Dry matter production and distribution model in intercropped cassava

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ABSTRACT

Different stands of two contrasting maize (*Zea mays* L.) varieties and two equally contrasting cassava (*Manihot esculenta* Cranz) varieties were established as intercrops in experiments at Fumesua and Kwadaso near Kumasi (6° 43' N, 1° 36' W) in 1986 and 1987. The main objectives involved the comparison of harvest index (HI), efficiency of storage root production (ESRP), and initial start of starch accumulation (ISS) of cassava intercropped and monocropped. The determination of HI, ESRP, and ISS of the two cassava cultivars could then be used to visualize genetic differences and the effect of the environment on dry matter distribution. The determination of the proportion of dry matter assimilation at a particular time, distributed to the storage organs of intercropped cassava, was also the other objective in order to describe the distribution of dry matter over storage roots of cassava. Asymptotic relationships were established between dry weights and harvest indices, indicating that harvesting efficiency, although increased with dry matter increase, became constant and did not change with further increase in total dry matter. This should be of interest because of the economics of dry matter increase beyond this point. The dry matter at which the harvesting efficiency became constant, ESRP, seemed not to be influenced by only genotype, but also by cropping practise and season. Partitioning of assimilates to the storage roots of intercropped cassava was observed to be bimodal, and closely followed the pattern of radiation income for the Kumasi area. Sink size and activity as well as soil moisture content and, presumably, the plant water potential, were also important factors in the partitioning of current dry matter gains into the storage roots.

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RÉSUMÉ

ASAFU-AGYEI, J. N. & OSAFO, D. M.: *Modèle de la production et la distribution de manioc semé en lignes alternantes d' une autre culture.* Des différentes récoltes sur pieds des deux variétés contrastées de maïs (*Zea mays* L.) et deux variétés contrastées de manioc (*Manihot esculenta* Cranz) étaient semées comme des cultures en lignes alternantes dans les expériences à Fumesua et Kwadaso auprès de Kumasi (6° 43' N, 1° 36' W) en 1986 et 1987. Les objectifs principaux comprenaient la comparaison d' indice de moisson (IM), efficacité de la production de racine de stockage (EPRS) et le commencement initial de l'accumulation de fécule (CIAF) de manioc semé en lignes alternantes et en monoculture. La détermination de IM, EPRS et CIAF des deux variétés de manioc pourraient être utilisé ensuite pour envisager des différences génétiques et l'effet des conditions environmentales sur la distribution de matière séche. La détermination de la proportion de l'assimilation de matière sèche à un temps particulier, distribuée aux organes de stockage de manioc semé en lignes alternantes était aussi l' autre objectif afin de décrire la distribution de matière sèche sur les racines de stockage de manioc. Les rapports asymptotiques étaient établis entre les poids du produit sec et les indices de moisson indiquant l'éfficacité du moissonage, malgré le fait qu'elle augmentait avec une augmentation de matière sèche, devenait constante et ne changeait pas avec l'augmentation supplémentaire en matière sèche totale. Ceci doit nous intéresser à cause de côté économique de l'augmentation de matière sèche au-dessus de ce point. Le niveau de matière sèche auquel l'efficacité de moissonage devenait constante, EPRS, semblait de ne pas être influencé par le génotype seulement mais par la pratique de culture et la saison. La partition des assimilats aux racines de stockage de manioc semé en lignes alternantes était observée d' être bimodal et suivait étroitement le modèle de pénétration de rayonnement pour la zone de Kumasi. La dimension d' enfoncement et d'activité, ainsi que le contenu d' humidité de sol, et, vraisemblablement, le potentiel d'eau végétale étaient également des facteurs importantes dans la partition des gains de matière sèche actuelle en racine de stockage.

Introduction

Leaf area development, leaf photosynthetic rate, and sink potential, among other factors, have been suggested as means to improve yield (Cock *et al.*, 1979; El-Sharkawy & Cock, 1990). However, they have not been found useful as selection criteria in cassava (Veltkamp, 1986). Harvest index (HI) as a selection tool is useful, but this index is not constant in cassava (Kawano *et al.*, 1978). According to Boerboom (1978), results have been wrongly interpreted in the literature because harvest index was considered only at a certain instant of time or at a certain total weight. Cassava may be harvested between 6 and 24 months after planting, and HI may not have a constant level. In a semi-perennial crop such as cassava, a high HI during the rainy season could revert to a reduced HI during the dry season, because reserves are needed to sustain the plant and for resumption of growth. HI values could be misleading.

Boerboom (1978) suggested the efficiency of storage root production (ESRP) and the initial start of starch accumulation (ISS) to describe the phenomenon of dry matter partitioning during root-filling phase in cassava. The ESRP is the regression coefficient of the linear equation between the storage root weight and the total dry weight. The ISS is the plant weight at which storage root production starts. Because it is more consistent for any length of the growth period of the cassava crop than the time dependent HI, ESRP as a selection index in cassava seems more useful (Boerboom, 1978).

Keating, Evenson & Fukai (1982) used the ratio of the change in storage organ dry weight to change in total dry weight as an estimate of the differences in assimilate partitioning to storage organs over a particular time interval. This was a more sensitive measure of the short- term changes in assimilate partitioning than just the ratio of storage organ dry weight to total dry weight at harvest, which is the harvest index.

Firstly, this study aimed at determining the HI, ESRP, and ISS of two cassava cultivars, intercropped and also monocropped in1986 and 1987. Since performance of mixed stands might not be predictable from that of pure stands, it is inadvisable to extrapolate the performance of the intercrop to the monocrop. The determination of HI, ESRP, and ISS of the two cassava cultivars could be used to visualize genetic differences and the effect of the environment on dry matter distribution. This is necessary to compare and establish their usefulness as selection criteria in cassava. If the desire of the farmer to maximize yield has mainly been by using the maize/cassava crop association, then choice of varieties and selective fertilization, among others, are necessary to minimize interspecific competition between the components for a fuller exploitation of the yield potential of the two crops.

Secondly, this investigation determined the proportion of dry matter assimilation, at a particular time, distributed to storage organs of intercropped cassava, because yield might not be synonymous with total biomass. This would serve as basis for critical agronomic interventions during the growth cycle of the cassava plant.

Materials and methods

The trials were conducted using a randomized complete block design with a 2^4 factorial arrangement of four main factors, each evaluated at two levels. There were four blocks per trial. The plots measured 8.0 m × 8.0 m. In Trial 1 (Fumesua 1986, first rainy season), the treatments were maize variety (Dorke and Dobodi), maize density (20,000 and 40,000 plants/ha), cassava cultivar (Bosome Nsia and Ankra), and maize fertilization (45 and 180 kg/ha N). Dorke (CRI) is a 90-day early white dent maize variety. It is open-pollinated and was developed in 1984 by the Crops Research Institute, Kumasi, Ghana. Dobidi (CRI) is a 120-day full season white dent, open-pollinated variety released the same year by the CRI.

Bosome Nsia is an early (8-9 months maturity) but late-branching local cassava cultivar grown mainly in the coastal savanna areas of Ghana. It grows to a height of 180 cm in 9 months. It probably originated from a local collection from Kpeve in the Volta Region of Ghana which was called 'Asram Asia', meaning a '6-month' variety. Ankra is a long season (12-18 months maturity), late-branching local cassava cultivar widely grown in the forest and transitional areas of Ghana. It was selected in 1933 (Doku, 1965) from an introduction from Mauritius. It is 280 cm high at 12 months, and it is very susceptible to African cassava mosaic virus (ACMV).

The maize was planted at 50 cm × 100 cm spacing, one plant/hill for the lower density and two plants/hill for the higher density. Fertilizer was applied as 45:19:19 (comprising 19:19:19 kg/ha N:P_2O_5:K_2O of compound fertilizer at planting, and 26 kg/ha N of sulphate of ammonia side-dressed at 5-6 WAP of the maize) at the lower fertilizer level. At the higher level, four times this rate of N was applied. Planting dates were 26 Mar 86 and 3 Apr 86 for maize and cassava, respectively.

The trial 2 was conducted during the second rainy season of 1987 at Kwadaso, because drought at critical periods destroyed the maize crop at Fumesua during the first rainy season of 1987. The treatments were similar to those of 1986 at Fumesua, except that the maize fertilization treatment was replaced by a cassava density treatment of 10,000 and 20,000 plants/ha. The cassava was planted at 100 cm × 100 cm spacing for the lower density and 100 cm × 50 cm spacing for the higher density. Planting dates were 8 Jul and 9 Jul 87 for maize and cassava, respectively. In all the trials, the within-row spacing for maize and cassava were adjusted for the desired plant population densities.

The theoretical harvest indices were calculated by using the asymptotic function HI = b(1 - c/x), developed by Boerboom (1978), from the linear regression equation, y = bx - a. By his definition, HI = harvest index, x = dry weight of whole plant, y = dry weight of storage roots, b = regression coefficient, a = intercept with y-axis, and c = intercept with x-axis. The author calculated *b* and *c* to represent ESRP and ISS, respectively. As defined, ESRP is a more sensitive measure of short-term changes in assimilate partitioning than is harvest index, HI = (storage organ DW)/(total DW at harvest). As the plant grows older, the relative importance of ISS for HI steadily decreases (Ramanujam & Lakshmi, 1984).

Differences in assimilate partitioning to storage roots at a particular growth period were observed when the storage root yield was plotted against the corresponding total yield during that period. The slope indicated the proportion of total dry matter production being partitioned into storage roots at that particular time according to the methods of Keating *et al.* (1982).

Cultural practises

The cassava stem cuttings were about 20 cm long, and were planted on the flat in rows spaced 1 m apart. Row length was 8 m long, and plots measured 8 m × 8 m. In all the trials, cassava was planted in rows between two adjacent maize rows. Interplanting of cassava into the maize and maize planting were simultaneous, except in a situation where time did not permit this. In such cases, the cassava planting was completed within 8 days of planting the maize.

Fertilizer applied to maize was equivalent to 90:38:38 (comprising 38:38:38 kg ha^{-1} N:P_2O_5:K_2O of compound fertilizer at planting and 52 kg/ha N of sulphate of ammonia side-dressed at 5-6 WAP maize). All fertilizer applications were by banding in furrows, 5 cm from the maize plants.

Weeds were controlled by a pre-emergent application of Primagram 500, a weedicide comprising a combination of 250 g/l metolachlor, 235 g/l atrazine, and 10 g/l atrazine-related compounds. A rate of 2.0 kg a.i./ha of the weedicide was applied at each trial. Supplemental handweeding was done in all the trials where necessary to control weed regrowth after the herbicide application. Maize harvesting date was between 90 and 105 DAP for 'Dorke', and between 120 and 130 DAP for 'Dobidi'. Cassava harvesting date was not earlier than 9 months and not later than 12 months for 'Bosome Nsia'. For 'Ankra', harvesting was not earlier than 12 months. Grain yield in maize was corrected to 15 per cent moisture, while storage root yield in cassava was either by fresh weight or dry weight (air-forced oven at 70 °C for 3 days).

Estimates of DM partitioning determined for maize, using the above approach, would not have been very helpful, since HI is a fixed value in cereals. In cassava, it is common practice to harvest the crop at any time between 6 and 24 months after planting when HI may not have reached its constant value. It was concluded, therefore, that such a study in the maize component, using the methods described above, would be irrelevant in explaining the observations made in intercropped cassava, and were excluded for the purposes of this presentation.

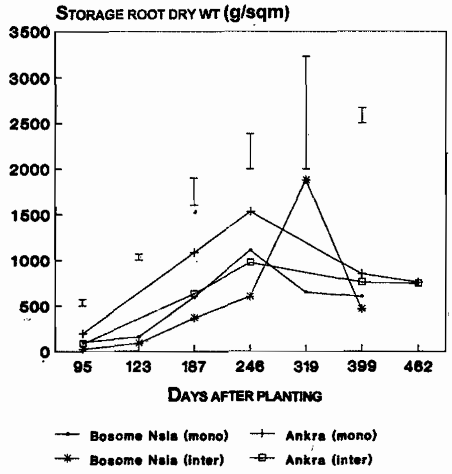

Fig. 1. Root dry weight of cassava, monocropped (mono) and intercropped (inter), Fumesua, 1986. I = twice SE for each dry weight harvest date.

Results and discussion

Efficiency of dry matter production in cassava

The dry weight values indicated that the monocrops yielded higher than their corresponding intercrops, and 'Ankra' yielded higher than 'Bosome Nsia'. In 1986 (Fig. 1), 'Ankra' monocrop at 187 DAP yielded significantly higher than 'Bosome Nsia' monocrop (45 per cent), 'Bosome Nsia' intercrop (66 per cent), and 'Ankra' intercrop (42 per cent). Similarly, in 1987 (Fig. 2), 'Ankra' monocrop at 187 DAP yielded significantly higher than 'Bosome Nsia' monocrop (48 per cent), 'Bosome Nsia' intercrop (72 per cent), and 'Ankra' intercrop (75 per cent). Cassava is a long-duration crop, and it was proper to target a specific period at which an attribute of the crop could be confidently used as selection criterion to differentiate various types. For the intercropped and monocropped cassava, the pattern for dry matter accumulation in the storage root closely followed the pattern for the whole plant dry matter accumulation. It is, therefore, relevant to suggest that intercropping cassava with maize did not influence relative partitioning of dry matter to the storage roots. This is consistent with work reported elsewhere (Mason *et al.*, 1986).

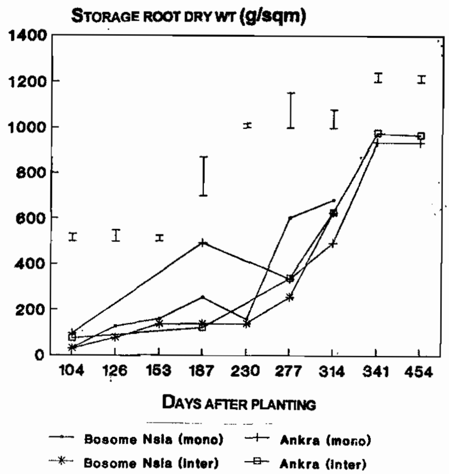

Fig. 2. Root dry weight of cassava, monocropped (mono) and intercropped (inter), Kwadaso, 1987. I = twice SE for each dry weight harvest date.

Differences between the magnitude of the regression coefficients proved that in 1986, ESRP (=b) value of 'Bosome Nsia' monocrop was significantly greater ($P<0.05$) than that for 'Bosome Nsia' intercrop and 'Ankra' monocrop, but was same as 'Ankra' intercrop. While Ankra intercrop was significantly higher than 'Bosome Nsia' intercrop, 'Ankra' monocrop had the same magnitude of the regression coefficient as Bosome Nsia' intercrop (Table 1). It was not the same for 1987.

Differences between the magnitude of the regression coefficients proved that in 1987, ESRP (=b) value of 'Bosome Nsia' monocrop was not significantly different from that of 'Bosome Nsia' intercrop, but was significantly lower than 'Ankra' monocrop and 'Ankra' intercrop. In 1987, 'Ankra' intercrop was also significantly higher than 'Bosome Nsia' intercrop as in 1986. However, 'Ankra' monocrop had the same magnitude of the regression coefficient as 'Bosome Nsia' intercrop (Table 2) as in 1986. Differences in efficiency between the monocrop and the intercrop were, however, not apparent in either year, being below 2 kg/plot dry weight (Fig. 3-6), which seemed to be the threshold dry weight that must be attained before any meaningful differences could be established. The higher efficiencies did not seem to have been generally reflected in yields. It is probable that the extra efficiency was needed for the intercrops to survive and produce in the midst of intense inter- and intra-species competition.

Trends for the ISS were similar to those for the ESRP in 1986. Differences between the magnitude of ISS proved that in 1986, ISS (=c) value of 'Bosome Nsia' monocrop was significantly greater ($P<0.05$) than that for 'Bosome Nsia' intercrop and 'Ankra' monocrop, but was same as 'Ankra' intercrop. While 'Ankra' intercrop was significantly higher than 'Bosome Nsia' intercrop, 'Ankra' monocrop had the same magnitude of ISS as 'Bosome Nsia' intercrop (Table 1). In 1987, the trends were similar except that the ISS was the same for 'Ankra' intercrop and 'Bosome Nsia' intercrop, while 'Ankra' monocrop was significantly higher than that for 'Bosome Nsia' intercrop (Table 2).

Higher ISS values did not necessarily contribute to higher yield when 'Ankra' was compared to 'Bosome Nsia'. The values for ISS seemed to indicate that 'Bosome Nsia', when intercropped, required a smaller initial plant weight to begin storage root production. Thus, in 1986, it could be inferred that 'Bosome Nsia' intercrop started to produce storage roots at a plant weight of 24 g whilst 'Ankra' intercrop did so at 41 g. It seemed, therefore, that the early maturing variety, 'Bosome Nsia', began storage root production earlier than the late-maturing variety, 'Ankra'. Considering their maturities, this seems to be a plausible

TABLE 1

Parameters for Dry Matter Distribution of Two Different Cassava Cultivars Grown at Fumesua in 1986

Cultivar	*Number of harvest*	*ESRP (=b)*	S_b	*a*	*ISS (=c)*	r^2	*Age of plants at final harvest (weeks)*	*x at final harvest (kg)*	*y at final harvest (kg)*	*n*
Bosome Nsia (monocrop)	4	0.733	0.039	0.33	0.45	0.96**	57	3.9	2.6	16
Bosome Nsia (intercrop)	6	0.620	0.013	0.15	0.24	0.96**	57	1.7	1.1	96
Ankra (monocrop)	4	0.624	0.076	0.19	0.30	0.87**	66	5.5	3.6	12
Ankra (intercrop)	5	0.689	0.021	0.28	0.41	0.93**	66	2.7	1.7	80

For each cultivar, the regression equations y = bx - a was calculated from the given number of harvest data.

x = dry weight of whole plant/plot; y = dry weight of storage roots/plot; ESRP = efficiency of storage root production = b, the regression coefficient of the formula y = bx - a; S_b = standard error of regression coefficient b; a = intercept with y axis; ISS = initial plant weight at which production of storage roots start = intercept with x axis = a/b = c; r^2 = square of correlation coefficient between y and x.

** value of correlation coefficient, r, significant at 1% level probability.

TABLE 2

Parameters for Dry Matter Distribution of Two Different Cassava Cultivars Grown at Kwadaso in 1987

Cultivar	*Number of harvest*	*ESRP (=b)*	S_b	*a*	*ISS (=c)*	r^2	*Age of plants at final harvest (weeks)*	*x at final harvest (kg)*	*y at final harvest (kg)*	*η*
Bosome Nsia (monocrop)	7	0.587	0.028	0.088	0.15	0.97**	45	2.2	1.3	14
Bosome Nsia (intercrop)	7	0.629	0.016	0.153	0.24	0.94**	45	2.1	1.2	112
Ankra (monocrop)	5	0.658	0.051	0.319	0.48	0.95**	65	3.2	1.8	10
Ankra (intercrop)	6	0.689	0.014	0.225	0.33	0.96**	65	2.8	1.8	96

For each cultivar, the regression equations y = bx - a was calculated from the given number of harvest data.

x = dry weight of whole plant/plot; y = dry weight of storage roots/plot; ESRP = efficiency of storage root production = b, the regression coefficient of the formula y = bx - a; S_b = standard error of regression coefficient b; a = intercept with y axis; ISS = initial plant weight at which production of storage roots start = intercept with x axis = a/b = c; r^2 = square of correlation coefficient between y and x.

** value of correlation coefficient, r, significant at 1% level probability.

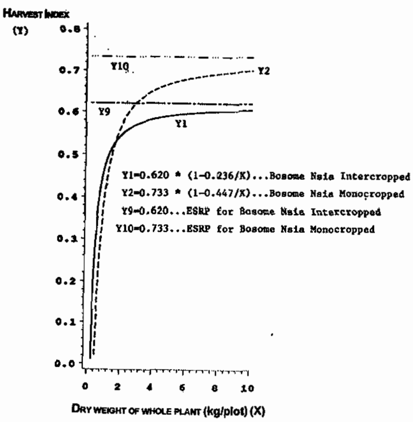

Fig. 3. Relationship between harvest index and whole plant dry weight of Bosome Nsia, 1986, Fumesua.

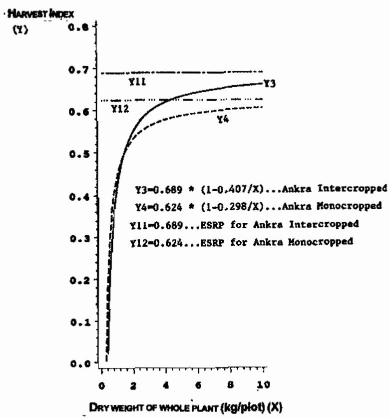

Fig. 4. Relationship between harvest index and whole plant dry weight of Ankra, 1986, Fumesua.

explanation. This was, however, not so for the monocrops. While efficiency in this instance seemed to be genetically determined, Veltkamp (1986) found that differences in yield of storage roots were mainly the result of differences in ESRP for plants grown at different daylengths.

It appeared that efficiency index, as calculated, became more important under conditions of stress as might have been so under intercropping. The differences in 1987 were significant compared to 1986. Apart from the fact that rainfall was generally low in 1987, the 2nd season is not the best season to plant cassava because the younger plants would have to undergo a continuous harsh dry period of about 5 months. Doku (1965) has established that March to July is the most favourable period for cassava growth in Ghana. August to February, particularly August,

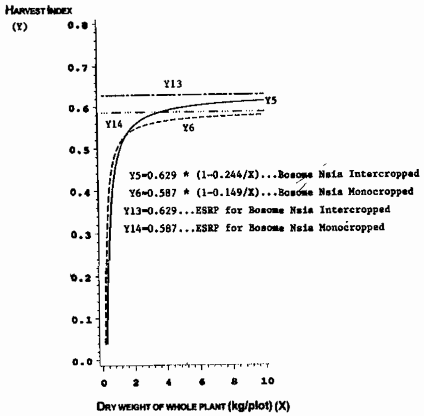

Fig. 5. Relationship between harvest index and whole plant dry weight of Bosome Nsia, 1987, Kwadaso.

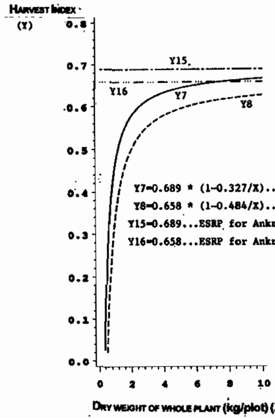

Fig. 6. Relationship between harvest index and whole plant dry weight of Ankra, 1987, Kwadaso.

December and January are comparatively dry and not much food is produced and stored during this period.

The results for the monocrops seemed to suggest that root production efficiency is also environmentally determined. Therefore, cropping practise will probably influence efficiency of storage root production.

Asymptotic relationships were established when the theoretical harvest indices were plotted against whole plant dry weight (Fig. 3-6). This meant that harvesting efficiency, although increased with dry matter increase, became constant and did not change with further increase in total dry matter after a threshold level. This dry matter at which harvesting efficiency became constant, ESRP or the constant values indicated should be of interest to researchers. It might not be economical to delay harvest as an attempt to increase dry matter in cassava beyond this point. The plateau in harvesting efficiency occurs after the 4th month in India (Ramanujam & Lakshmi, 1984), indicating that the pattern of DM partitioning became constant after the initiation of tuber bulking. If this situation were true, then selection in cassava could be early in the growth cycle.

However, higher ESRP values did not always lead to higher root yield. ESRP seemed uninfluenced by genotype alone, but by cropping practise and season. If ESRP and ISS are to be used as selection criteria as other reports suggest (Boerboom, 1978; Ramanujam & Lakshmi, 1984; Veltkamp, 1986), then other factors have to be considered. However, they are still worthy substitutes for HI. Boerboom (1987) has observed that some results have been wrongly interpreted, because HI was considered only at a certain instant of time or at a certain total weight. The results of this study suggest that ESRP could be considered as a useful selection trait for cassava. If it was still required, HI could easily be calculated from ISS and ESRP at any weight of whole plant.

High yield in cassava has been attributed to a high total crop dry weight in relation to foliage development, leaf area duration and canopy architecture (Doku, 1965; Sinha & Nair, 1971; Cock, 1976; Holmes & Wilson, 1976; Cock *et al.*, 1979), and high harvest index (Jennings, 1970; Williams, 1972). Doku (1965) suggested that characters to look for when breeding for yield in cassava seemed to be the ability to retain many leaves, a large leaf area, and a large green stem area during the most favourable growing period in the life of the plant. He further stated that high values of these characters would result in high photosynthetic area index. ESRP could be a tool for comparison and selection in conjunction with the yield characters suggested by Doku (1965).

Dry matter partitioning to storage roots of intercropped cassava

The proportion of DM distributed to the storage roots of intercropped cassava increased significantly from 123 DAP to a peak at 246 DAP. Thereafter, it significantly decreased at 319 DAP and then increased again to a second peak at 399 DAP for 'Bosome Nsia' in 1986 (Table 3). The rise at 399 DAP was not significant, but this tendency could be attributed to the production of fresh leaves and growth activation during the beginning of the rainy season in Apr 87. Photosynthate partition increased significantly from 95 DAP, reaching a peak at 187 DAP in 'Ankra' and did not change again until a second peak estimated at 462 DAP (Table 3). In 1987, DM allocation increased from first measurement until a peak at 187 DAP, then there was a significant drop at 230 DAP, followed by another peak at 314 DAP for 'Bosome Nsia' (Table 4). Results indicated that for 'Ankra', partition of DM to storage roots reached a peak at 187 DAP, then rose significantly to another peak at 341 DAP (Table 4).

The proportion of DM partitioned seemed to have shown an active bimodal distribution pattern for both varieties in both years. At the first peak,

TABLE 3

Proportion of Total Dry Matter Partitioned to the Storage Root of Intercropped Cassava at Fumesua in 1986

	'Bosome Nsia'				'Ankra'		
DAP	*Proportion*	*SE*	R^2	*DAP*	*Proportion*	*SE*	R^2
95	0.19	0.06	0.44	95	0.33	0.07	0.63
123	0.31	0.04	0.78	187	0.67	0.06	0.89
187	0.59	0.05	0.91	246	0.56	0.05	0.89
246	0.82	0.05	0.95	399	0.67	0.05	0.93
319	0.57	0.08	0.80	462	0.85	0.03	0.98
399	0.71	0.07	0.88				
SE	0.10			SE	0.09		

Significance is at $P = 0.05$

TABLE 4

Proportion of Total Dry Matter Partitioned to the Storage Root of Intercrppped Cassava at Kwadaso in 1987

	'Bosome Nsia'				'Ankra'		
DAP	*Proportion*	*SE*	R^2	*DAP*	*Proportion*	*SE*	R^2
104	0.23	0.03	0.81	104	0.20	0.50	0.53
126	0.41	0.06	0.75	187	0.60	0.05	0.91
153	0.54	0.04	0.94	277	0.50	0.05	0.87
187	0.65	0.05	0.93	314	0.55	0.03	0.96
230	0.35	0.02	0.28	341	0.72	0.03	0.98
277	0.41	0.08	0.67	454	0.75	0.05	0.95
314	0.72	0.05	0.94				
SE	0.07			SE	0.08		

Significance is at $P = 0.05$

which was usually at about 6 months after planting (187 DAP), 59 and 65 per cent of the current photosynthate were partitioned to the storage roots in 'Bosome Nsia' in 1986 and 1987, respectively. The corresponding proportions were 67 and 60 per cent for 'Ankra'. The allocation at 187 DAP was such that 'Ankra' distributed 12 per cent more to its storage roots compared to 'Bosome Nsia' in 1986. 'Bosome Nsia', however, provided 8 per cent more of the photosynthate to its storage roots in 1987 compared to 'Ankra'. Cassava planted at Kwadaso in the 1987 minor season seemed to have benefited from more rainfall than cassava planted at Fumesua (Table 5) in 1986, because total rainfall at Fumesua for the period May 86 - Apr 87 was 1005 mm, 26 per cent less than total rainfall at Kwadaso for the period Aug 87 - Jul 88, which was 1350 mm.

It is expected that higher residual soil moisture levels, due to the greater amount of rainfall received before the attainment of the peak, ensured a faster rate of movement of carbohydrates within the plant and, probably caused a higher proportion of the photosynthate to be translocated to the storage roots. Thus, 'Bosome Nsia' allocated 9 per cent more assimilate at 187 DAP in 1987 compared to 1986, while 'Ankra' on the other hand allocated 10 per cent more in 1986 compared to 1987. The extra moisture probably explains why cassava could withstand competition from the maize better in 1987. The benefit accruing from the additional moisture (34 per cent more rainfall) did not appear to have been translated into yield. Other data that would be presented elsewhere by the author seemed to suggest that at Kwadaso, the 1987 dry tuber yield was 19 per cent more for 'Ankra' than the dry tuber yield for 'Ankra' at Fumesua in 1986. The dry yield for 'Bosome Nsia' was, however, 44 per cent less at Kwadaso than at Fumesua. This was probably because of the drier weather conditions which prevailed at Fumesua during the shorter growth period required by 'Bosome Nsia'.

TABLE 5

Monthly Total Rainfall (mm) at Growing Sites

Month	*Fumesua 1986*	*Fumesua 1987*	*Kwadaso 1987*	*Kwadaso 1988*
Jan	22	2	12	0
Feb	42	40	74	0
Mar	94	126	114	32
Apr	112	119	230	119
May	156	46	66	128
Jun	214	156	238	357
Jul	139	136	178	98
Aug	14	156	144	13
Sep	62	210	352	145
Oct	133	88	120	162
Nov	0	8	0	8
Dec	0	4	0	0

Work at CIAT (1972) showed that at 6-8 months after planting (MAP), storage roots accounted for up to 80 per cent of the total weight of the cassava plant. In Australia, Keating *et al.* (1982) found that by Jun-Jul, all the assimilates had been translocated to below ground storage organs. This phasic pattern of dry matter partitioning agreed with the findings of Hume (1975) in Ghana. It also agreed with the work of Zandstra (1978) who found storage root dry matter as a percent of total dry matter production, at any particular time period during the growing season, to increase from 25 per cent after 4 months to 40, 48, and nearly 58 per cent after 8, 12, and 18 months, respectively. His work also showed that rates of increase and decline varied with year and variety. The results suggest that during early growth, the proportion of photosynthate partitioned into the storage roots would be small, probably because the sink capacity is low. The proportion demanded by the sink would then increase gradually as storage root bulking occurs.

In a dry period, bulking rate was low, and assimilates were recovered in above-ground parts (Hume, 1975). In Venezuela, San Jose & Mayobre (1982) found that with the onset of rains, and as the season progressed, production of new leaves resulted in an increase in proportion of DM allocated to storage roots. Also, changes in leaf characteristics led to substantial changes in dry matter allocation.

The solar radiation income for the two locations were similar (Table 6). The solar radiation income for the period May 86 - Apr 87 was 2185.1, just 2 per cent more than the solar radiation income for the period Aug 87 - Jul 88, which was 2139.6. Radiation levels were lowest between June and September (Table 6). These were the months in which the proportion of dry matter allocated to the storage roots was lowest. The radiation levels showed the same bimodal distribution pattern as dry matter allocation to storage roots, and as such, radiation levels could be partly responsible for the pattern of dry matter distribution observed in these studies.

The pooled data of the proportion of dry matter

TABLE 6

Mean Monthly Solar Radiation Income (Watts m^{-2}) for Kumasi Area

Month	*1964-1988*	*1986*	*1987*	*1988*
Jan	172.1	184.8	156.2	158.9
Feb	195.1	208.9	186.7	187.6
Mar	207.4	195.0	195.5	196.8
Apr	211.8	211.6	204.3	202.4
May	206.6	208.9	199.6	207.9
Jun	181.8	190.4	179.3	177.5
Jul	154.0	135.9	155.3	162.7
Aug	140.4	135.9	147.0	125.7
Sep	159.0	155.3	171.0	150.6
Oct	186.1	171.9	188.6	189.5
Nov	194.8	183.9	187.6	183.0
Dec	162.1	160.8	151.6	160.8

partitioned, based on values presented in Tables 3 to 4, for each cultivar and year, indicated that for every unit of DM synthesised, 0.53, 0.62, 0.47, and 0.55 were accumulated in storage roots by 'Bosome Nsia' in 1986, 'Ankra' in 1986, 'Bosome Nsia' in 1987, and 'Ankra' in 1987, respectively. On the average, therefore, the proportion of photosynthate partitioned to storage root was higher in 'Ankra' than in 'Bosome Nsia', and was also higher in 1986 than in 1987 for all the varieties. Work by Ramanujam & Lakshmi (1984) supported this assertion that dry matter partitioning was under genetic control, although a relatively smaller proportion of photosynthate partitioned to storage roots could also be attributed to a short growing season as in yam and cassava (Bhagsari, 1988).

A lower plant water potential resulting from drier soil conditions, and a lower storage root sink demand for assimilate during growth could also be reasons for the reduced proportion of photosynthate partitioned to the storage roots. In Ghana, cassava is almost always intercropped with maize, and it was therefore necessary to study the allocation of dry matter under intercropped conditions. However, as suggested earlier, allocation was not expected to vary much under mono- and intercropped conditions. The general pattern of dry matter partitioning observed in the investigations was similar and comparable to results for the summer in Hawaii (Manrique, 1990), and in Australia (Keating *et al.* 1982) under monocropped conditions.

If peak DM partitioning was at about 6 MAP, as shown by this study, then it can be confirmed that selection could be effective for desired traits like root yield in cassava at this period. Thus, the initial genetic evaluation for yielding ability can be effectively made at 6 MAP, instead of latter stages which obviously is more expensive in time and resources, both human and material. Other workers like Ramanujam & Lakshmi (1984) have made similar observations. However, differences in root yield 'y' at final harvest between cultivars will also depend on differences between weights of whole plant 'x' as well as on differences in the relation, y = bx - a, as observed by Boerboom (1978).

When plots were made between weights of storage roots and whole plant, there was no deviation from linearity at all stages of harvest for each cultivar and each season and year. Therefore, variations in environmental conditions cannot hinder the application of these methods for selection in cassava.

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