MORPHOLOGICAL AND AGRONOMIC TRAITS ASSOCIATED WITH YIELD PERFORMANCE OF SWEET POTATO

Jose L. Bacusmo and A. L. Carpena

Instructor, Philippine Root Crop Research and Training Center, Visayas State College of Agriculture, ViSCA, Leyte, and Associate Professor, Department of Agronomy, U.P. at Los Baños, College, Laguna, Philippines.

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ABSTRACT

Leaf area index, crop growth rate, leaf angle of young leaves, internode length, number of roots per plant and mean root weight showed a positive correlation with root yield. Specific leaf weights, net assimilation rate at 30 and 60 days after planting and moisture content showed negative correlation with yield. Compensatory relationship between mean root weight and number of roots per plant was demonstrated in high yielding varieties of sweet potato. The extent of direct and indirect effects of 7 shoot characters and 5 root components on root yield was determined using path-coefficient analysis.

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KEY WORDS: Sweet potato. *Ipomoea batatas.* Growth pattern. Morphological and agronomic characters. Root yield.

INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam.) is one of the most important staple food crops in the Philippines. Its edible roots provide dietary carbohydrates to millions of Filipinos especially to those who are living in areas where agro-climatic conditions do not favor growing of cereal crops such as rice and corn. Recognizing the importance of sweet potato, some institutions have recently initiated breeding programs of this crop. Primarily, these programs are aimed toward improving the level of productivity of sweet potato.

Like any other crop, the productivity of sweet potato is the integrated result of all the physiological processes that occurred in the plant system starting from germination until the time of harvest. Thus, a systematic breeding program for yield must start with the identification of plant characters on which yield depends followed by studies on the genetic control of those characters. Finally, characters which are confirmed to be important to yield will be incorporated into new varieties.

In sweet potato, the relationship of variation in plant traits to yield is not widely known. Few experiments dealing on this subject were available and these were mostly conducted in the sub-tropical climates of China and Japan. The insufficient understanding on this regard poses perplexity to breeders in the tropics in developing and selecting new varieties with better yield.

This study related the growth patterns of sweet potato to root yield and identified some morphological and agronomic characters that significantly influence root production of sweet potato.

MATERIALS AND METHODS

Fresh tip cuttings of 16 sweet potato varieties, about 30-35 cm long, were planted on ridges at a distance of 100 cm x 25 cm.

Sampling Procedure.— Thirty days after planting, plant samples from 1.5 m^2 quadrats were gathered for determination of leaf area and dry matter accumulation. Samples were partitioned into leaf blades, vines, fibrous roots and storage roots. These were sundried then oven-dried at a temperature of 60°C until constant weights were attained. Approximate leaf area was calculated by taking leaf discs from 50 expanded leaves per quadrat using a leaf puncher. In every leaf blade, one disc was taken at the middle of the whole leaf and another 2 at the part regarded as the center of a half leaf. Leaf disc samples were also oven-dried until constant weights were obtained. Leaf area was calculated using the equation:

$$\text{Leaf area} = \frac{\text{Dry weight of leaf blades x Disc area}}{\text{Dry weight of leaf disc}}$$

Succeeding samplings were done at 30-day intervals. Plants were harvested 135 days after planting. Varieties with total yield of 15 tons/ha or higher and those with total root yield of less than 15 tons/ha were referred as high and low yielding varieties, respectively.

Growth Analysis Parameters.— The following growth analysis parameters were calculated:

1. Crop growth rate (CGR) - the increase in plant dry weight per unit time and was computed as:

$$\text{CGR} = \frac{W_2 - W_1}{\text{G. A. } (t_2 - t_1)}$$

Where W_1 and W_2 were the total dry weights of plant samples at time 1 (t_1) and time 2 (t_2), and G.A. was the ground area occupied by the sample plants.

2. Leaf area index (LAI) - the ratio of leaf area to the ground area occupied by each sampling quadrat at a particular stage of crop growth.

3. Leaf area ratio (LAR) - the ratio of leaf area to the total dry matter at a particular stage of crop growth.
4. Net assimilation rate (NAR) - the increase in plant dry weight per unit leaf area per unit time was computed using the equation:

$$NAR = \frac{W_2 - W_1}{A_2 - A_1} \times \frac{\mathrm{Log}_e A_2 - \mathrm{Log}_e A_1}{t_2 - t_1}$$

Where W_1 and W_2 were the total dry weights of plant samples, and A_1 and A_2 were the leaf area values at time 1 and time 2, respectively.

Agronomic and Morphological Data. —

1. Number and weight of marketable roots — obtained by counting and weighing roots with a diameter of at least 4.0 cm.
2. Number and weight of non-marketable roots — obtained by counting and weighing roots with a diameter of less than 4.0 cm.
3. Mean root weight — computed as:

$$MRW = \frac{\text{Root weight per plant}}{\text{Number of roots per plant}}$$

4. Moisture content — the percent weight reduction in fresh weight of samples (transverse discs punched from fresh roots at harvest and oven-dried at 60°C).
5. Leaf angle — obtained by measuring the angle between central lobe and the horizontal of 80 sample leaves per cultivar at 2 months after planting.
6. Specific leaf weight based on dry weight (SLWD) — obtained by getting the dry weight of 100 leaf discs and then expressing it as weight per unit leaf area.
7. Vine measurements — obtained by measuring the diameter and internode length of vines using a vernier caliper and a ruler.

RESULTS AND DISCUSSION

Crop Growth Rate.

CGR increased linearly at 30 and 60 days after planting then gradually declined after 90 and 120 days (Fig. 1). High yielding varieties generally exhibited higher CGR than the low yielding ones. The root-shoot ratio was wide during the first 60 days after planting after which it narrowed when the plants were already at 90 and 120 days of development. This seemed to indicate that during the first 60 days, root initiation occurred while root bulking occurred from 60 days after planting up to harvest.

Leaf Area Index.

Significant differences on LAI of 16 sweet potato varieties indicated varietal differences in photosynthetic capacity. Increment of LAI for all varieties was rapid during the first 30 days after planting then levelled off during the subsequent stages of

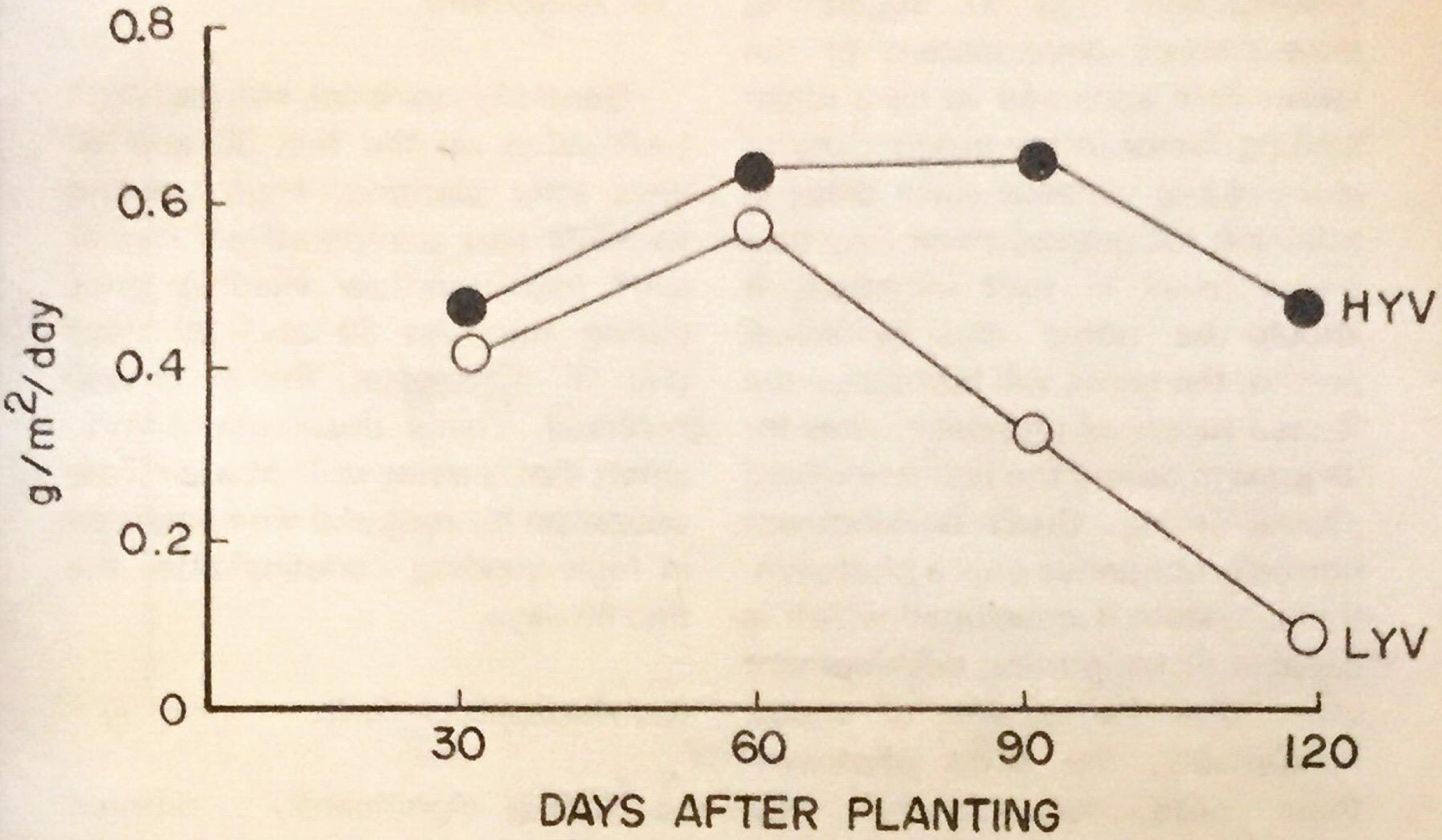

Fig. 1. Mean crop growth rate of high and low yielding varieties of sweet potato at four stages of sampling (Days after planting).

sampling. Increase in LAI value was lowest when the crop approached maturity (120 days) possibly due to the nearly balanced rate of leaf initiation and leaf senescence. It was noted that levelling off of LAI coincided with the period when storage roots started to bulk.

Generally, high yielding varieties maintained higher LAI than the low

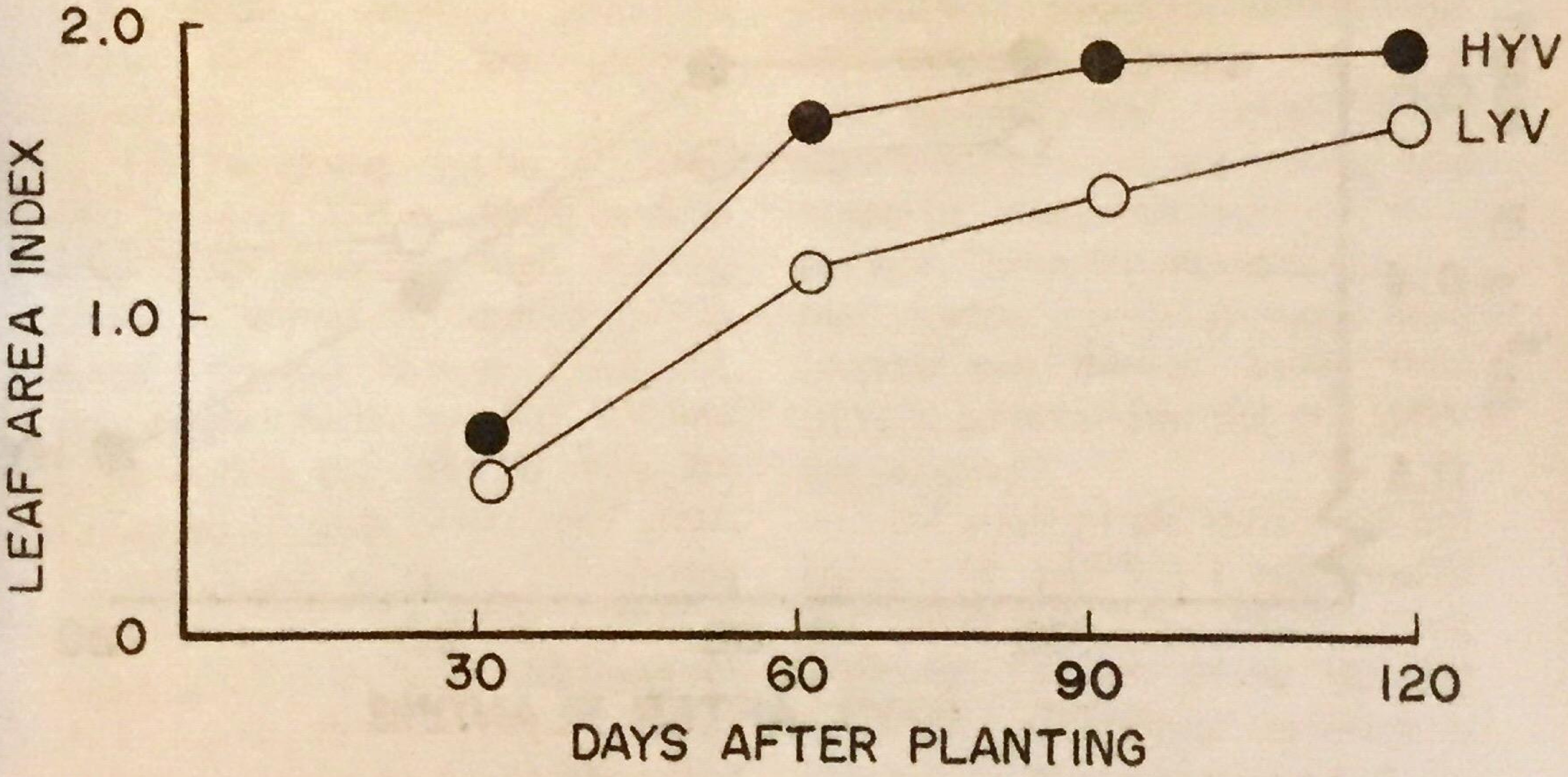

Fig. 2. Mean leaf area index of high and low yielding varieties of sweet potato at four stages of sampling (Days after planting).

yielding ones (Fig. 2), suggesting slow canopy development of the latter. This appeared to be a major limiting factor in the productivity of low yielding varieties since delay in attaining full ground cover may also ensue delay in root initiation. It should be noted that in sweet potato, the shoot will first utilize the limited supply of photosynthates for its growth during the first few weeks after planting. Such development normally continues until a photosynthetic system is developed which is capable of supporting development other than for growth of shoot. Presumably, the extra photosynthate production coupled with favorable environmental factors trigger root initiation which eventually leads to shoot-root priority of assimilate translocation.

Leaf Area Ratio.

Generally, varieties showed high LAR value on the first 30 and 60 days after planting. High yielding varieties had comparatively higher LAR than the low yielding ones during the first 30 and 60 days (Fig. 3). Thereafter, the trend was reversed. These observations indicated that greater shift of assimilate utilization for root and vine occurred in high yielding varieties after the first 60 days.

Net Assimilation Rate.

NAR significantly differed among varieties. It was observed that some low yielding varieties maintained high NAR during the first 30 and 60 days. Remarkable

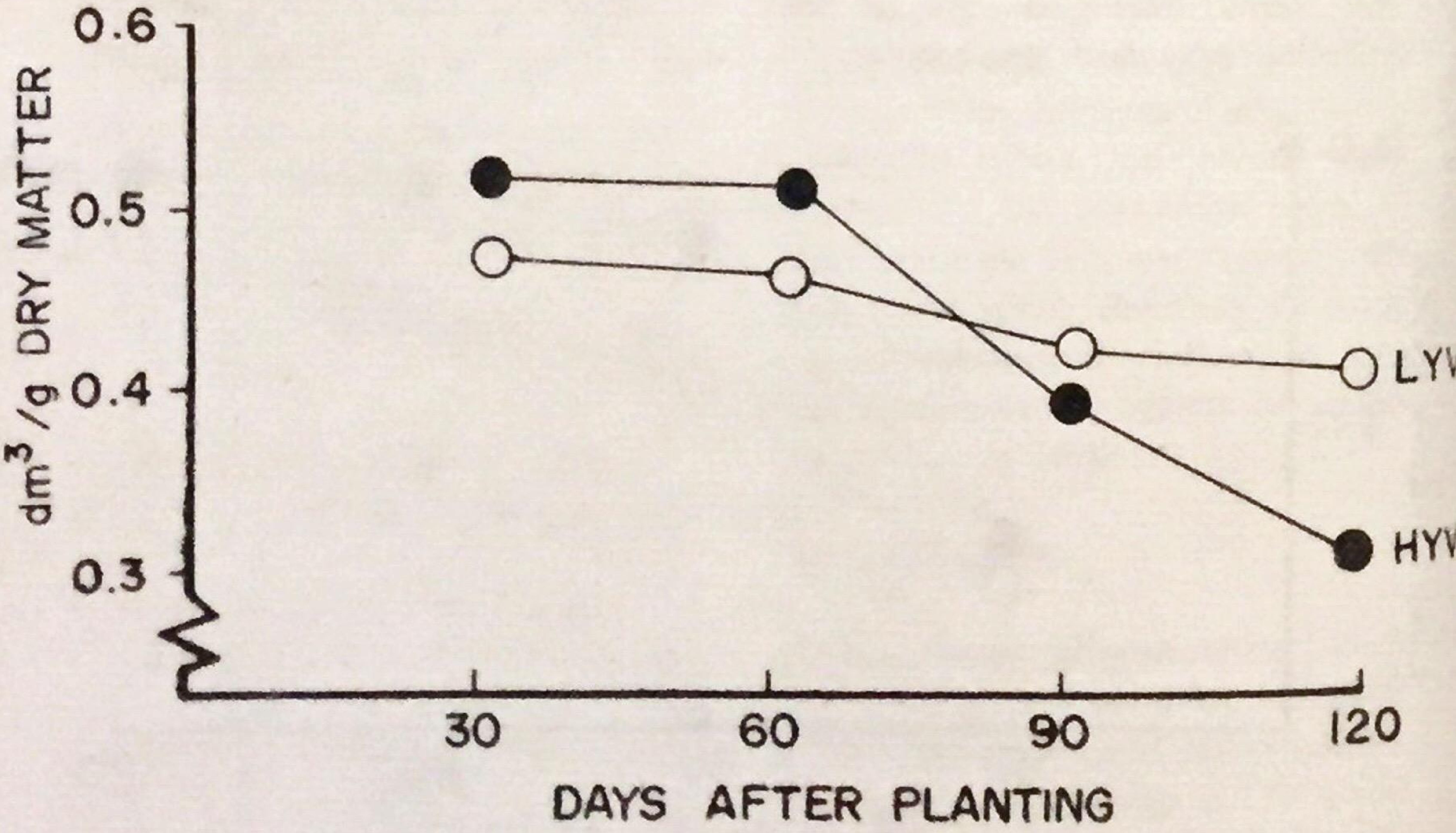

Fig. 3. Mean leaf area ratio of high and low yielding varieties of sweet potato at four stages of sampling (Days after planting).

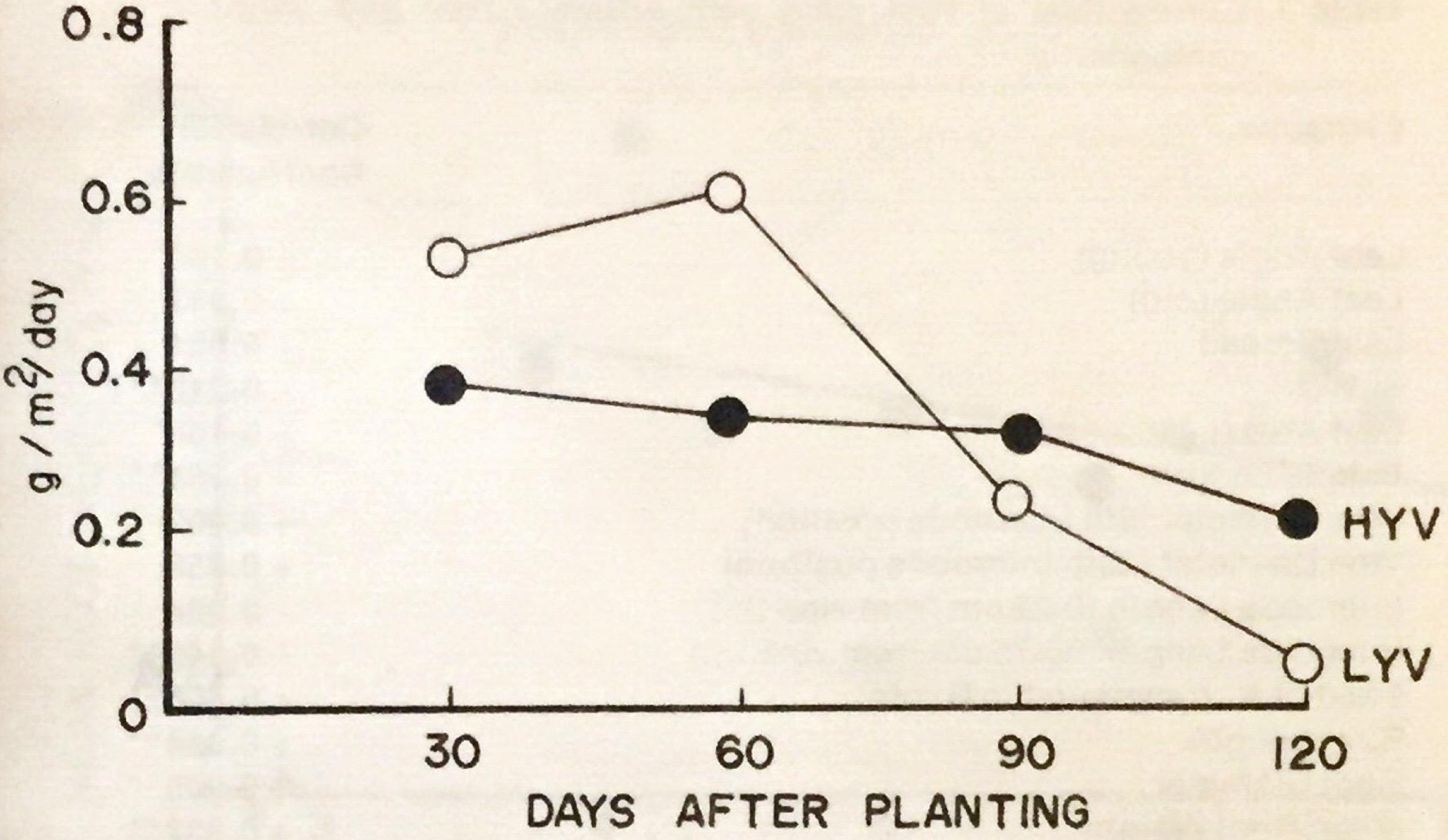

Fig. 4. Mean net assimilation rate of high and low yielding varieties of sweet potato at four stages of sampling (Days after planting).

differences in NAR of high and low yielding varieties occurred at 90 to 120 days after planting (Fig. 4). This somehow confirmed the work of Austriaco (1979) which showed that high yielding varieties produced higher NAR than low yielding varieties.

The foregoing results indicated that LAI and CGR could be used as criteria for selecting high yielding cultivars suited to cultivation in areas with low fertility. Evidently, genotypes which show high LAI and CGR during the first 60 days are expected to give better root yield. Extensive use of these parameters as criteria for selection within a segregating population will however be limited by the great deal of labor and time required in sampling and by the destructive nature of sampling.

Shoot Characters.

Correlation of root yield with different shoot and root components is summarized in Table 1. Significant negative relationship was indicated between root yield and specific leaf weight while significant positive relationship was noted between root yield and area per leaf. These results indicated that high yielding varieties generally have broader but thinner leaves (low SLWD) compared to the low yielding varieties.

Leaf angle of old leaves did not show any significant relationship with root yield suggesting that erectness of old leaves do not contribute substantial variation in root yield. This was expected because LAI of the crop throughout the growing season did not reach a

Table 1. Correlations of root yield with different root and shoot components.

Character		Correlation Coefficients
Leaf Angle (young)		+ 0.188*
Leaf Angle (old)		+ 0.043
Leaf Spread		- 0.024
SLWD		- 0.216**
Leaf Area/Leaf		+ 0.188*
Petiole Length		+ 0.268**
Vine Diameter (5th internode position)		+ 0.003
Vine Diameter (20th internode position)		+ 0.058
Internode Length (0-25 cm from vine tip)		- 0.034
Internode Length (50-75 cm from vine tip)		- 0.145**
Yield of Non-marketable Roots		+ 0.406**
Root Length		+ 0.354**
Root Diameter		+ 0.200**
Mean Root Weight		+ 0.837**
Root Moisture Content		- 0.149**
No. of Non-marketable Roots/Plant		+ 0.585**
No. of Marketable Roots/Plant		+ 0.181**
LAI at first	30 days	+ 0.217**
	60 days	+ 0.294**
	90	+ 0.456**
	120	+ 0.429**
LAR at first	30 days	+ 0.6758**
	60	+ 0.208**
	90	- 0.043
	120	- 0.392**
CGR at first	30 days	+ 0.289**
	60	+ 0.079
	90	+ 0.418**
	120	+ 0.293**
NAR at first	30 days	- 0.011
	60	0.104*
	90	0.299**
	120	+ 0.242**

*Significant at 5% level of probability.
**Significant at 1% level of probability.

value of 3.0 to 4.0 which Yuan (1966) reported as optimum for sweet potato. In this case, more horizontal leaves which ensure efficient ground cover may be even more desirable. Leaf angle of young leaves showed significant relationship with root yield.

Positive relationship between root yield and internode length of

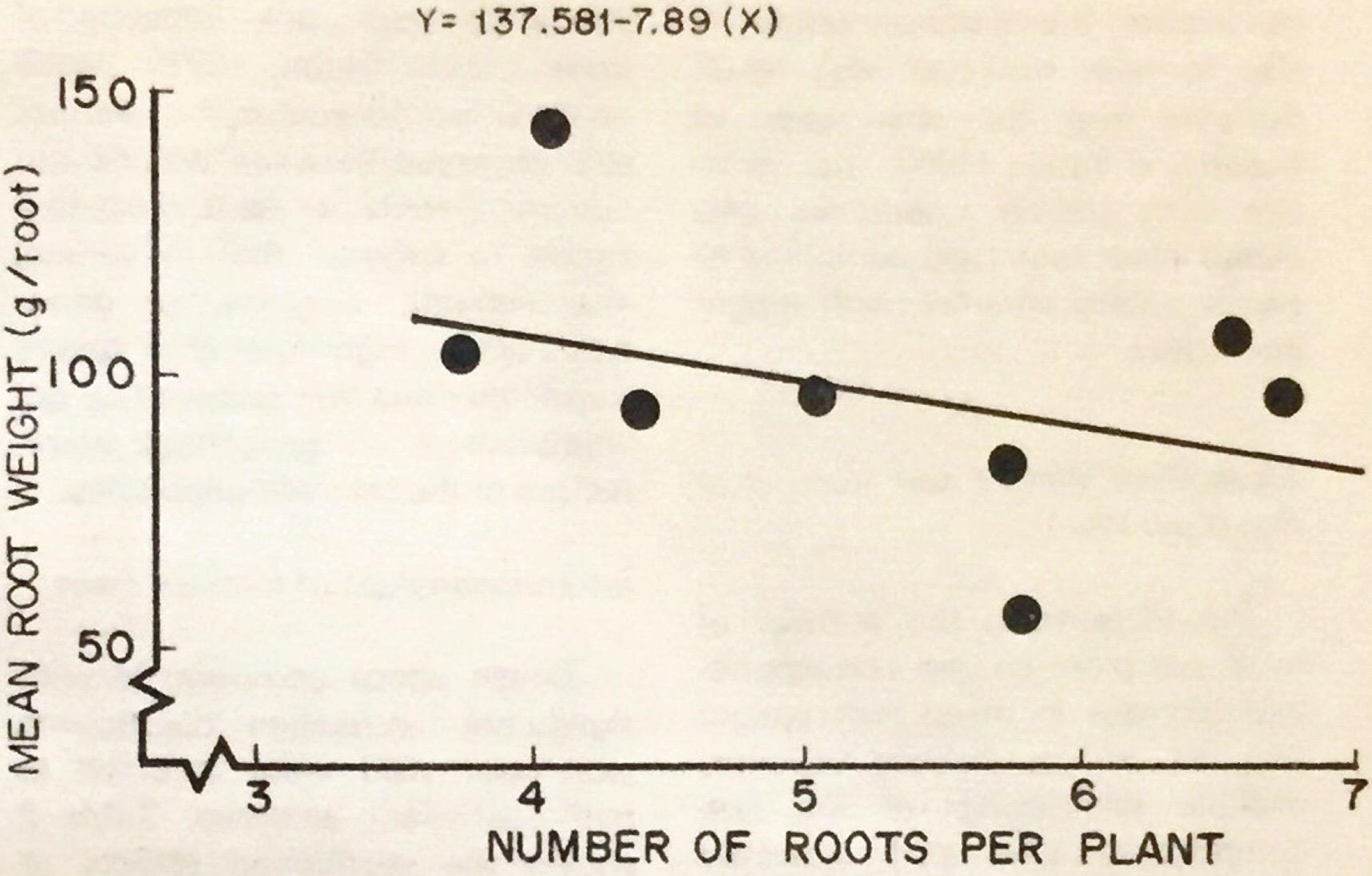

Fig. 5. Relationship of mean root weight and number of roots per plant in high yielding varieties of sweet potato.

mature vines was demonstrated. These observations suggested that selection for genotypes with short internodes on mature vines is important in selecting better yielding sweet potato varieties. It is possible that short internodes also signify high number of nodes where leaves

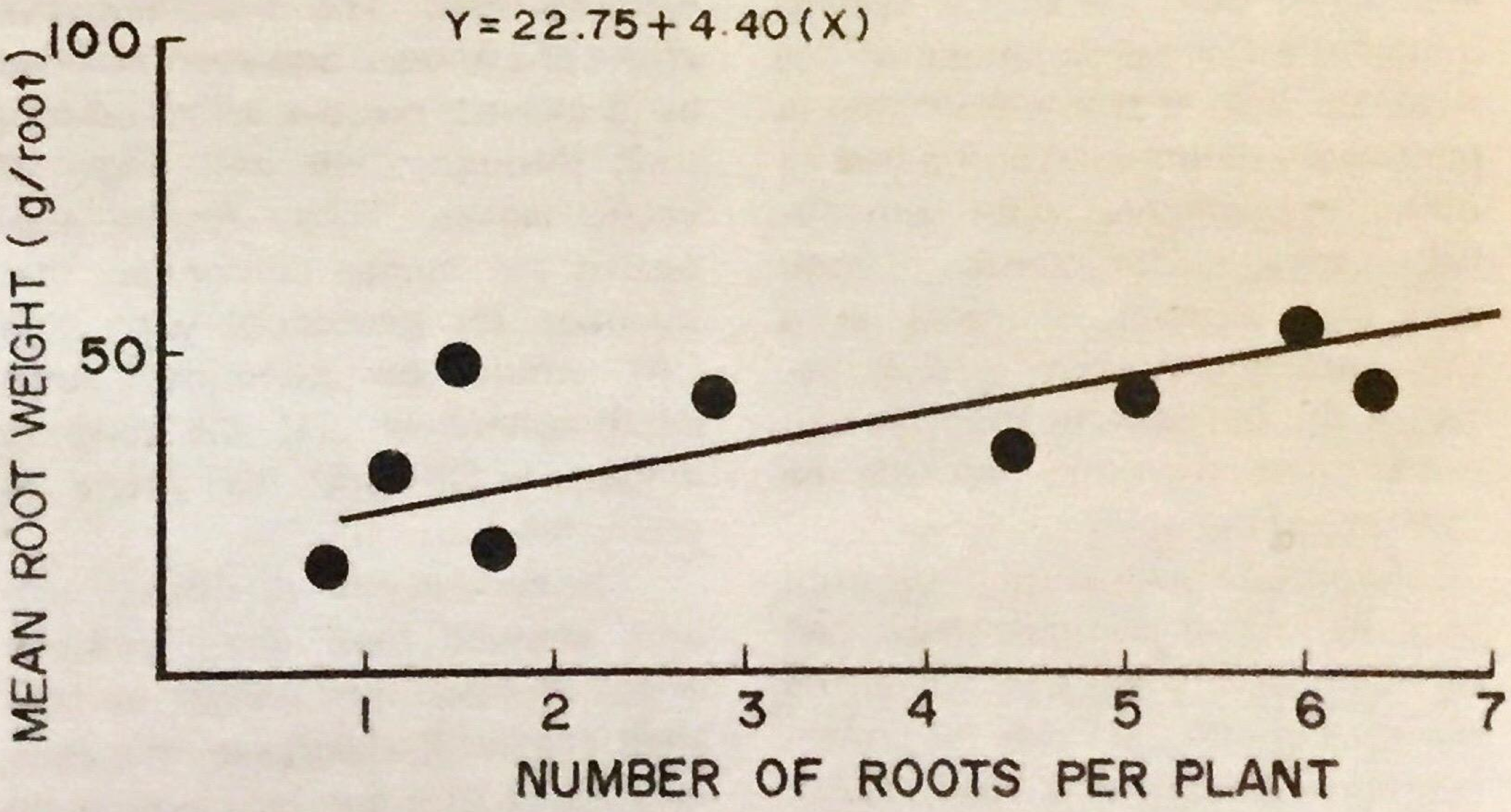

Fig. 6. Relationship of mean root weight and number of roots per plant in low yielding varieties of sweet potato.

can initiate, thus a denser canopy is also formed. However, this result deviated from the observation of Fujise and Tsuno (1965) that varieties with shorter internodes produced lower root yield compared to sweet potato varieties with longer internodes.

Mean Root Weight and Number of Roots per Plant.

An increase in the number of roots per plant caused corresponding decrease in mean root weight (Fig. 5). In low yielding varieties, positive relationship of the two components was also indicated (Fig. 6). These observations indicated a compensatory relationship between mean root weight and number of roots per plant. Varieties with high number of roots per plant can be construed to possess large sink capacity. However, limited assimilates from the source system inhibit the full development of the available sink. If this relationship is genetically determined and is true to other populations, then simultaneous selection for increase of both size and number of roots in a genotype would seem unlikely because the increase in the value of either component may preclude the increase of the other.

Available literature indicated that the rate of photosynthesis can be influenced to some extent by the demand of storage roots for photosynthates (Hozyo and Park, 1977). Moreover, providing a good source of assimilates does not improve an inherently poor sink capacity of sweet potato (Hahn, 1977). Based on these reports and on the relationship observed between weight and number of roots per plant, it seemed logical to suggest that in varietal improvement, selection of genotypes with a high number of tubers should be done first followed by the improvement of the canopy architecture of the selected genotypes.

Interrelationships of Various Traits.

Seven shoot components with significant correlation coefficients with root yield were included in path-coefficient analyses. Table 2 shows the partitioned effects of shoot characters on root yield. Leaf angle, CGR and NAR had direct positive influences on root yield but with less indirect effects through other components. Significant direct negative effects of specific leaf weight, internode length and LAI were revealed. The direct negative effect of LAI was, however, nullified by its indirect positive effect on root yield through CGR and angle of young leaves. These results supported the earlier contention that selection for genotypes with high LAI would be beneficial since improvement of LAI will tend to increase CGR and leaf angle of young leaves.

The second path-coefficient analysis showed high direct positive effect of mean root weight on root yield (Table 3). Likewise, the indirect effect of mean root weight on yield through its influence on number per plant was high while the

Table 2. Partitioned effects of seven shoot characters on root yield.

Characters Correlated	Path Coefficient
Specific Leaf Weight (Y_1) vs Root Yield	
Direct effect via Y_1 (P10)	.348
Indirect effect via Y_2 (r12 P20)	.032
Indirect effect via Y_3 (r13 P30)	.041
Indirect effect via Y_4 (r14 P40)	.016
Indirect effect via Y_5 (r15 P50)	.041
Indirect effect via Y_6 (r16 P60)	.027
Indirect effect via Y_7 (r17 P70)	.025
Total	-.216
Internode Length (Y_2) vs Root Yield	
Direct effect via Y_2 (P20)	.151
Indirect effect via Y_1 (r12 P10)	.074
Indirect effect via Y_3 (r23 P30)	.016
Indirect effect via Y_4 (r24 P40)	.016
Indirect effect via Y_5 (r25 (P50)	.004
Indirect effect via Y_6 (r26 (P60)	.026
Indirect effect via Y_7 (r27 P70)	.014
Total	.145
Leaf Angle (Y_3) vs Root Yield	
Direct effect via Y_3 (P30)	.186
Indirect effect via Y_2 (r23 P20)	.013
Indirect effect via Y_1 (r13 P10)	.076
Indirect effect via Y_4 (r34 P40)	.015
Indirect effect via Y_5 (r35 P50)	.058
Indirect effect via Y_6 (r36 P60)	.099
Indirect effect via Y_7 (r37 P70)	.008
Total	.188
Leaf Area per Leaf (Y_4) vs Root Yield	
Direct effect via Y_4 (P40)	.161
Indirect effect via Y_3 (r34 P30)	.018
Indirect effect via Y_2 (r24 P20)	.015
Indirect effect via Y_3 (r14 P30)	.035
Indirect effect via Y_5 (r45 P50)	.003
Indirect effect via Y_6 (r46 P60)	.010
Indirect effect via Y_7 (r47 P70)	.034
Total	.186
Leaf Area Index (Y_5) vs Root Yield	
Direct effect via Y_5 (P50)	.236
Indirect effect via Y_4 (r45 P40)	.002
Indirect effect via Y_3 (r35 P30)	.046
Indirect effect via Y_2 (r25 P20)	.003
Indirect effect via Y_1 (r15 P10)	.061
Indirect effect via Y_6 (r56 P60)	.326
Indirect effect via Y_7 (r57 P70)	.019
Total	.217
Crop Growth Rate (Y_6) vs Root Yield	
Direct effect via Y_6 (P60)	.426
Indirect effect via Y_5 (r56 P50)	.180
Indirect effect via Y_4 (r46 P40)	.004
Indirect effect via Y_3 (r36 P30)	.043
Indirect effect via Y_2 (r26 P20)	.009
Indirect effect via Y_1 (r16 P10)	.002
Indirect effect via Y_7 (r67 P70)	.016
Total	.288
Net Assimilation Rate (Y_7) vs Root Yield	
Direct effect via Y_7 (P70)	.022
Indirect effect via Y_6 (r67 P60)	.083
Indirect effect via Y_5 (r57 P50)	.014
Indirect effect via Y_4 (r47 P40)	.038
Indirect effect via Y_3 (r37 P30)	.006
Indirect effect via Y_2 (r27 P20)	.003
Indirect effect via Y_1 (r17 P10)	.119
Total	.299
Residual Factor (Y_z) vs Root Yield	.410

indirect effects through the other components of the above association were negligible. Number of roots per plant revealed direct positive effect and a marked indirect effect on root yield through mean root weights, the magnitude of which was almost equal to the direct effect.

Table 3. Partitioned effects of five root components on root yield.

Characters Correlated	Path Coefficient
Mean Root Weight (X_1) vs Root Yield	
Direct effect (W10)	+0.699
Indirect effect via X_2 (r12 W20)	+0.110
Indirect effect via X_3 (r13 W30)	-0.002
Indirect effect via X_4 (r14 W40)	+0.000
Indirect effect via X_5 (r15 W50)	+0.024
Total	+0.837
Number of Roots/Plant (X_2) vs Root Yield	
Direct effect (W20)	+0.276
Indirect effect via X_1 (r12 W10)	+0.294
Indirect effect via X_3 (r23 W30)	-0.001
Indirect effect via X_4 (r24 W40)	-0.000
Indirect effect via X_5 (r25 W50)	+0.016
Total	+0.585
Moisture Content (X_3) vs Root Yield	
Direct effect (W30)	+0.012
Indirect effect via X_2 (r23 W20)	-0.028
Indirect effect via X_1 (r13 W10)	-0.126
Indirect effect via X_4 (r34 W40)	-0.000
Indirect effect via X_5 (r35 W50)	-0.010
Total	-0.150
Root Diameter (X_4) vs Root Yield	
Direct effect (W40)	+0.001
Indirect effect via X_3 (r36 W20)	+0.001
Indirect effect via X_2 (r24 W20)	-0.000
Indirect effect via X_1 (r14 W10)	+0.192
Indirect effect via X_5 (r45 W50)	+0.008
Total	+0.200
Root Length (X_5) vs Root Yield	
Direct effect (W30)	+0.077
Indirect effect via X_4 (r45 W40)	+0.000
Indirect effect via X_3 (r35 W30)	-0.002
Indirect effect via X_2 (r25 W20)	+0.059
Indirect effect via X_1 (r15 W10)	+0.220
Residual Factor (Y_z) vs Root Yield	0.568
CGR at first 30 days	+0.289**
60	+0.079
90	+0.418**
120	+0.293**
NAR at first 30 days	-0.011
60	0.104*
90	0.299**
120	+0.242**

*Significant at 5% level of probability.

**Significant at 1% level of probability.

From the foregoing results, it appeared that the major part of variation in root yield can be attributed to variation in mean root weight of the different varieties of sweet potato. The effect of number of roots per plant appeared to be of lesser magnitude than that of mean root weight. This was, however, expected due to a compensatory relationship between these traits. The high direct positive effects of these components, their positive mutual association and the negligible indirect effect through other components seemed to suggest the possibility to breed or select for simultaneous improvement of mean root weight and number per plant. Caution should be taken toward this idea since the path-coefficients were based on results from an aggregate of high and low yielding varieties while regression correlation analysis revealed negative associations when only the high yielding varieties were accounted for.

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