grateful and appreciative of the kind assistance from his research team: Mark Kidney, Salena Khan, A. Le Gendre, and Field Team: Puran, Harripaul and Robin.

REFERENCES

Akparobi SO, Ekanayake IJ, Akoroda MO (1998). Early vegetative growth response of four improved cassava (*Manihot esculenta* Crantz) clones to varying temperatures. In: Root crops and poverty Alleviation of 6th symposium of ISTRCAB, held in Lilongwe, Malawi, 22nd-28th October 1995. Ekanayake IJ and Akoroda MO (eds). ISTRC-AB, IITA, Ibadan,Niger, pp. 360-266.

Carvahlo LJ, Mattos-Cascardo CBJ, Ferreira M, Loureiro M (1993). Studies on proteins and enzymes related to tuberization and starch biosynthesis in cassava roots. In: Roca W., Thro A. (eds.). Proceedings of the 1st International Scientific Meeting of the Cassava Biotechnology Network. Cali, Colombia: CIAT, 234-238.

Cereda MP, Vilpoux O (2003). Conservacao de raizes. In: Cereda MP, Vilpoux O, (eds.). Tecnollogia, uso e potencialidades de tuberosas amilaceas Latinoamericanas. Sao Paulo, Brazil: Fundacao Cargill, 13-29.

Cock JH, Franklyn D, Sandoval G, Juri P (1979). The ideal cassava plant for maximum yield. Crop Sci. 19:271-279. http://dx.doi.org/10.2135/cropsci1979.0011183X001900020025x

Didier P, El-Sharkawy MA (1994). Sink-source relations in cassava: Effects of reciprocal grafting on yield and leaf photosynthesis. Exper. Agric. 30:359-367. http://dx.doi.org/10.1017/S0014479700024479

Dominguez CE, Ceballos LF, Fuentes C (1982). Morfología de la planta de yucca. In: Dominguez CE. (ed.). Yuca: Investigación, Producción y Utilización. Cali, Colombia: CIAT/PNUD, pp. 28-49.

Ekanayake IJ (1996). Cassava: Procedures for growth analysis, Crop Improvent Division, IITA, Nigeria, p. 25.

Gray VM (2000). A comparison of two approaches for modelling cassava (Manihot esculenta Crantz) crop growth. Ann. Bot. 85:77-90. http://dx.doi.org/10.1006/anbo.1999.0999

Hunt R, Causton DRB, Shapely Askew AD (2002). A model for classical growth analysis. Ann. Bot. 90:485-488. http://dx.doi.org/10.1093/aob/mcf214

Keating BA, Wilson GL, Evenson JP (1985). Effect of photoperiod on growth and development of cassava (*Manihot esculenta* Crantz). Austr. J. Plant Physiol. 6:621-630. http://dx.doi.org/10.1071/PP9850621

Lahai MT, George JB, Ekanayake IJ (1999). Cassava (*Manihot esculenta* Crantz) growth indices, root yield and its components in upland and inland valley ecologies of Sierra Leone. J. Agron. Crop Sci. 182:239-247. http://dx.doi.org/10.1046/j.1439-037x.1999.00299.x

Lozano JC, Toro JC, Castro A, Belloti AC (1977). Production of planting cassava material. Cassava Information Centre Series, GE-17, CIAT, Colombia. PMCid:PMC1277718

Medina RD, Faloci MA, Gonzalez AM, Mroginsk LA (2007). *In vitro* cultured primary roots derived from stem segments of cassava can behave like storage organs. Ann. Bot. 99:409-423. http://dx.doi.org/10.1093/aob/mcl272.

Onwueme C (1978). Evaluation of the performance of cassava (*Manihot esculenta* Crantz) when grown from inverted stem cuttings. J. Agric. Sci. 90:149-156. http://dx.doi.org/10.1017/S0021859600048693

Sagrilo E, Filho PGV, Peque-o MG, Vidigal MCG, Kvitschal MC (2008). Dry matter production and distribution in 3 cassava (*Manihot esculenta* Crantz) cultivars during the second vegetative plant cycle. Braz. Arch. Biol. Technol. 51:6

San Jose JJ, Maybore F (1982). Growth Relationships of Cassava (*Manihot esculenta* Crantz): Crop Development in a Savanna Wet Season. Ann. Bot. 50(3):309-316

Sousa MV, Nassar NMA (2007). Amino acids profile in cassava and its interspecific hybrid. Genet. Mol. Res. 6(2):292-297.PMid:17573659.

Toro JC, Castro A, Celis E (1976). Selección y preparación de material para siembra de yucca. In: Curso sobre Producción de Yucca, Cali, Colombia, Centro Internacional de Agricultura Tropical (CIAT), pp. 197-204.