GROWTH, DEVELOPMENT AND YIELD OF SOME TROPICAL ROOT CROPS

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SUMMARY

The effect of size of the vegetative planting propagule on tuber yield is attributable mainly to its effects on rate of bulking and lead area duration. The difference in root tuber yield between cultivars within species of root crops is due mainly to the differences in their rate of bulking and, in some instances, to the duration of bulking and leaf area duration.

Time of planting and mulching influence yield via leaf area duration. Spacing affects leaf area duration and rate of bulking. Staking increases leaf area duration and rate and duration of bulking. Age of planting setts affects leaf area index and leaf area duration.

Greater leaf area duration can be achieved by a combination of high leaf area index with a short period of leaf growth or low leaf area index with longer period of leaf growth. The latter combination is a better one provided that the leaf area index does not remain below the optimum for maximum dry matter production for a long period. Plant breeders should try to produce plants with rapid leaf development between the time of planting and tuber initiation and after tuber initiation plants should maintain an optimum leaf area index for a long period.

RESUME

L'effet de la dimension de la propagule végétative sur le rendement des tubercules est surtout attribuable à ses effects sur le taux de développement de la tubercule et de la durée de zone foliaire. La différence de rendement entre cultivars de méme espèce de plantes à racine est essentiellement dûe aux différences de leur taux de développement et dans certains cas, à la durée de développement des tubercules et à celle de la zone foliaire. La période de semis et le paillage influencent le rendement sous l'effet de la durée de zone foliarie. L'espacement affecte la durée de la zone foliaire et le taux de développement de la racine, le tuteurage prolonge la durée de la zone foliaire, de même que le laux et la durée du développement de la racine. L'âge des boutures de semis affecte l'index de la zone foliaire et la durée de la zone foliaire.

On peut obtenir une durée de la zone foliaire par la combinaison d'un index élevé de la zone foliaire à une courte période de la croissance foliaire, ou d'un index bas de zone foliaire à une période plus longue de la croissance foliaire. La dernière combinaison est plus interessante pourvu que l'index de la zone foliaire ne reste pas en dessous des conditions optima pour la production de matière sèche maximale sur une longue période. Les phytogénéticiens devraient s'efforcer de produire des plantes au développement foliaire rapide entre le temps de semis et l'initiation des tubercules; de plus, les plantes devraient conserver un index de zone foliaire optimale sur une longue période après l'initiation des tubercules.

RESUMEN

El efecto del tamaño de los propágulos vegetativòs para siembra, sobre el rendimiento de tubérculos, se atribuye principalmente al grado de engrosamiento y duración del área foliar que produce. La diferencia del rendimiento de tubérculos entre cultivares dentro de especies de cultivos con tubérculos es debida principalmente a las diferencias en su grado de engrosamiento y en algunos casos, a la duración del engrosamiento y área foliar.

La época de siembra y la cobertura tienen influencia a través de la duración del área foliar. El espaciamiento afecta la duración del área doliar y el grado de engrosamiento. El estacado aumenta la duración del area foliar y del engrosamiento. La edad de los propagulos afecta el índice de área foliar y la duración de la misma.

La mayor duración del área foliar puede lograrse con una combinación de un índice elevado de área foliar con un período corto de crecimiento de la hoja o un índice bajo de área foliar con un período mas largo de crecimiento de la hoja. Esta última combinación es mejor, siempre que el índice de área foliar no permanezca por debajo del optimo, para una producción máxima de materia seca, por un período largo. Los fitomejoradores deberían de tratar de producir plantas con un desarrollo rápido de hojas en el período desde la siembra hasta la iniciación de tubérculos y las plantas deberían obtener un índice óptimo de área foliar por un período largo.

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INTRODUCTION

This paper is concerned mainly with cassava, yams and tannia. Cassava is usually propagated by stem cuttings. When the stem cuttings are planted they usually produce many shoots and in most cassava cultivars there is a period of growth of about four to eight months. During this period most of the assimilates are diverted into the leaf blades and stems. This is followed by a period of tuberization, and at this stage there is competition between the stems and roots for the available assimilates. The proportion of assimilates diverted into the root tubers varies with cultivar, spacing and the number of shoots developed per plant.

Yams are usually propagated by stem tubers. The tubers usually produce aerial stems which are weak, and in cultivation the plants are usually supported by long poles up which they twine in either a clockwise or an anti-clockwise direction, depending on the species. Sobulo[23] considered the growth cycle of white yam as comprising four stages. The first is that in which the sett is still dormant; the second is that in which growth of the main shoot and root occurs; the third stage is the period of tuber initiation, leading to rapid tuberization and the senescence of roots and shoots; the fourth stage is the loss of stem and root material while tuber dry matter reaches a maximum value.

Tannia plants are propagated by means of corms. The growth cycle in this crop can similarly be considered to comprise four different stages.The first is the period during which the sett remains dormant; the second is the period of the growth of the primary shoot and roots; in the third period, initiation of the secondary corms is followed by rapid tuberization, and in the fourth stage there is rapid senescence of the leaves with the approach of the dry season.

In most root crops, tuber yield depends on two main factors, firstly, the rate at which assimilates are translocated into the storage organs and, secondly, the duration of such translocation. The rate at which assimilates are translocated to the tubers will depend on the total amount of assimilates available, the proportion of the assimilates available for tuber development, and the number of tubers initiated. The total amount of assimilates available will in turn depend on the leaf area of the plants and the photosynthetic efficiency of the leaves. Duration of assimilate translocation is dependent on the time at which tuber initiation occurs and the leaf area duration after this time.

These physiological factors which operate at different stages of growth of the crops, and which determine the final yield of the tubers are influenced by agronomically determined variables, such as (a) the size of the planting sett, (b) the age of the planting sett, (c) cultivar, (d) fertilizer application, (e) time of planting, (f) number of shoots per plant, (g) mulching, (h) spacing and (i) staking. This paper deals with the effect of the above agronomic factors on growth and tuber yield of cassava, yams and tannia.

REVIEW OF THE EFFECTS OF AGRONOMIC FACTORS ON YIELD

Effect of size of planting sett on growth and yield

The dry matter available for the growth of the young shoots after planting will usually depend on the dry weight of the planting sett and this in turn will depend normally on the size of the sett. Since the size of the sett is likely to affect at least the early growth of the plants, it might be expected that it will also affect the final tuber yield. Bremer and Taha[2] noted that in the Irish potato, large sized seeds produced plants with longer leaf area duration and associated greater dry weight and tuber yield than small sized ones. In cassava, Jergaseelan[18] showed that root tuber yield increased with increasing length of planting sett. In yams, a relationship exists between weight of sett planted and yield of tubers[15,19]. Experiments with tannia (*Xanthosoma sagittifolium* Schott)[7] and lesser yam (*Dioscorea esculenta)*[11] showed that corm and tuber yield respectively increased with the increase in seed size. (Table 1)

In the second tannia experiment, which included the following additional treatment: ridge, flat, very large setts, extra large setts, mulched or bare, final corm yield was shown to be closely related to mean maximum leaf area index (LAI) (Table 2).

The correlation coefficient between LAI and corm yield in this experiment was 0.93. The increase in corm yield with increase in the size of sett may therefore be attributed to the increase in maximum LAI obtained by increasing the size of sett. In this experiment, the difference in the corm yield from the use of very large and extra large setts was not significant. The lack of significant difference in the corm yield between these treatments can be attributed to their not bringing about significant differences in the LAI. Enyi[8] also showed that fresh weight yield of corm (Y) was closely associated ($r=0.71$) with leaf blade areas (X) with a linear regression $Y=0.107X-19.4$.

Purewal and Dargan[22] found a close correlation between LAI and corm yield in *Colocasia* sp. In an experiment with lesser yam, increase in seed size led to an increase in tuber number per plant (Fig. 1) and an increase in tuber weight per plant (Fig. 2). However, the proportion of tubers that did not reach harvesting size increased with an increase in sett size. LAI also increased with size of planting sett (Fig. 3) and the maximum number of tubers initiated appeared to be related to the leaf area of the plant achieved at the start of tuber initiation.

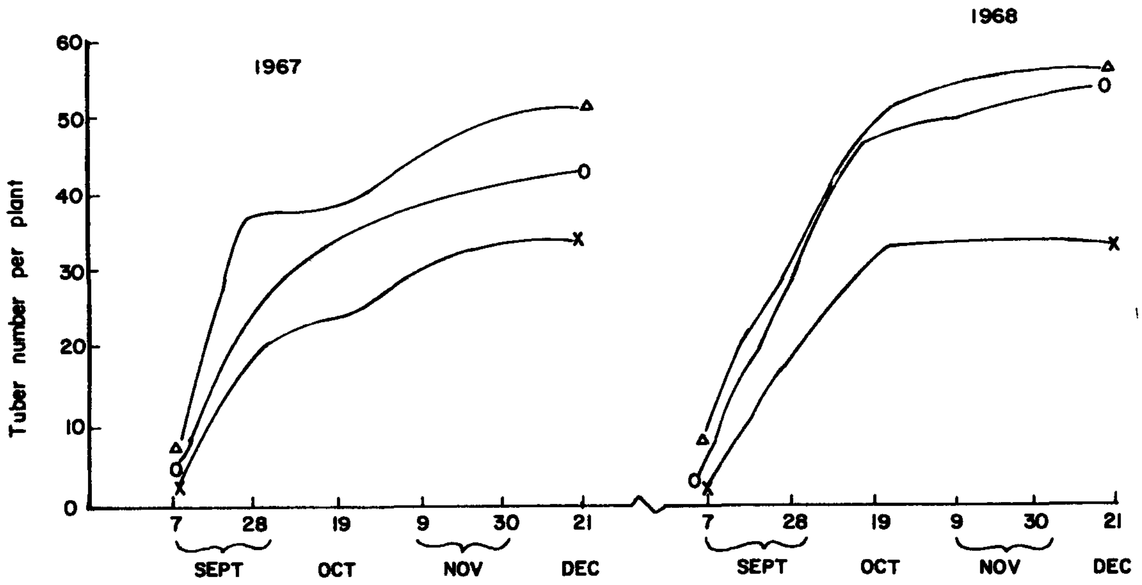

Fig 1. Effect of seed sett on tuber number in 1967 and 1968. Large sett ____, medium sett o----o, small sett ----. (Means of spacing treatments) (Lesser yam)

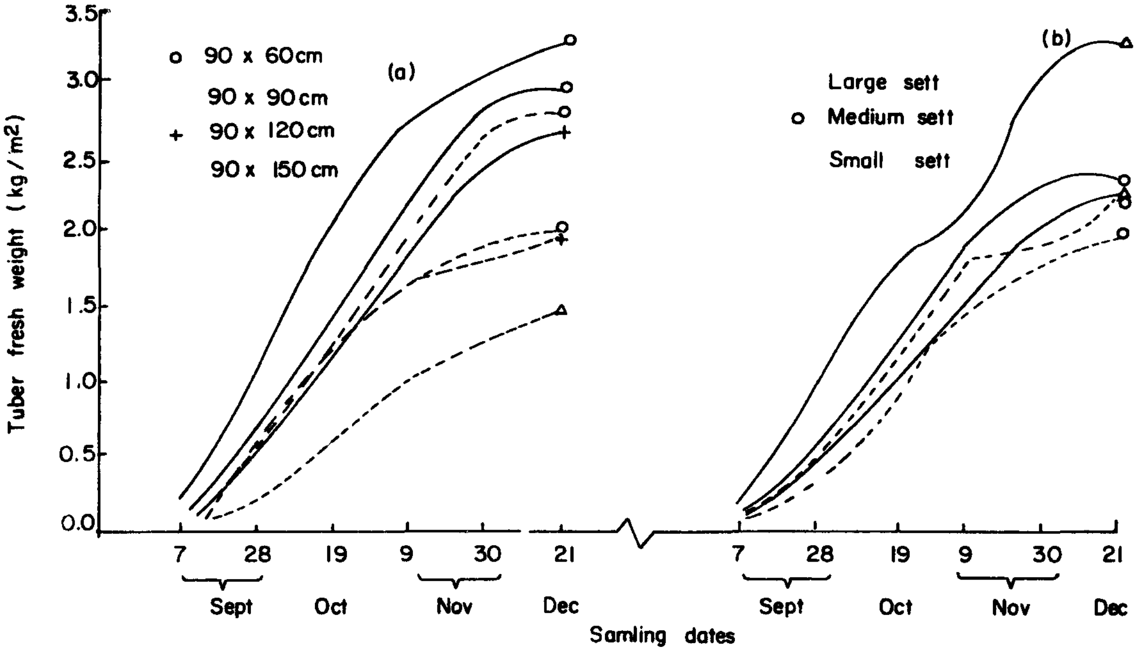

Fig.2. The change with time in tuber fresh weight in 1967(—) and 1968 (---)
(a) Effect of spacing treatment (b) Effect of seed size (Lesser yam)

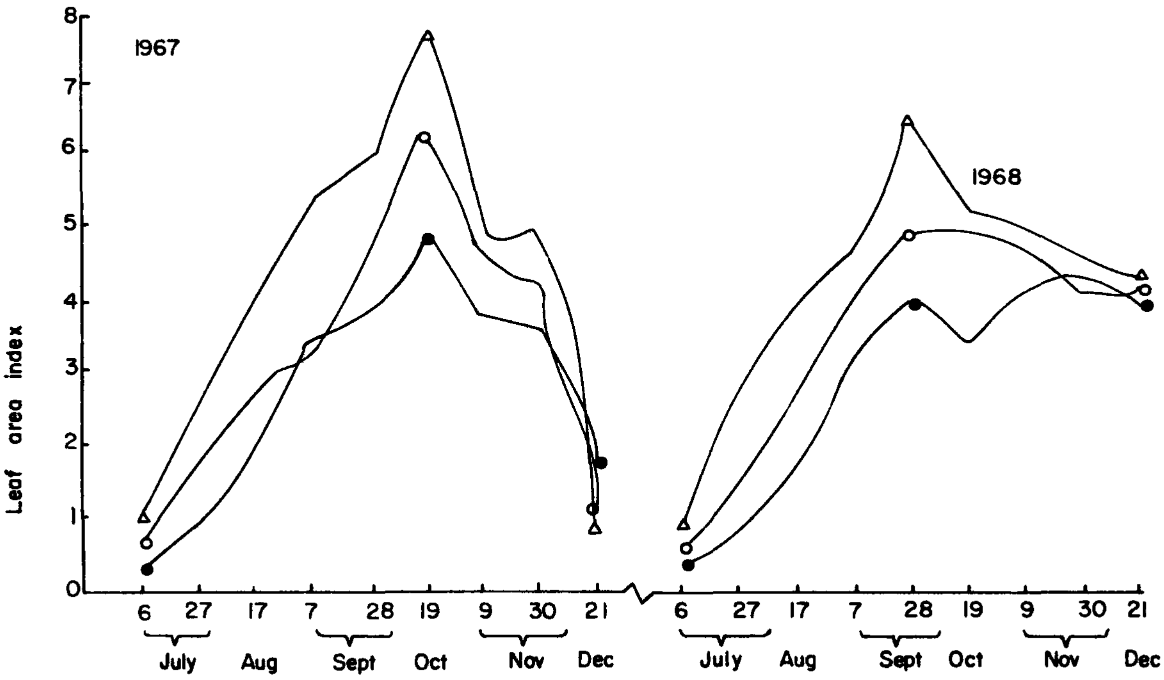

Fig.3. The change with time in leaf area index. Effect of sett size. Large sett medium sett o---o, small set----(means of spacing treatreaments) (Lesser yam)
Arrow indicates time of tuber initiation.

Leaf area duration increased with the inrease in sett size and in this experiment tuber yield (X) was shown to be closely related (r=0.932) to leaf area duration between time of tuber initiation and final sampling (DF) according to the regression X=376DF + 8233. In lesser yam, it can be concluded that increase in tuber yield with increasing seed size is due to the associated increase in tuber number, leaf area duration and bulking rate (Table 3).

Effect of age of sett on growth and yield

For yams the most successful planting material is the small whole tuber or seed yam. If sufficient seed yams are not available, then setts cut from the tuber are used and are referred as tops, middles and bottoms. The top is morphologically the oldest section of the tuber, while the bottom is the youngest. The tops are usually preferred to bottoms or middles.

Morphologically the primary 'corm' of cocoyam (*Xanthosoma sagittifolium*) is the main stem of the plant and the secondary 'corms' are its branches. The age of the planting sett when the main stems are cut to produce setts will depend on its position on the corm, those produced from the top being the youngest and those from the bottom the oldest.

Chemical analysis of the various sections of the main corm used for planting experiments by Enyi[8] showed that the concentration of N, P and K decreased in the top four sections followed by an increase in the age of the corm. It is likely that the differences in the chemical composition of the sett may affect the growth of the plants and therefore may influence the final yield of corms. It was also found that plants produced from the last two sections of the corm developed much greater leaf areas and total dry weight than those produced from the first four sections. In the present experiment, there was a close association (r=0.98) between Ca% in the setts and the subsequent dry weight of the plants produced from them. The linear regression was X=412Y – 187 where X = the dry weight and Y = Ca% in the sett. There was also a close (r=0.71) association between leaf blade areas and fresh weight yield of corm with linear regression Y=0.107X–19.4 where Y = yield of tuber and X = leaf blade area. It appears that the differences in the corm yield brought about by differences in the age of the planting sett may be due to differences in the chemical composition of the setts.

The nutrient content (g/sett) of planting setts in cassava is shown in Fig. 4 (Enyi[10]). N, K, Mg and Ca content increased with the age of the sett and data in Table 4 shows that root tuber yield increased with an increase in the age of the planting sett.

The increase in yield of the tuber with increasing age of the sett may be due to the higher dry matter content of the older setts. This experiment also shows that there is a positive linear relationship between dry matter of the sett and the yield of tuber (X=0.072Y – 0.196, r=0.959) where X is the tuber yield in Kg/plant and Y the dry weight of sett. The advantage of the older setts over the younger ones in production of root tuber yield may also be due to the higher N and K content in the former compared with the latter setts, and the results show that root tuber yield is positively and linearly related to N content in the sett (X=7.93Y + 0.37, r=0.985) where Y is the N content in the sett and also linearly related to K content in the sett (X=8.89Y + 1.010, r=0.926) where Y is the K content in the sett. Although leaf area measurements were not carried out in this experiment, it is likely that the higher dry matter N and K contents in the older setts encouraged greater leaf area development, and therefore led to greater yield of root tubers. The effect of age of sett on root tuber yield reported in this experiment is similar to that reported by Jergaseelan[18].

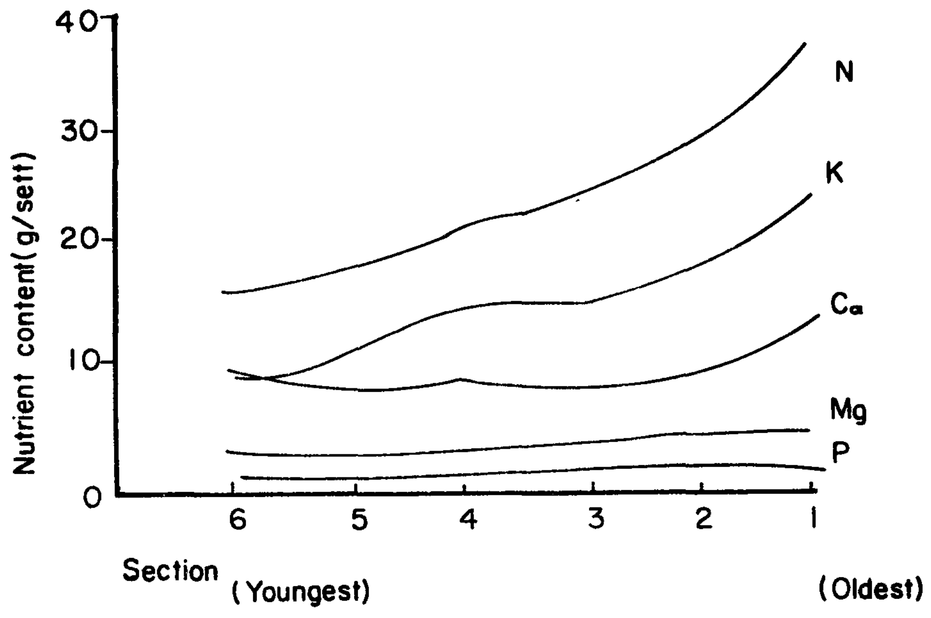

Fig.4. Nutrient content in the various planting setts

Effect of fertilizer application on growth and yield

In most root crops, the most important elements in applied fertilizers are nitrogen and potassium. Increase in tuber yield in yams by application of nitrogenous fertilizers have been shown by a number of workers (Vine[25], Nye[20], Irving[17], Giradot[15], Obi[21], Stephens[24], Djokoto and Stephens[5], Chapman[3], Anon.[1]). The yield increased between 10—20%. In an experiment with lesser yam nitrogen application encouraged greater total dry matter production and had a favourable effect on dry matter accumulation in the vine and petioles. Nitrogen application also increased the proportion of dry matter being diverted into the tubers of staked yams (Table 5).

Nitrogen application also increased leaf area duration and tuber number per plant (Table 5) and mean bulking rate (Table 6).

In this experiment, the regression of tuber yield on leaf area duration (D) shows that tuber yield is highly and positively related (r=0.97) to D. Since tuber yield is positively related to D, the increase in tuber yield as a result of nitrogen application might be attributed to the favourable effects of this treatment on leaf area development. In this experiment, increased leaf area was connected with increased vine growth and the calculated correlation coefficient for the relationship between leaf area index (L) and dry weight of vine at time of maximum L was 0.95. Since nitrogen increased dry matter accumulation in the vines, it therefore increased L by encouraging the growth of vine.

Yams have been shown to respond to low levels of potash applications (Irving[17], Giradot[15], Ferguson and Haynes[14]).

In an experiment with lesser yam, Enyi showed that the application of potassium increased dry matter accumulation in the tubers but had no effect on the other organs and at final sampling it increased the proportion of dry matter diverted into the tubers of both staked and unstaked plants (Table 5).

Potassium had no significant positive effect on leaf area duration (Table 5) but increased the rate of bulking (Table 6). In tannia (Enyi[9]) the application of fertilizer increased leaf area index (Fig. 5) and also the dry weight of both primary and secondary corms (Fig. 6). Since in tannia corm yield is positively related to maximum leaf area index, fertilizer application appears to increase corm yield mainly by encouraging greater leaf area development.

Effect of mulching on growth and yield

Mulched tannia plants had a significantly greater leaf area index than unmulched plants (Enyi[7]). Mulched plants also outyielded unmulched plants (Table 7).

In this experiment, corm yield was directly related to maximum leaf area index (Table 2) so that the beneficial effect of mulching on the corm yield of this crop may be attributed to its favourable effect on leaf area development.

Effect of time of planting on growth and yield

In most crops, greater yields are usually associated with early planting or sowing. For example, in potatoes, Dyke[6] showed in a survey that the yield of main crop potatoes declined at the rate of about 753kg/ha for each week's delay in planting beyond the second or third week in April.

In cassava experiments (Enyi[12]), early planting also led to an increase in the yield of root tubers, root tuber number per plant, individual tuber weight and root tuber: stem weight ratio (Table 8).

Relative leaf area duration in this experiment decreased with delay in planting because of the reduction in the period of leaf growth brought about by late planting (Table 9).

In the 1967 and 1968 trials, the rate of bulking decreased when planting was delayed until after 29th April and 13th May respectively. The decrease in root tuber yield resulting from late planting therefore might be attributed to the decrease in both the rate and period of bulking.

Root and tuber yield was also associated with leaf area duration and, since leaf area duration decreased with delay in planting, the decrease in root tuber yield might also be attributed to the decrease in leaf area duration.

In lesser yam, delay in planting also led to decrease in the yield of tubers (Table 10), tuber number per plant and relative leaf area duration.

In the late planted setts (T5 and T6), tuber initiation was delayed so that the period of bulking and tuber growth was reduced. The rate of bulking of these plants was also lower than those of early planted setts. These two factors probably contributed to the lower yield of T5 and T6 treatment plants. Enyi[11] showed that in lesser yam, a close and positive relationship exists between the number of tubers initiated and the leaf area index at the time of initiation. Since leaf area indices of plants from late planted setts were low at the time of initiation, the number of tubers initiated by these plants were probably lower than early planted ones.

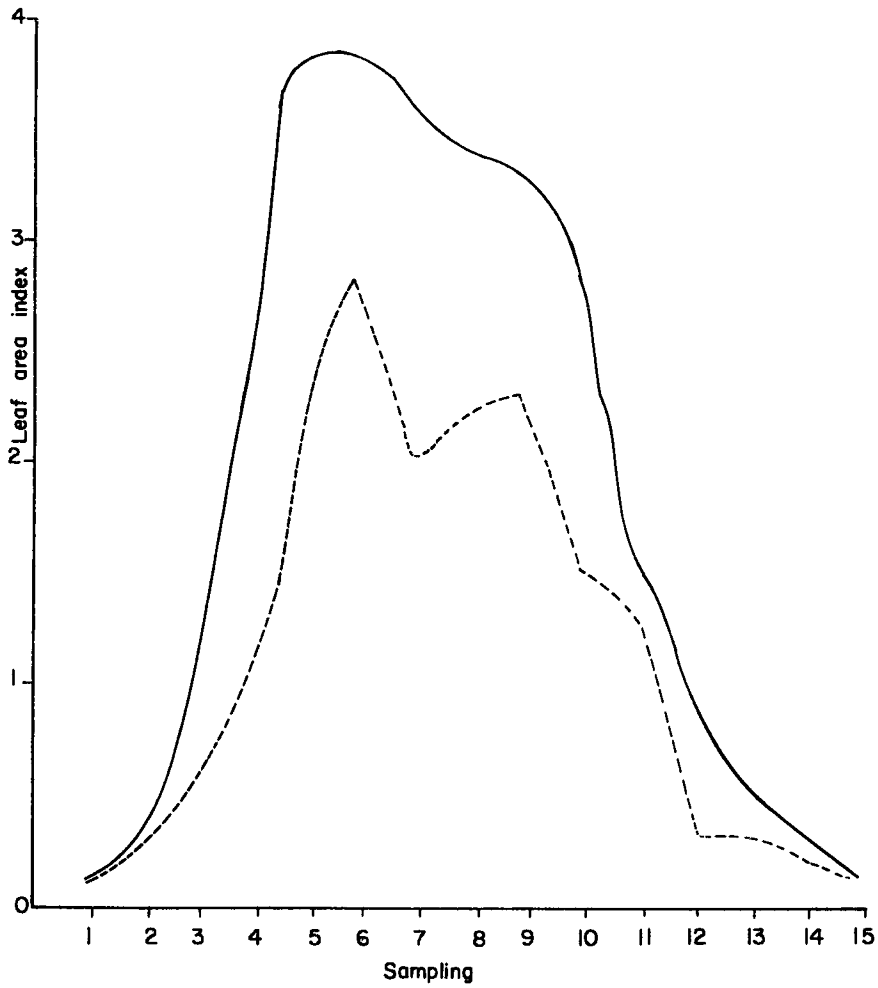

Fig. 5. Changes with time in leaf area index (Tannia) ——fertilized plants, ------unfertilized plants.

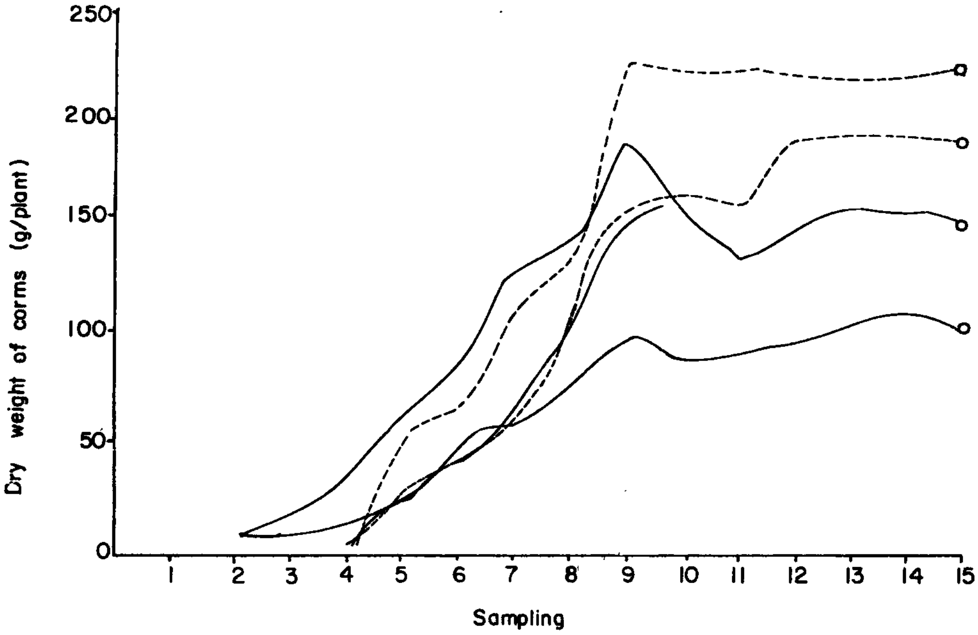

Fig. 6. Changes with time in dry weight of corms (Tannia) ●—● Primary corms of fertilized plants; ○—○ Primary corms of unfertilized plants; ○---○ Cormels of fertilized plants; □——□ Cormels of unfertilized plants

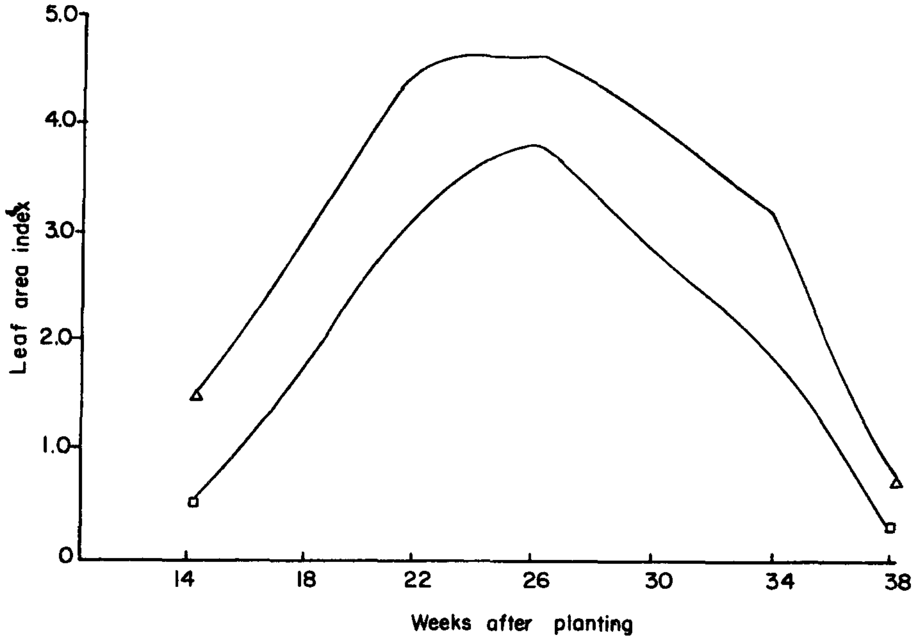

Fig. 7. Mean leaf area index △, mulch; □, no mulch (Tannia)

The lower number of tubers initiated by plants from later planted setts might have been responsible for the low tuber number of these plants at harvest (Table 10). In the date of planting experiment with lesser yam, tuber yield was shown to be positively related to leaf area duration with a correlation coefficient of 0.93 in 1967 and 0.95 in 1968. The decrease in tuber yield with delay in planting may therefore be attributed partly to the reduction in leaf area duration with delay in planting.

Effect of spacing on growth and yield

In a spacing experiment with tannia, (*Xanthosoma sagittifolium*) (Enyi[7]) the yield of corms increased with wider spacing (60 X 60cm, 90 X 90cm, 120 X 120cm and 150 X 150cm = 38.0, 41.2, 50.8 and 62.6kg/45dm^2 of land surface respectively. Corm yield in tannia was also closely and positively associated with maximum leaf area index (LAI) and, since LAI normally increases with increasing plant density, one would expect an increase in the yield of this crop to occur with increasing plant density. It is probable that at high plant density, the number of secondary corms formed from the main corm was reduced, and this probably led to the reduction in the number of 'sinks' available to accommodate the product of photosynthesis. In lesser yam, Enyi[7], increasing plant density led to an increase in tuber yield (Fig. 2), relative leaf area duration, and mean bulking rate per hectare (Table 11).

In this experiment there was a closer relationship between tuber yield and leaf are duration from tuber initiation onwards (D_F) than between yield and total leaf area duration, (D_T). The regression equation for the relationship between D_T and tuber yield (X) is $X=201D_T + 12876$ ($r=0.735$) and that between D_F and tuber yield is $X=376D_F + 8233$ ($r=0.932$). The highly positive linear relationship between D_F and tuber yield shows the importance of achieving and maintaining high leaf area during the period of tuber initiation and growth. Fig. 8 shows that leaf area duration achieved with increasing plant density was mainly due to the increase in leaf area index.

In lesser yam, the spacing effect was achieved by increasing leaf area duration and bulking rate per unit area.

In a cassava variety trial in Tanzania (1971/72 growing season), increase in plant density led to an increase in the yield of root tubers per hectare, the rate of bulking per hectare and relative leaf area duration (Table 12).

Most workers have reported that tuber yield in root crops is highly and positively correlated with leaf area duration. (Bremner and Taha[2], Enyi[11,12,13]) In the result presented in Table 12, a reduction in the interow spacing from 120 to 60cm led to an increase in the yield of tuber and rate of bulking by about 92 and 120% respectively, and an increase in leaf area duration by about 6%. In this experiment therefore, root tuber yield was more dependent on bulking rate than on leaf area duration.

Increase in plant population therefore led to an increase in tuber yield by increasing the rate of bulking per unit area.

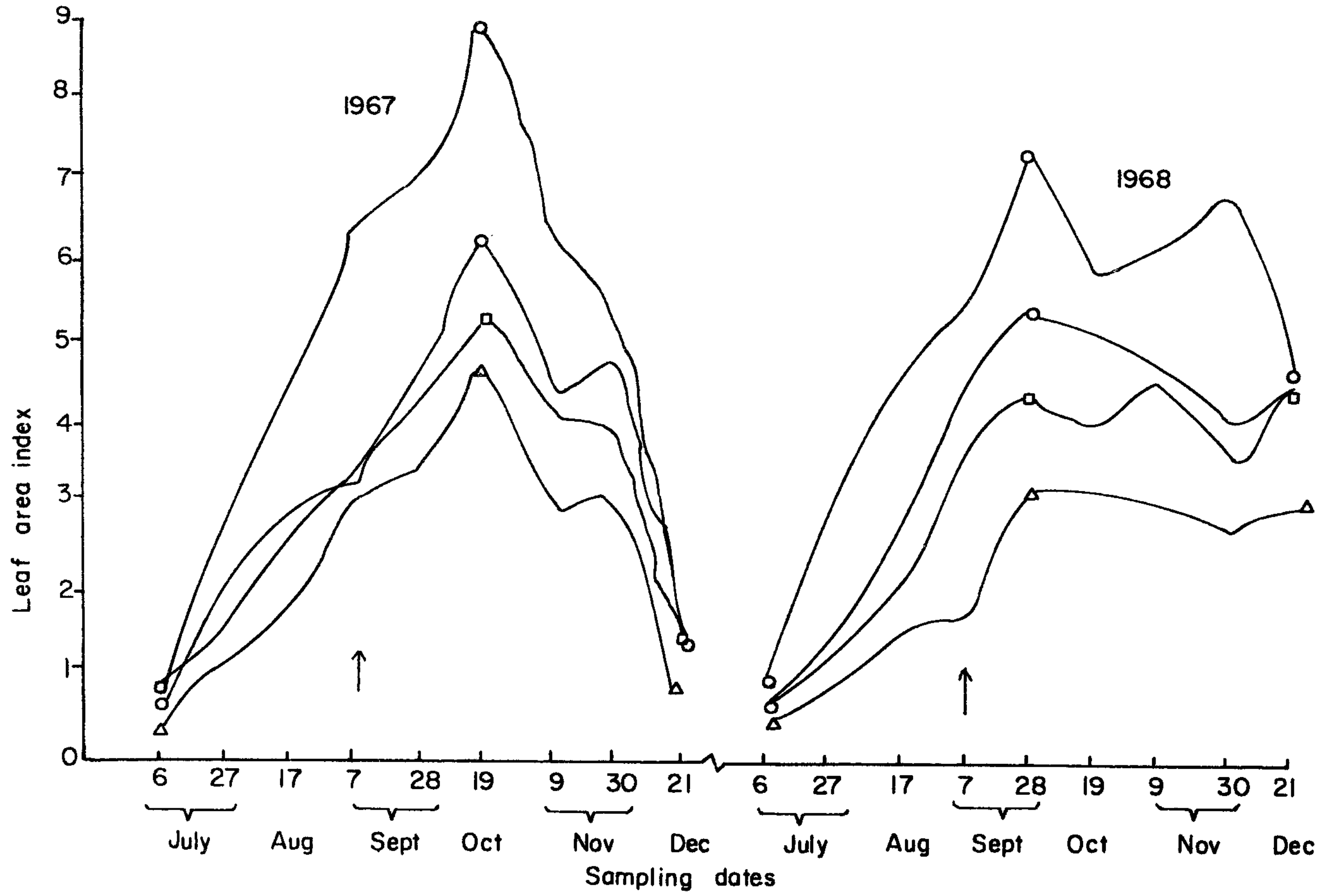

Fig.8. Effect of spacing treatments of leaf area index (lesser yam) O, 90 x 60m; o, 90x 90cm; □, 90 x 120 cm; △, 90 x 150 cm. Arrow indicates time of tuber initiation.

Effect of cultivar on growth and yield

Bremer and Taha[2] reported that there were differences in leaf area duration (D) of two cultivars of Irish potatoes studied by them and, as a result of this, cultivar Majestic produced more tuber dry weight than King Edward because of the greater D of the former than of the latter. The total tuber yield of Majestic at final harvest was greater than that of King Edward, due mainly to the longer period of tuber bulking in the former cultivar.

In cassava, a cultivar experiment, in Tanzania during the 1971/72 growing season showed Msitu Zanzibar outyielding Aipin Valenca, and the two cultivars in turn outyielded Amani 4026/16 (Table 13).

From these results however it can be seen that root tuber yield was poorly correlated with leaf area duration. The calculated correlation coefficient between root tuber yield and leaf area duration was 0.44.

In this investigation root tuber yield was positively and highly correlated with the rate of bulking per unit area ($r=0.866$). The relationship between tuber yield (metric t/ha) (Y) and bulking rate (kg/ha/wk) (B) is $y=0.0053B+10.3$. Since in this investigation there was no difference in the period of bulking between the cultivars, the cultivar difference in tuber yield can be attributed to differences in their bulking rates. William and Ghazali[27] reported that in the three cassava cultivars studied by them, the lowest yielding had the highest leaf area per stem. They also showed that the leaves of the highest yielding cultivar possessed attenuated lobes with a more vertical midday orientation. In the cassava cultivar investigation in Tanzania (Enyi[11,12,13]), the highest yielding cultivar had the highest leaf area per plant, and although Amani 4026/16 possessed narrower individual lobes, its root tuber yield was lower than that of Aipin Valenca, which possessed broad lobes. Also the mean angle of orientation of the leaves from the horizontal was greater in Amani 4026/16 than in Aipin Valenca. In this investigation therefore, there was no definite relationship between size of lobes, mean angle of the leaves from horizontal and root tuber yield.

Effect of staking on growth and yield

The aerial stems of yams are weak and in cultivation are usually supported by long poles up which they twine in a clockwise or anti-clockwise direction. Irvine[16] demonstrated that if the vines were supported by stakes to a height of 6 ft. their yield was almost double that of those supported to a height of only

3 ft. Similar results have been reported by Correll, Schubert, Gentry and Hawley[4] and Waitt[25]. The effect of staking on tuber yield in yams has been attributed to greater exposure of the leaves to sunlight.

In an experiment with lesser yam (Enyi[11]), staking increased tuber yield, tuber number per plant, mean tuber weight and mean bulking rate, and reduced the number of days between planting and tuber initiation (Table 14).

Staking also increased leaf area index (Fig. 9) and leaf area duration (Table 14). The increase in leaf area duration was due mainly to the effect of staking on increasing leaf area index and not on the duration of leaf growth. Increased leaf area was associated with increased vine growth, and the calculated correlation coefficient for the relationship between leaf area index (L) and dry weight of vine at time of attainment of maximum L was 0.95. Thus staking increases leaf area development by increasing the growth of vine. In this experiment, tuber yield was highly and positively correlated with leaf area duration (D) so that staking increased tuber yield by increasing D. The staking effect can therefore be associated with the difference in tuber number, rate and period of bulking, leaf area duration and individual tuber size.

Effect of shoot number per plant on growth and yield

Cassava setts when planted usually produce many shoots. Competition between these for nutrients and assimilates is likely to be great and could result in the reduction of the final tuber yield. If the shoot number from the cassava sett is reduced early in the growth stage of the plant, then competition between the shoots for the assimilates will be reduced and this may lead to a greater diversion of the assimilates to the root tubers, thereby resulting in an increase in the final yield of the root tubers.

In an experiment with cassava, (Enyi[12]), single shoot cassava plants (S_1) outyielded multi-shoot plants (Sm). Mean net assimilation rate, rate of bulking, individual tuber size and root tuber/stem weight ratio were all greater in S_1 than in Sm plants. However, Sm plants had greater tuber number and leaf area duration than S_1 (Table 15).

Yield results indicate that competition between shoots and roots for assimilates was more intense in the multi-shoot than in the single shoot plants. The accumulation of dry matter in the root tubers may be determined by the amount of assimilates available for tuber growth or by the capacity of the tubers for absorption of assimilates, the former being dependent on the rate of production of assimilates and the latter on the number and rate of growth of the tubers. In this trial, there was little or no difference in the mean root tuber number of single-shoot and multi-shoot plants, so that the difference in dry matter accumulation in the tubers of the two types of plant can be attributed to the difference in the amount of assimilates available for root growth.

Calculation of mean bulking rate (B) and net assimilation rate (E) for the period between samplings two and seven in the 1968 trial revealed that (B) was positively related to (E). The regression equation for

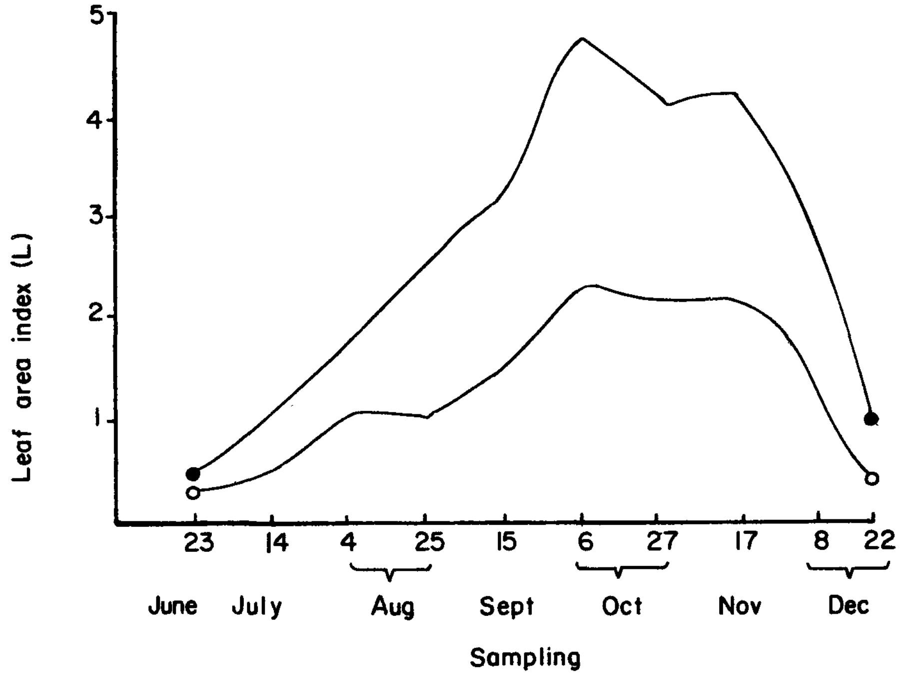

Fig.9. Changes with time in leaf area index in stake (●——●) and unstaked o——o lesser yam.

the relationship between E and B being B=1165E + 1340. Higher E in single shoot plants is therefore the probable cause of their greater bulking rates.

In the same investigation, only 27% of the variation in root tuber yield between treatments could be attributed to variation in leaf duration (D). However, the product of D and mean net assimilation rate accounted for 75% of the variation in yield between the treatments.

When D values of single-shoot plants were plotted against their yields the latter was found to be closely related to D, variation in D accounting for 95% of the total variation in tuber yield between the treatments.

Single-shoot plants were therefore superior to multi-shoot plants with regard to root tuber yield because of the greater bulking rate due to their high net assimilation rate.

The greater bulking rate brought about by the high net assimilation rate of the single shoot plants resulted in their greater root tuber yield than the multi-shoot plants. The increase in net assimilation rate of single shoot plants was due to the reduction in leaf area index brought about by the reduction in the number of shoots per sett.

REFERENCES

1. Anon. (1966) Consolidated review of trial and demonstrations results 1961–1964. F.F.H.C. Fertilizer Program F.A.O. Rome.

2. Brenner, P.M. & Taha, M.A. (1966) Study in potato agronomy. The effects on variety seed size and spacing on growth, development and yield. *J. Agric. Sci. Camb.* 66, 241–52.

3. Chapman, T. (1965) Some investigations into factors limiting yields of the White Lisbon Yam under Trinidad conditions. *Trop. Agric. Trin. 42*, 145–51.

4. Correll, D.S., Schubert, B.G., Gentry, H.S. & Hawley, W.O. (1955) The search for plant precursors of cortisome. *Econ. Bot.* 9, 107–75.

5. Djokoto, R.K. & Stephens, D. (1961) Thirty long-term fertilizer experiments under continuous cropping in Ghana. *Emp. J. Exp. Agr.* 29 (114): 181 (115): 245.

6. Dykes, G.V. (1956) The effect of date of planting on the yield of potatoes. *J. Agric. Sci. Camb.* 47, 122–8.

7. Enyi, B.A.C. (1967a) Effect of spacing, sett size, ridging and mulching on the development and yield of cocoyam (*Xanthosoma sagittifolium* Schott) *Trop. Agric. Trin.* 44, 53–60.

8. —————— (1967b) Effects of age on an establishment and yield of cocoyam setts *Xanthosoma sagittifolium* Schott)

9. —————— (1968) Growth of cocoyam (*Xanthosoma sagittifolium Indian J. Agric. Sci.* 38, 627–33.

10. —————— (1970) The effect of age on establishment and yield of cassava setts (*Manihot esculenta* Crantz). *Beitrage zur tropischen und subtropischen Land wirtschaft and Tropenveterinarmedizin* 8, 71–5.

11. —————— (1972a) The effects of seed size and spacing on growth and yield of lesser yam (*Dioscorea esculenta*) *Ann. Appl. Biol.* 72, 221–9.

12. —————— (1972b) Effect of shoot number and time of planting on growth, development and yield of cassava (*Manihot esculenta* Crantz) *J. Hort. Sci.* 47, 457–66.

13. —————— (1972c) The effect of spacing on growth, development and yield of single and multi-shoot plants of cassava (*Manihot esculenta* Crantz). II. Physiological factors. *E. Afr. Agric. For. J.* 38, 27–34.

14. Ferguson, T.U. & Haynes, P.N. (1970) The response of yams (*Dioscorea* spp.) to nitrogen, phosphorus, potassium and organic fertilizers. *Proc. Second Int. Symp. Trop. Root Crops* 1, 93–6.

15. Giradot, L.V. (1956) Planting and fertilizer experiments with yams. *Liberia (Suakoko) Cent. Agric. Exp. St.* Note 9.

16. Irvine, F.R. (1940) *A text-book of West African Agriculture.* Oxford University Press.

17. Irving, H. (1956) Fertilizer experiments with yam in Eastern Nigeria. *Trop. Agric. Trin.* 33, 67–8.

18. Jergaseelan, K.N. (1951) Studies in the growth and yield of cassava. *Trop. Agric.* 107, 168–71.

19. Nakanishi, H. & Negura, Y. (1958) Productivity of (a) pieces of tubers of Chinese yam in relation to their position on the tuber from which they were cut, and (b) of whole tubers raised from aerial tubers in relation to their size, for early harvesting *J. Hort. Ass. Japan* 27(2), 120–4.

20. Nye, P.H. (1954) Fertilizer responses in the Gold Coast in relation to time and method of application. *Emp. J. Exp. Agric.* 22(86), 101.

21. Obi, J.K. (1959) The standard D.N.P.K. experiments. Reg. Res. Sta. Samaru. Min. Agr. N. Reg. Nigeria. Technical Report No. 8.

22. Purewal, S.S. & Dargan, K.S. (1956) Effect of spacing on development and yield of arum (*Colocasia esculenta*) *Indian J. Agric. Sci.* 27, 151.

23. Sobulo, R.A. (1972) Studies on white yam (*Dioscorea rotundata*). I. Growth analysis. *Expl. Agric.* 8(2), 99–106.

24. Stephens, D. (1960) Fertilizer trials on peasant famrers in Ghana. *Emp. J. Exp. Agr.* 28 (109), 1.

25. Vine, H. (1953) Experiments on the maintenance of soil fertility at Ibadan, Nigeria. *Emp. J. Expl. Agr.* 21(81), 65.

26. Waitt, A.W. (1961) Review of yam research in Nigeria. Memoir 31. Dept. of Agric. Res. Nigeria.

27. Williams, C.N. & Ghazali, S.J. (1969) Growth and productivity of tapioca (*Manihot utilissima*) (1) Leaf characteristics and yield. *Expl. Agric.* 5, 183–93.

TABLE 1

Effect of seed size on yield of tannia and lesser yam

Sett size	Tannia ($kg/45dm^2$)	Lesser yam 1967 experiment. (kg/ha)	Lesser yam 1968 experiment. (kg/ha)
Small	42.5	20,583	15,060
Medium	48.6	24,598	20,080
Large	53.4	25,853	23,343
	l.s.d.(p=0.05)	2,058	2,008

TABLE 2

Relationship between mean maximum LAI and corm yield

	Ridge	Flat	Mulched	Unmulched	Very large setts	Extra large setts
Max.LAI	4.8	4.2	5.0	3.9	4.1	4.9
Corm yield (kg/plot)	17.5	15.8	21.4	11.9	15.0	18.3

TABLE 3

Effect of seed size on bulking rate, relative leaf area duration (RIAD) and final tuber number in lesser yam

	Bulking rate(kg/ha)		Tuber number/plant		RLAD(DF)
Year	1967	1968	1967	1968	1967
Large sett	1556	1456	32	40	48.7
Medium sett	1456	1355	31	37	41.2
Small sett	1330	1255	28	29	34.7

TABLE 4

Yield of setts and dry weight per sett

	1 (Bottom)	2	3	4	5	6 (Top)	SE
Yield of root (kg/plant)	3.42	2.65	2.35	1.98	1.65	1.80	3.3
Dry weight sett (g/sett)	47.2	41.0	36.6	32.6	27.2	24.2	-

TABLE 5

Dry weight of tubers as % of total dry weight (CI) and relative leaf area duration (RLAD) for the entire sampling period

	CI%				
Sampling dates	No	N_1	Ko	K_1	SE($22D_F$)
27.X.67	17.5	11.6	16.5	12.6	± 1.9
8.X.ii67	54.5	57.4	55.6	56.3	± 1.1
27.X.67	7.2	8.8	5.3	10.6	± 1.9
8.X.ii67	53.9	53.5	49.9	57.5	± 1.1
RLAD (mean for staked and unstaked)	61.1	77.9	66.7	72.3	± 4.5
Tuber no/plant	31	35	34	32	± 1.2

TABLE 6

Effect of N, K and staking on mean bulking rate (kg/ha/wk)

	Ko	K_1	No	N_1
Unstaked plants	1054	1280	1141	1193
Staked plants	2222	2459	2184	2497

TABLE 7

Effect of mulching on yield of corms (kg/plant)

	Ridge	Flat	Very large setts	Extra large setts	LSD (P=0.05)
Mulched	23.7	19.1	19.6	23.3	5.6
Bare soil	11.3	12.5	10.5	13.3	

TABLE 8

Root tuber yield and yield attributes at final harvest

	Planting dates			
	29th April (T1)	13th May (T2)	27th May (T3)	10th June (T4)
Root tuber yield kg/ha	30,622	22,590	20,833	$16,064 \pm 679$
Root tuber no/plant	13.3	10.6	11.6	8.9 ± 0.67
Weight/root tuber	265	242	206	203 ± 17
Root tuber:stem weight ratio	1.7	1.6	1.4	1.1 ± 0.09

TABLE 9

Relative leaf area duration (T1 Sm=100.0)

	Planting dates(see Table 8)							
	T1		T2		T3		T4	
Year	S1*	Sm**	S1	Sm	S1	Sm	S1	Sm
1967	65.6	100.0	47.2	73.9	41.1	64.9	33.1	47.8
1968	66.8	100.0	53.2	79.1	49.2	71.6	35.7	56.7

S1*= single shoot plants
Sm**=multi-shoot plants

TABLE 10

Effect of date of planting on tuber yield: tuber number/plant: bulking rate and relative leaf area duration

	Time of planting					
	10 Apr. (T1)	24 Apr. (T2)	8 May (T3)	22 May (T4)	5 June (T5)	19 June (T6)
Tuber yield (kg/ha)	20,331	24,849	14,056	15,060	12,801	8534±1179
Tuber number/plant	36	37	29	22	21	21
Bulking rate kg/ha/wk	1,593	1,982	1,381	1,481	904	1,155 (LSD at 5%=226)
Relative leaf area duration (T2=100.0)	97.2	100.0	66.8	52.8	38.8	25.7

TABLE 11

Effect of spacing on tuber yield, leaf area duration and bulking rate

	Spacing treatments			
	90 x 60cm	90 x 90cm	90 x 120cm	90 x 150cm
Tuber yield (kg/ha)	30,120	25,100	21,586	17,820
Relative leaf (D_T)	76.4	54.3	49.3	36.4(large seed)
Area duration (D_F)	57.2	41.7	37.2	28.9 (D_F=100.0)
Bulking rate	1,883	1,657	1,406	1,205

TABLE 12

Effect of spacing on root tuber yield, rate of bulking and relative leaf area duration (Tanzania 1971/72)

	Spacing treatments		
	90 x 60cm (S1)	90 x 90cm (S2)	90 x 120cm (S3)
Root tuber yield metric t/ha	66.6	69.0	36.1±4.8
Rate of bulking (kg/ha/wk)	11,760	10,310	4,560±485
Relative leaf area duration	79.2	70.6	67.4±4.3

TABLE 13

Effect of variety on root tuber yield, rate of bulking and relative leaf area duration

	Varieties		
	Amani 4026/16	Aipin Valenca	Msitu Zanzibar
Root tuber yield metric t/ha	43.0	61.1	67.6±4.8
Rate of bulking (kg/ha/wk)	6,400	11,030	9,200±485
Relative leaf area duration	62.2	56.8	98.2±4.3

TABLE 14

Effect of staking on tuber yield at harvest and yield attributed

	Staked	Unstaked	SE
Root tuber yield (metric t/ha)	20,331	13,303	±577
Rate of bulking (kg/ha/wk)	2,340	1,167	±65
Relative leaf area duration	80.2	58.7	±6.5
Tuber number per plant	36	30	±1.2
Mean tuber weight (g)	47.3	36.2	±1.8
Number of days from planting to tuber initiation	146.3	160.1	±1.7

TABLE 15

Effect of shoot number on yield, yield attributes, leaf area duration and net assimilation rates (All data as differences between S. and Sm)

	1967	1968
Root tuber yield kg/ha (Sl-Sm)	4,016±679	14,558±1,380
Root tuber number/plant(Sl-Sm)	-2.2±0.95	-1.5
Weight/root tuber (Sl-Sm)	265±17	146±26
Root tuber/stem W.ratio(Sl-Sm)	0.6±0.16	1.3±0.17
Relative leaf are duration(Sl-Sm)	-34.4	- 33.2
Net assimilation rate (Sl-Sm) ($g/dm^2/wk$)	0.17	0.22

Sl=single shoot, Sm=multi-shoot