Annals of Botany **76**: 337–341, 1995

Accumulation and Partitioning of Dry Matter in Taro [*Colocasia esculenta* (L.) Schott]

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Received: 13 December 1994 Accepted: 28 April 1995

A field study was conducted as part of an ongoing effort to collect data on patterns of leaf area development and dry matter accumulation and partitioning among various plant parts during growth and development of two taro cultivars. Plants were harvested for biomass about every 6 weeks during the growing season. At each harvest, plants were separated into various plant parts, and their dry matter content was determined. The first 80 d after planting were characterized by low rates of dry matter accumulation, with only leaves, petioles, and roots showing substantial growth. Afterwards, increases in total dry matter were mainly the result of corm and sucker growth. Corm bulking occurred after the attainment of maximal leaf area indices. The absence of an optimal leaf area index for a longer period of time may have prevented the realization of higher dry matter yields. The partitioning of dry matter to the corms of both cultivars remained almost constant especially after 150 d after planting. This process was in contrast to the partitioning of dry matter to the suckers, which increased significantly until the end of the growing cycle.

Key words: Taro, *Colocasia* sp., growth, dry matter partitioning.

INTRODUCTION

Taro (*Colocasia esculenta*) is a herbaceous, perennial root crop belonging to the Araceae family. It serves as an important food staple for inhabitants in some subtropical and virtually all tropical regions. Morphologically, this plant is characterized by a subterranean edible stem or corm enclosed by dry, scale-like leaves. Secondary corms or suckers, which develop from the main corm, are used as vegetative material for replanting. The above-ground portion of the plant consists of four to five peltate leaves. As with other root crops (e.g. *Xanthosoma* spp.) belonging to the same family, taro research has been given low priority. The National Academy of Sciences (1978) classified it as a neglected food crop with promising economic potential and this situation has not changed considerably since then.

Current yield levels in taro production are relatively low. On a worldwide basis, the crop yields only about 5799 kg ha^{-1} compared with 14746 kg ha^{-1} for potato (*Solanum tuberosum* L.) and 13628 kg ha^{-1} for sweet potato (*Ipomoea batatas* L.) (F.A.O., 1992). However, commercial yields of over 70000 kg ha^{-1} have been attained for fertilized taro under experimental conditions (Silva *et al.*, 1992). This demonstrates that the yields obtained by farmers are far below the crop's potential. There is, therefore, a need to develop technology to improve agricultural production of taro and transfer it to production sites. Increasing taro yields, however, will require a thorough understanding of the physiology and development of the crop, as well as the impact of various abiotic, biotic, and management factors on crop growth and development.

Crop simulation models have increased in importance as research tools for agrotechnology transfer and have promoted a more comprehensive understanding of the complex physical and biological interactions affecting yield performance of crops (Beinroth, 1990; Singh, Tsuji, and Beinroth, 1990; Goenaga *et al.*, 1991). Field-growth analysis data for taro as well as environmental inputs such as rainfall, temperature, and solar radiation from taro-producing areas are necessary parameters that are lacking for the development and subsequent validation of a crop stimulation model for taro.

This study was undertaken as a continued effort to collect such growth analysis data to develop the SUBSTOR-Aroid model (Goenaga *et al.*, 1991; Singh *et al.*, 1992) which will serve to accelerate transfer of agrotechnologies for aroid production in the tropics. The main objective was to determine dry matter accumulation and partitioning to various plant parts during growth and development of two taro cultivars.

MATERIALS AND METHODS

A field experiment was conducted at the Isabela ARS farm, in Isabela, Puerto Rico, USA. The soil is a well-drained Oxisol (clayey, kaolinitic, isohyperthermic, Tropeptic Eutrustox) with pH 6·1; bulk density, 1·4 g cm^{-3}; organic carbon, 2·0%; and exchangeable bases, 8·3 cmol(+) kg^{-1} soil. Preplant soil nitrate and ammonium at the 0–15 cm depth were 11·0 and 9·1 μg g^{-1} of soil, respectively. Table 1 shows maximum and minimum air temperatures, mean monthly rainfall, Class A pan evaporation, and mean solar radiation during the experimental period at the test site.

Taro plants of cultivars Blanca and Lila were planted in the field on 25 Jun. 1992, and arranged in a split-plot design with five replications. Each replication contained two main

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TABLE 1. *Average maximum and minimum air temperatures, total rainfall, Class A pan evaporation, and solar radiation for Jun. to May, 1992, at the test site*

Month	Maximum temperature (°C)	Minimum temperature (°C)	Rainfall (cm)	Pan evaporation (cm)	Solar radiation (mJ m^{-2})
Jun.	30·9	20·6	11·9	14·4	21·45
Jul.	30·7	21·3	14·1	16·8	21·40
Aug.	31·5	20·8	19·1	16·4	21·70
Sep.	31·2	21·0	10·3	12·1	17·96
Oct.	31·7	20·1	14·9	12·7	18·48
Nov.	28·9	20·2	18·5	10·4	15·40
Dec.	28·1	19·0	12·0	10·3	14·48
Jan.	27·4	18·7	8·6	10·4	15·03
Feb.	27·5	17·6	2·8	11·9	18·37
Mar.	29·0	18·1	9·3	16·4	20·54
Apr.	29·8	19·1	20·5	14·8	20·79
May	29·4	21·8	12·4	14·7	18·81
Average	29·7	19·8	12·9	13·4	18·70

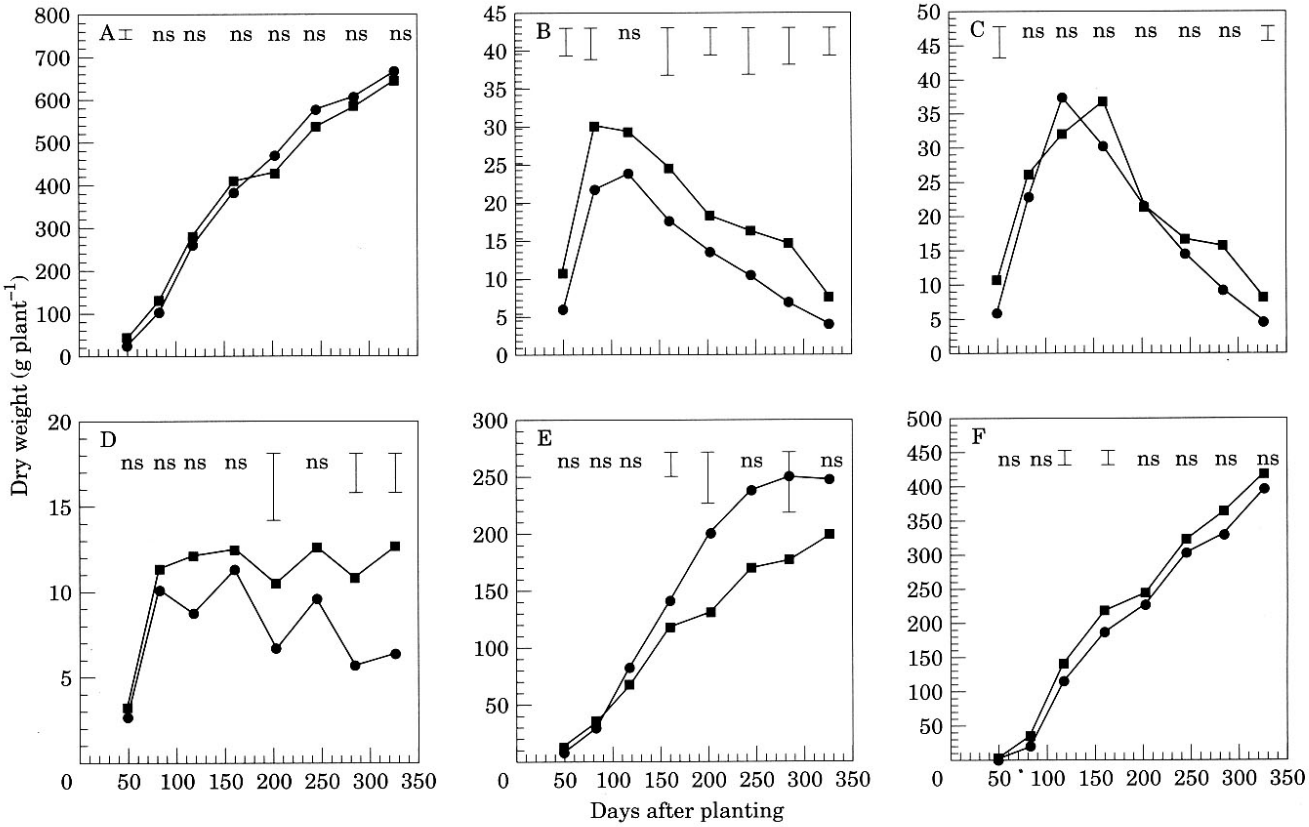

FIG. 1. Dry weight of plant organs of two taro cultivars as influenced by plant age. The vertical bars are significant l.s.d. values at $P < 0·05$. A, Total dry weight. B, Leaves. C, Petioles. D, Roots. E, Corms. F, Suckers. (■) Blanca, (●) Lila.

plots (cultivars), which were split to accommodate eight biomass harvests. The subplots contained 20 plants spaced 0·91 × 0·46 m apart, from which the inner six were sampled. The experiment was surrounded by two rows of guard plants.

The vegetative material used for planting consisted of taro suckers with fresh weights of about 70 g (7·2 g d. wt). Cultivar Blanca produces white-fleshed corms and is characterized by the production of elongated cormels which run some distance from the main plant before developing into suckers. Cultivar Lila produces purple-fleshed corms, and cormel production is centralized around the main plant.

At planting, each plant received 3·5 g of phosphorus provided as triple superphosphate. Plots were drip-irrigated when the soil water tension, measured with tensiometers at a depth of 15 cm, exceeded 20 kPa. Throughout the experimental period, fertilization was provided biweekly through the drip system at the rate of 5·6 and 7·6 kg ha^{-1} of

N and K, respectively, using a mixture of potassium nitrate and urea as the nutrient sources. The experimental area was hand weeded as necessary. These management practices allowed the plants to develop under nonlimiting conditions with respect to soil moisture and nutrient availability in order to study the maximum dry matter yield potential of each cultivar.

Plants were harvested and biomass measurements were made at 48, 82, 117, 159, 201, 243, 285, and 327 d after planting (DAP). At each harvest, leaves of plants were cut at the midrib–petiole intersection and brought to the laboratory for leaf area determination using a LI-COR 3000A area meter. Each of the six plants in the subplots was harvested by digging an area of 0·42 m^2 around each plant and to a depth of 30·5 cm. Plants were then pulled from the soil, washed, and separated into petioles, corms, cormels, roots, and suckers. Samples were dried to constant weight at 70 °C for dry matter determination.

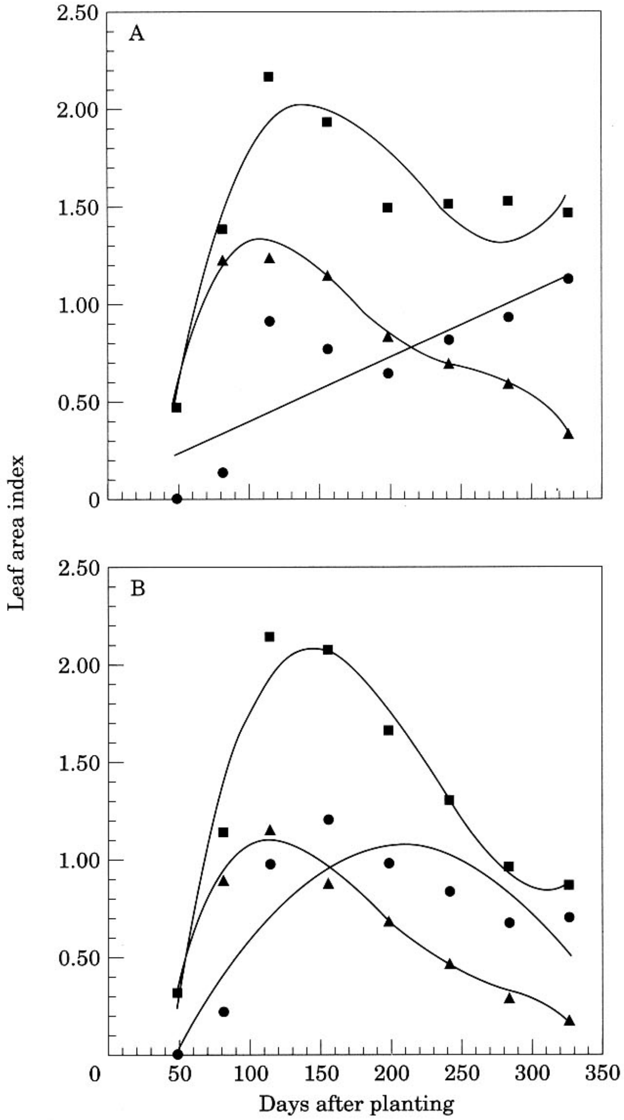

FIG. 2. Relationship between leaf area index and days after planting in two taro cultivars. A, Blanca. B, Lila. (■) Total leaf area index (LAI), (▲) LAI of main plant, (●) LAI of suckers.

Best-fit curves were determined using the general linear model (GLM) procedure of the SAS program package (SAS Institute, 1987). Only coefficients significant at $P \leqslant 0{\cdot}05$ were retained in the models.

RESULTS AND DISCUSSION

Dry matter accumulation

There was a similar pattern of total dry matter accumulation in both cultivars throughout the growing cycle (Fig. 1 A). The first 48 DAP were characterized by low rates of total dry matter accumulation in both cultivars. This growth stage was followed by a period of rapid growth in which total dry matter increased almost linearly until about 159 DAP. This was a result of increased rates in dry matter accumulation in most plant parts (Fig. 1 A–F). Thereafter, the increase in total dry matter was the result of corm and sucker growth (Fig. 1 E, F). These growth patterns are in accordance with other studies with aroids in which three distinct stages of growth have been reported (Igbokwe, 1983; Goenaga and Singh, 1992; Goenaga, 1994).

Maximum total (main plant plus suckers) leaf area indices (LAIs) were obtained at about 117 DAP and then declined sharply for both cultivars (Fig. 2 A–B). The maximum number of leaves on the main plants of Lila was 7·3 at 64 DAP and the number then declined rapidly, whereas, in Blanca, the total number of leaves did not change appreciably between 48 and 137 DAP (Fig. 3). At 117 DAP, LAIs of suckers from both cultivars represented an average of 44% of the total plant LAI, and this percentage increased to 79% at 327 DAP (Fig. 2 A, B). The LAI of suckers, therefore, represented a major fraction of the total LAI, particularly in late stages of growth. However, little is known about the contribution of assimilates from leaves of suckers towards the edible component of the plant (i.e. corms). Although corms represented a major sink for

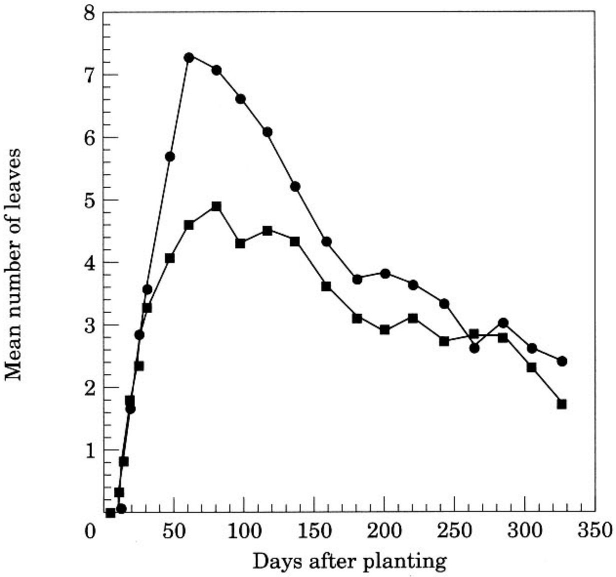

FIG. 3. Influence of plant age on the number of leaves produced by two taro cultivars. (■) Blanca, (●) Lila.

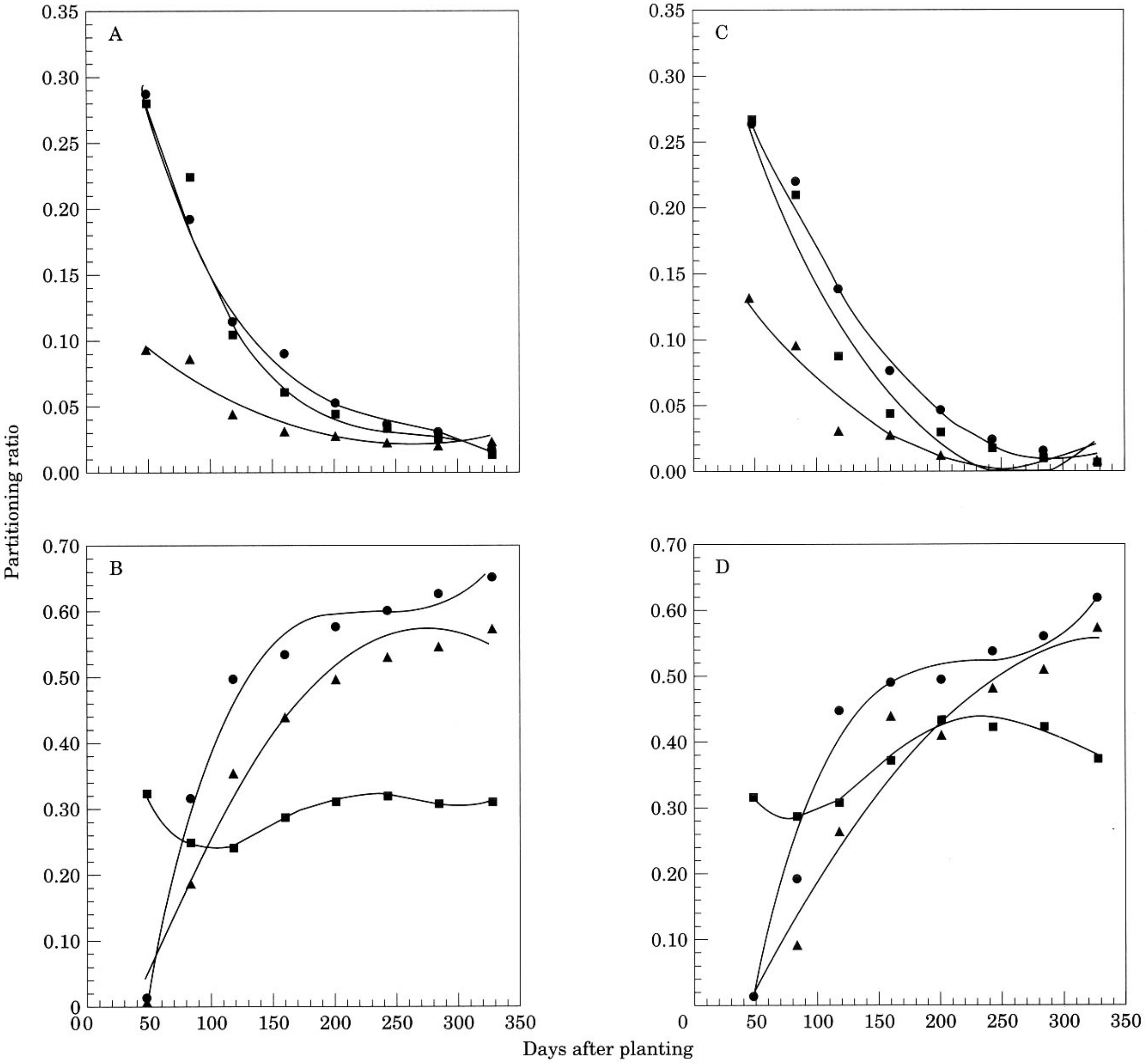

FIG. 4. Relationship between dry matter partitioning to different plant organs and days after planting in two taro cultivars. A, B, Blanca. C, D, Lila. In (A) and (C): (■) leaves, (●) petioles, (▲) roots. In (B) and (D): (■) corms, (●) suckers, (▲) cormels.

assimilates after 117 DAP (Fig. 1E), rapidly growing cormels of suckers comprised more than 50% of the plant total dry matter content after 201 DAP (Fig. 4B, D), and it is likely that assimilates from sucker leaves were translocated to the nearest source (i.e. cormels).

The LAI and canopy architecture determine the interception of solar radiation by a crop, and, consequently, the accumulation of dry matter in various plant parts. It is noteworthy that maximal LAI occurred at about 120 DAP but corm bulking continued until about 320 DAP (Figs 1E and 2A, B). This response may have prevented the realization of higher dry matter yields because of the absence of an optimal LAI over a longer period of time. Maintenance of an optimum LAI during the corm-bulking period could be accomplished by a slower leaf turnover (Sivan, 1980) or through the establishment of a high LAI (LAI > 5·0) before the initiation of the tuber-bulking period (Goenaga and Irizarry, 1994). Maximum corm and cormel dry matter yields in tanier (*Xanthosoma* spp.) were attained when LAI increased simultaneously with corm and cormel bulking and then levelled off for a prolonged period before finally declining late in the growing season (Goenaga and Singh, 1992).

Dry matter partitioning

Ratios of dry matter partitioning to leaves, petioles, roots, corms, cormels of suckers, and total suckers components (leaves + petioles + roots + cormels) are presented in Fig. 4. Except for differences in magnitude, the partitioning of dry matter to the various plant components was very similar for both cultivars. Early in the growing season, the plants allocated a greater percentage of dry matter to leaves and petioles; these organs accounted for over 40% of the total dry matter at 82 DAP (Fig. 4A, C). This response is expected during early growth, as plants become autotrophic and less dependent on stored assimilates from the planting material for growth. The reduction in the corm partitioning ratio (corm/total dry matter) that occurred from 48 to 82 DAP (Fig. 4B, D) is an indication of the importance of the planted seed piece as a primary source of assimilates for initial growth. As plants matured, the partitioning ratio decreased significantly for leaves, petioles and roots, changed little in corms, and increased significantly in cormels of suckers (Fig. 4A–D).

Although leaves and petioles are well developed in suckers early in the growing season, most of the suckers' dry matter was associated with the cormels. At 82 DAP, about 75 and 48% of the total dry matter partitioned to suckers of cultivars Blanca and Lila, respectively, was in the cormels. These percentages increased to about 90% for both cultivars by the end of the growing season (Fig. 4B, D). These results are of particular importance because taro cormels seldom reach a marketable size, but may compete for assimilates with the marketable main-plant corm. This situation contrasts greatly with that of other root crops (e.g. sweet potato, cassava, yam) in which photosynthate is translocated primarily to a single dominant sink during the bulking period (Huett and O'Neill, 1976; Goenaga and Irizarry, 1994; Pellet and El-Sharkawy, 1994). Studies are being initiated to determine if sucker production causes a significant diversion of assimilates from the main plant and, therefore, a reduction in commercial yields in upland taro.

The partitioning of dry matter to corms was very similar for both cultivars during the first 117 DAP (Fig. 4B, D). Afterwards, the sink capacity of corms varied among cultivars. Between 159 and 285 DAP, more than 37% of the total dry matter in Lila was in the corms, whereas the partitioning ratio of Blanca corms remained almost constant at about 30%. Growth analyses of *Xanthosoma* plants have shown that there are striking differences in the partitioning of dry matter to corms among cultivars (Goenaga and Singh, 1992). This physiological trait should, therefore, be taken into consideration in taro breeding programmes to improve yields.

This study demonstrates that, under optimum fertilization and irrigation management, corm dry matter yield and LAI increased significantly as compared with taro grown under rainfed conditions (Igbokwe, 1983). Further studies should be directed toward the screening of cultivars that can maintain a higher LAI during the corm-bulking period and have a higher partitioning of dry matter toward the corm rather than to the suckers under upland conditions. However, the necessity of selecting cultivars which produce three to five suckers per stand should be kept in mind, so that they can be used as planting material for the subsequent crop. Under the conditions of our study, plants produced an average of 12 suckers per plant (data not shown), which never attained a marketable size.

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