Growth and Development of Taro *(Colocasia Esculenta)* Under Dryland Conditions in Fiji

P.S. Sivan
Senior Research Officer
Ministry of Agriculture
Fiji

Abstract

The accumulation and distribution of dry matter and leaf area development pattern were determined in three cultivars of taro to characterize their growth and development pattern under dryland conditions. The growth and development pattern of taro was found to be similar to that of sugar beet and tannia. Corm development in taro commences early in growth and the leaves and corm develop synchronously up to maximum canopy at about 20 weeks. Thereafter, leaf growth slows down and the leaf area declines but corm growth continues until very little leaf area remains. Some factors determining yield are discussed in relation to the growth and development pattern of taro and possible means to improve yields are indicated.

Introduction

During recent years, the techniques of growth analysis to study both sequential change in plant dry matter accumulation and distribution and leaf area development have been widely employed in tropical root crops, yams (Sobulo, 1972; Njoku *et al.*, 1973), cassava (Enyi, 1972; Williams, 1974), sweet potato (Haynes *et al.*, 1967; Enyi, 1977) and tannia (Spence, 1970) to assess physiological factors limiting yield. Milthorpe (1967) and Wilson (1974) discussed the value of such studies in understanding the mechanisms controlling the yield of root crops and in identifying areas for investigation to overcome these limitations.

Growth studies on taro have been limited and the papers published refer to the wetland crop grown over a period of 12-15 months in Hawaii (Ching, 1970; Plucknett and de la Peña 1971). Taro in Fiji, is grown under dryland conditions for a duration of between 8-12 months,. It was assumed that due to a shorter growth cycle, the growth and development of taro under dryland conditions is likely to be different from that under wetland conditions in Hawaii. This study was carried out to determine dry matter accumulation and distribution and the leaf area development of taro to characterize its growth and development pattern under dryland condition.

Materials and Methods

Since the taro cultivars available in Fiji vary in leaf inclination, in addition to having different growth duration, care was taken in choosing contrasting varieties to generalize the growth and development pattern. The cultivars *Hawaii, Qawe* ni Urau and *Tausala* *ni Samoa* varied in the angle of leaf lamina to the vertical. The mean values of these angles were 80°, 70°, and 47° for the three varieties, respectively.

Replicated blocks of the three cultivars were planted and sampled in accordance with the requirements for growth analysis. The cultivars were planted in the main plots and replicated 5 times using similar sized planting materials in each replication. The main plots were split into 24 dates for harvest. Each subplot contained 20 plants spaced 60 cm apart from which 6 plants from the middle of the plot were sampled.

Fertilizers P (50 kg/ha) and K (200 kg/ha) were applied at planting. Nitrogen (200 kg/ha) was given in split application at 6 and 12 weeks after planting. The crop was kept free of weeds by regular spraying with weedicides.

Samples were taken from the subplots at bi weekly intervals. During the course of growth the originally planted material (referred to as the main plant from here onwards) produced side suckers which were also sampled. A day before harvest, leaf area was calculated, using a predetermined relationship between linear measurements and leaf area (similar to that described by Chapman 1964). At each harvest, fresh weights of suckers separated from the main plant, cleaned and each separated into lamina, petiole, corm and roots, were recorded. To facilitate drying, corms and petioles were sliced into thin sections. All plant components were dried to constant weights at 80°C for dry matter determination.

The time lag between the production of successive leaves was measured by tagging each leaf on the plants in the subplots reserved for the last harvest and noting the date when it opened. Leaf longevity was determined by claculating the period from the time the leaf opened to the time the leaf showed 50% or more yellowing.

The growth rates of cultivars were claculated by computer by fitting cubic polynomials to logarithmically transformed growth data using the program of Hunt and Parsons (1974).

Results

Accumulation and distribution of dry matter in the main plants of the three cultivars are shown in Fig. 1. Three phases in the growth of the main plant were recognized. Phase I lasted for about 6 to 8 weeks during which the plant lost dry matter in the first two weeks after planting and then started to accumulate slowly. Both the leaf (lamina + petiole) and corm dry matter decreased in the first two weeks and then increased slowly. This was followed by a grand growth period (Phase II) in which the plants accumulated dry matter very rapidly reaching a peak at 22 to 24 weeks.

Rapid increase in corm dry matter started about 8 weeks after planting and the corm continued to develop during the rest of this phase. However, the increase in leaf dry matter was slightly more rapid than the increase in corm dry matter during this phase. Root dry matter increased steadily during Phases I and II and reached its peak at about 24 weeks.

From about 24 weeks onwards Phase III was recognized during which total plant dry matter declined. Leaf dry matter in this phase decreased very rapidly and levelled off at very low values after 40 weeks. The corm dry matter continued to increase to a peak value in Qawe ni Urau and Tausala ni Samoa at 40 weeks and in Hawaii at 46 weeks. Decline in corm dry matter after the peak yield was due to onset of corm rot.

Fig. 1 also shows that the cultivars differed appreciably in the distribution of total plant dry matter among the various components. At peak plant yield, Qawe ni Urau and Hawaii produced significantly higher leaf yields than Tausala ni Samoa, although the cultivars did not differ significantly in total plant yield. Qawe ni Urau and Hawaii had respectively 60% and 58% of the total dry matter in the leaves compared to only 42% in Tausala ni Samoa. Since Tausala ni Samoa had greater proportion of dry matter in the corm, it produced significantly higher corm yield at this stage.

At maturity (peak corm yield stage), there was no significant difference between cultivars in total dry matter production or corm production. Most of the dry matter appeared in the corm.

Sucker development started when the main plants were about 10 weeks old. The sucker number per plant in all cultivars increased until 24 weeks. Most suckers produced by Hawaii cultivar averaged 8 suckers per plant whereas the other two cultivars averaged about 3 per plant.

The biological yield and total corm yield of Hawaii cultivar increased up to final harvest. In the other cultivars, the biological yield increased up to 24 weeks then levelled off. Corm yields in these cultivars increased up to 40 weeks and thereafter levelled off. Both the biological yield and the total corm yield of Hawaii were significantly higher than that of the other two cultivars during the later part of growth due to high yields from the suckers. The biological yield and total corm yield at final harvest were:

	Hawaii	Qawe ni Urau	Tausala ni Samoa
Biological yield (g/plant)	436 ± 31	286 ± 30	277 ± 23
Total corm yield (g/plant)	363 ± 18	251 ± 26	256 ± 21

Leaf production and leaf area

The rate of leaf production increased from planting up to 12 weeks and thereafter declined. Up to 18 weeks after planting, Hawaii and Qawe ni Urau produced leaves at significantly higher rate than Tausala ni Samoa. At peak growth, Hawaii and Qawe ni Urau averaged 1.2 leaves per week whereas Tausala ni Samoa averaged 0.9 leaf.

In the duration of the experiment, the main plant of Qawe ni Urau produced most leaves (32) whereas Hawaii and Tausala ni Samoa each produced about 27 leaves. Although Hawaii produced leaves at a faster rate early in growth, its growth was slower than Tausala ni Samoa at the later stage, hence the same total number of leaves. The mean life-span of leaves was: Hawaii 41.8 days, Tausala ni Samoa, 34.1 days; and Qawe ni Urau, 30.0 days. In all cultivars the leaf number per plant also increased up to 12 weeks and thereafter declined. Between 8 and 32 weeks Hawaii had significantly more leaves per plant whereas the other cultivars averaged 5.5 leaves per plant than the other two cultivars. At 12 weeks stage, Hawaii had 7.0 leaves per plant whereas the other cultivars averaged 5.5 leaves per plant.

High leaf number of Hawaii was due to high rate of leaf production and long leaf longevity. From planting up to 16 weeks, relatively large leaves (1400 to 2500 cm^2) were produced. During this stage, the cultivars differed significantly in leaf size (Qawe ni Urau, 2000-2500 cm^2, Tausala ni Samoa, 1500-1600 cm^2 and Hawaii: 1400-1500 cm^2).

The leaf area indices of the main plant at various stages of growth in Fig. 2 show that it increased with age and reached the maximum (Qawe ni Urau. 3.0; Hawaii, 2.5 and Tausala ni Samoa 2.0) between 16 and 20 weeks. This increase was due to increase in leaf number and leaf size. The rapid decline in leaf area index after 20 weeks was due to decline in leaf number and decrease in leaf size. Between 12 to 24 weeks, the significantly higher leaf area index of Qawe in Urau was due to its very large leaves. Lowest leaf area index of Tausala ni Samoa was due to low leaf number and small leaf size. Hawaii, although it had the smallest sized leaves, had higher leaf area than Tausala ni Samoa because of its higher leaf number.

The leaf area index of main plant plus the suckers are shown in Fig. 3. Due to high leaf area of the suckers, leaf area index of Hawaii reached over 4 and mid-crop compared to just over 3 in Qawe ni Urau and about 2.5 in Tausala ni Samoa. Due to its high sucker leaf area the decline in the leaf area index of Hawaii after maximum canopy was much slower, hence from about 16 to 18 weeks onwards until final harvest it had a significantly higher leaf area index than the other two cultivars.

The net assimilation rates of the cultivars (main plant and suckers) presented in Fig. 4 show that net assimilation rate decreased with age and was negative after 30 weeks. Although Qawe ni Urau and Hawaii had higher net assimilation rates than Tausala ni Samoa early in growth, the differences were not significant. At mid-crop Tausala ni Samoa had higher rate than Qawe ni Urau and Hawaii, but only the difference at 18 weeks was significant.

Discussion

Milthorpe (1967) and Wilson (1974) show two extreme patterns in leaf and storage organ development in root crops. In potato and some species of yams, (*D. alata* and *D. esculenta*) storage organ development occurs after the attainment of maximal leaf area. At the onset of storage organ development, leaf and stem growth slows down and eventually ceases. Leaf area declines rapidly but storage organ development continues until very little leaf area remains. In contrast to sugar beet, storage organ development starts early in growth and the storage organ and leaf develop synchronously. Eventually, storage organ growth dominates leaf growth but never completely and after maximal canopy development leaf area declines slowly over a long period of time. Spence (1970) showed that tannia (a species related to taro) resembles sugar beet in relation to leaf and storage organ development.

This study reveals that the growth of taro is similar to that of sugar beet. During the first two weeks, the plant loses dry matter as it becomes established, roots are formed and the first leaf is produced. This is followed at first by slow and then increasingly rapid plant development. Rapid corm development starts early and the leaf area and corm develop synchronously until maximal canopy is attained at about 20 weeks. This pattern of development in the early stage of ontogeny of taro and related tannia species is not surprising because the leaves arise sequentially from the apex of the underground corm. If leaf production continues some corm development must occur. The leaf area of dryland taro after maximal canopy, however, declines more rapidly than that of sugar beet. This is probably due to adverse growing conditions, for under good growing conditions the decline in leaf area is much slower. Ching (1970) and Plucknett and de la Peña (1971) found that in taro planted under high fertility and irrigated (wetland) conditions, the leaf area increases from planting to 6 months and then declines slowly to low values between 12 to 15 months. Rapid corm development under these conditions was found to commence between 3 to 5 months and to continue until 12 to 15 months. It appears that under less fertile and dryland conditions, corm development commences early and the crop growth period is shortened due to lack of moisture and nutrients.

In the South Pacific Islands, the corm of the main plant is of greater economic value than the sucker corms which are used only for replanting. The sucker corms are not used because of their small size. It appears that under dryland conditions, the sucker corms do not attain marketable size due to the short growing period. In the Hawaiian Islands where the crop growth cycle is much longer under wetland condition, the sucker corms are of reasonable size at harvest and both these and the corm from the main plant are utilized. Very high yields reported from Hawaii is largely due to high yields from sucker corms, there, two thirds of the yield come from the suckers.

The productivity of crops depends to a large extent on the manner of leaf area development and on the manner of leaf display in relation to the sun. It is now well established that at leaf area index of below 3, productivity is suboptimal and that below this level, plants with horizontally displayed leaves are more efficient in light interception and hence in productivity. At leaf area index of about 3, plant productivity is almost independent of leaf angle and at leaf area index of over 3, plants with erect leaves at the top of the canopy are more productive (Duncan, 1971; Loomis and Rapoport, 1976).

Loomis and Rapoport have also put forward several reasons suggesting that very high leaf area may be a disadvantage for tropical root crops. It can be seen in Fig. 3 that leaf area of dryland taro develops very slowly after planting and in one cultivar it never reached the optimum (leaf area index of 3) while in the other two cultivars it took 16 weeks to reach the optimum but remained at or above this level for only a short period. There is considerable scope to improve productivity through more rapid development of leaf area early in growth. Variations occur in the rate of leaf production, leaf size and leaf longevity within the existing cultivars and through selection or breeding, types with early leaf area development can be obtained. Spence (1970) found that nitrogen increased leaf number and leaf size in tannia. Adequate nutrients especially nitrogen and moisture will promote early leaf area development. Leaf area can also be increased by closer spacing. Sivan (1973) found that close spacing in taro increased yield substantially and this increase is attributed to high leaf area development at close spacing.

Lower net assimilation rates of Qawe ni Urau and Hawaii when their leaf area index reached over 3 indicate that these cultivars are less productive at high leaf area. The leaf area index of Tausala ni Samoa (erect leaf type) did not reach the optimum level, hence its productivity at high leaf area is not known. However, it appears certain that is productivity can be enhanced further by increasing its leaf area index to at least 3, if not above this level.

After maximum canopy (Phase III) in dryland taro, rapid decline in leaf area but continued rapid growth of corm until very little leaf area remains suggests that either or both of the following mechanisms may be involved.

(a) the assimilates from current photosynthesis are preferentially used for corm growth.

(b) the accumulated assimilates from older leaves are mobilized for storage in the corm.

There is evidence from cultivar Hawaii that higher leaf area in phase III improves yield. However, if high leaf area is maintained in this phase by production of large number of new leaves, then the competition for assimilates by the leaves may slow down or delay corm development. If high leaf area is maintained by prolonged leaf longevity, the competition from the leaves will be minimal. Differences that exist in leaf longevity of taro cultivars indicate the possibility of selection for slow turnover of leaves. Adequate fertilization and moisture will also delay leaf senescence. Control of diseases that cause premature death of leaves will improve leaf duration. Humphries and French (1965) have showed that gibberellic acid reduces rate of leaf production but increases leaf longevity and leaf area in sugar beet. This points towards the possibility of using plant hormones to maintain leaf area late in growth.

There are appreciable differences among the taro cultivars in their sink capacity. Rapid rate of corm development in Tausala ni Samoa indicates that it has greater corm sink than the other two cultivars. A very high ratio of corm to total dry matter at all stages of growth in this cultivar shows the possibility through breeding and selection to divert greater proportion of the plant assimilated into the corm.

Conclusion

The growth and development of taro is similar to that of sugar beet and tannia. Corm development under dryland conditions commences early in growth and the leaves and corm develop synchronously up to maximum canopy attainment at about 20 weeks. Leaf area increases during this stage due to increase in the rate of leaf production, leaf number and leaf size. After maximum canopy, leaf growth slows down and leaf area declines rapidly but rapid corm growth continues until very little leaf surface area remains. Decline in leaf area during this stage is due to decrease in the rate of leaf production, leaf number, leaf size and leaf longevity.

There is considerable scope to increase yield of taro through improvement in the leaf area development pattern. The aim should be to achieve optimum leaf area early in growth and to maintain this leaf surface for most part of the growth cycle. Continuous rapid turnover of leaves in taro appear to be a wasteful process for assimilates used in leaf production, otherwise, it could be used in corm growth. Attempts to reduce the turnover of leaves, however, must not conflict with the need to maintain optimum leaf area.

Variations among the taro cultivars in growth rate and sink capacity show the need to develop technology to select taro plants based on these characteristics.

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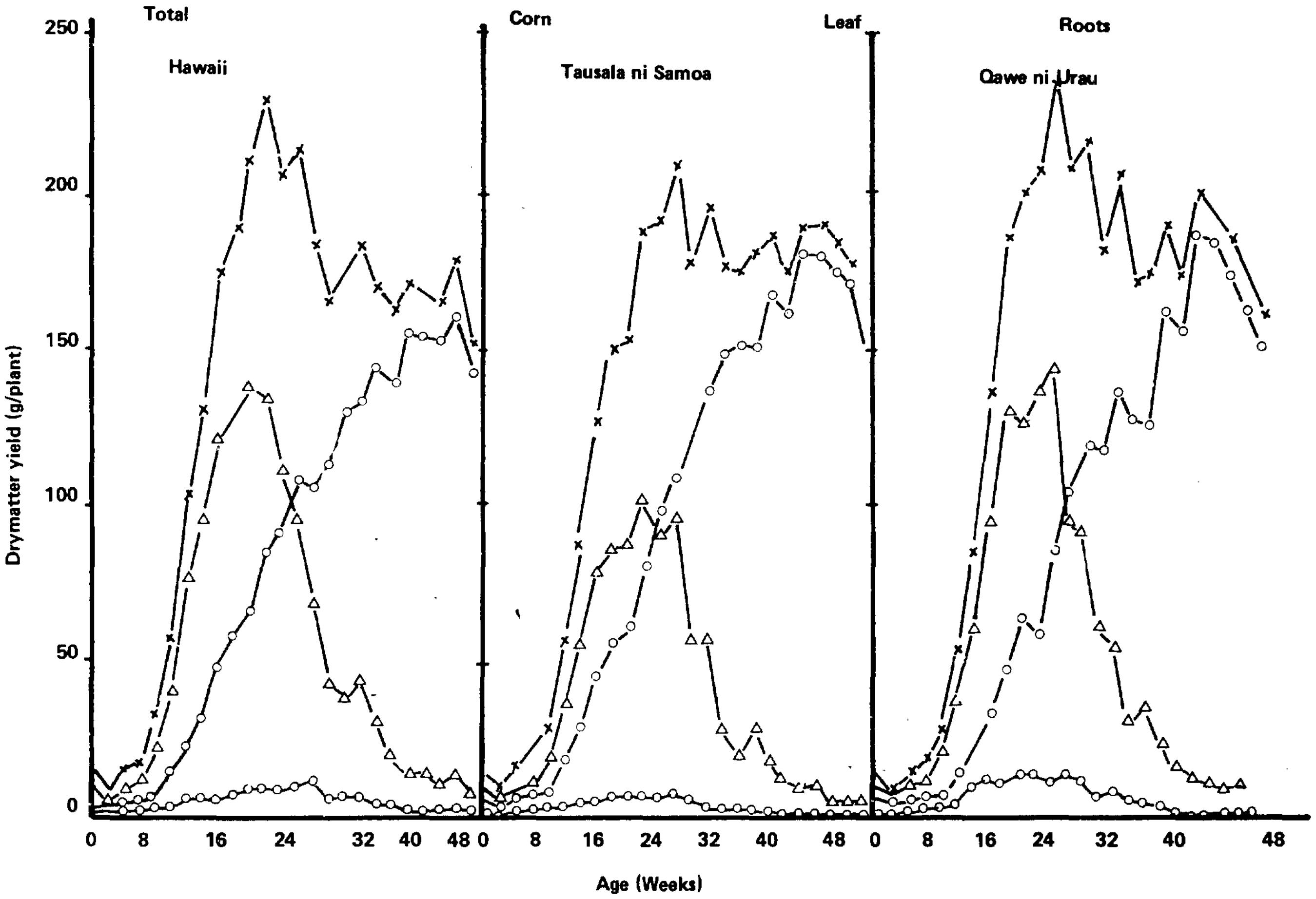

Fig. 1. Accumulation and distribution of dry matter in the main plants of three taro cultivars

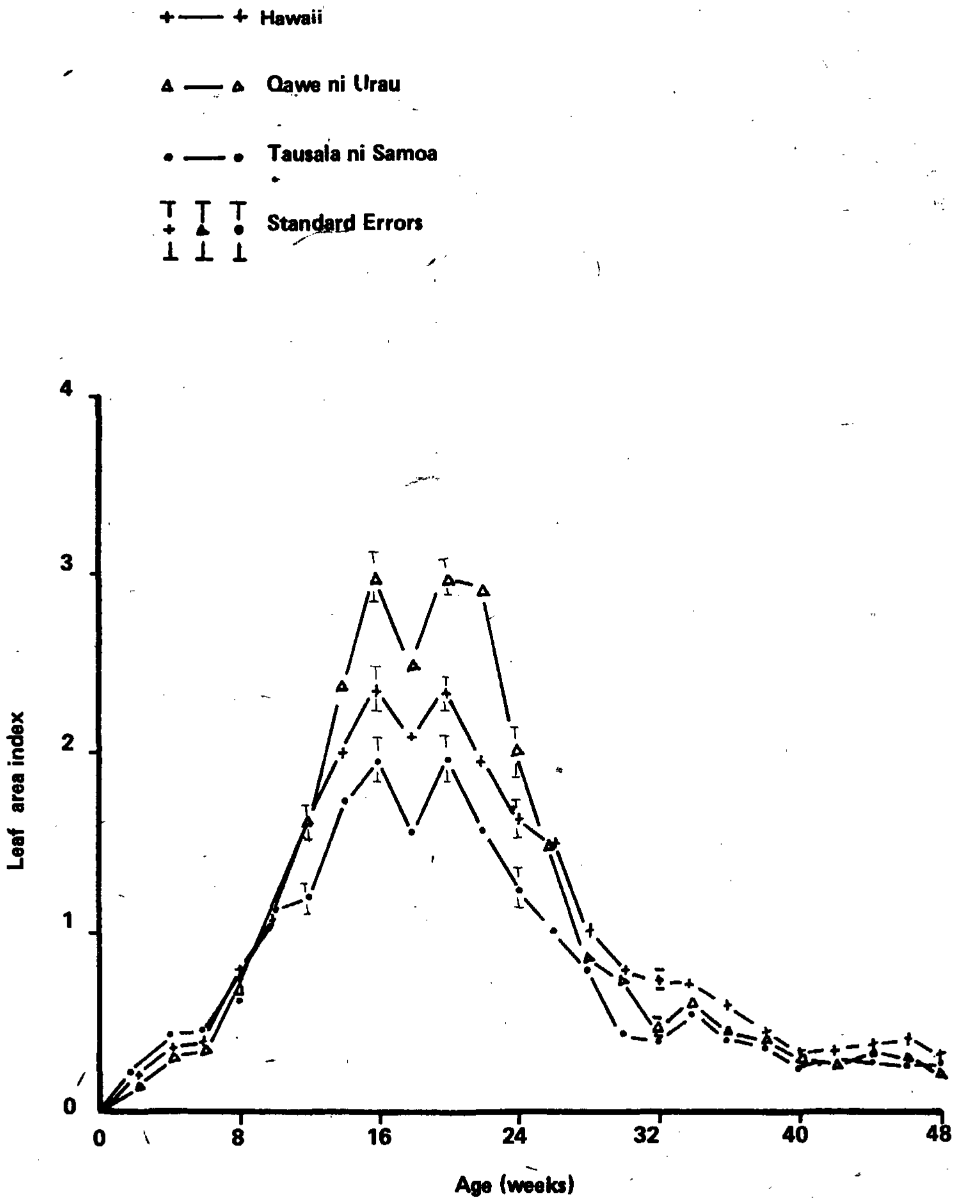

Fig. 2. Change in leaf area index of main plant for the taro cultivars with age

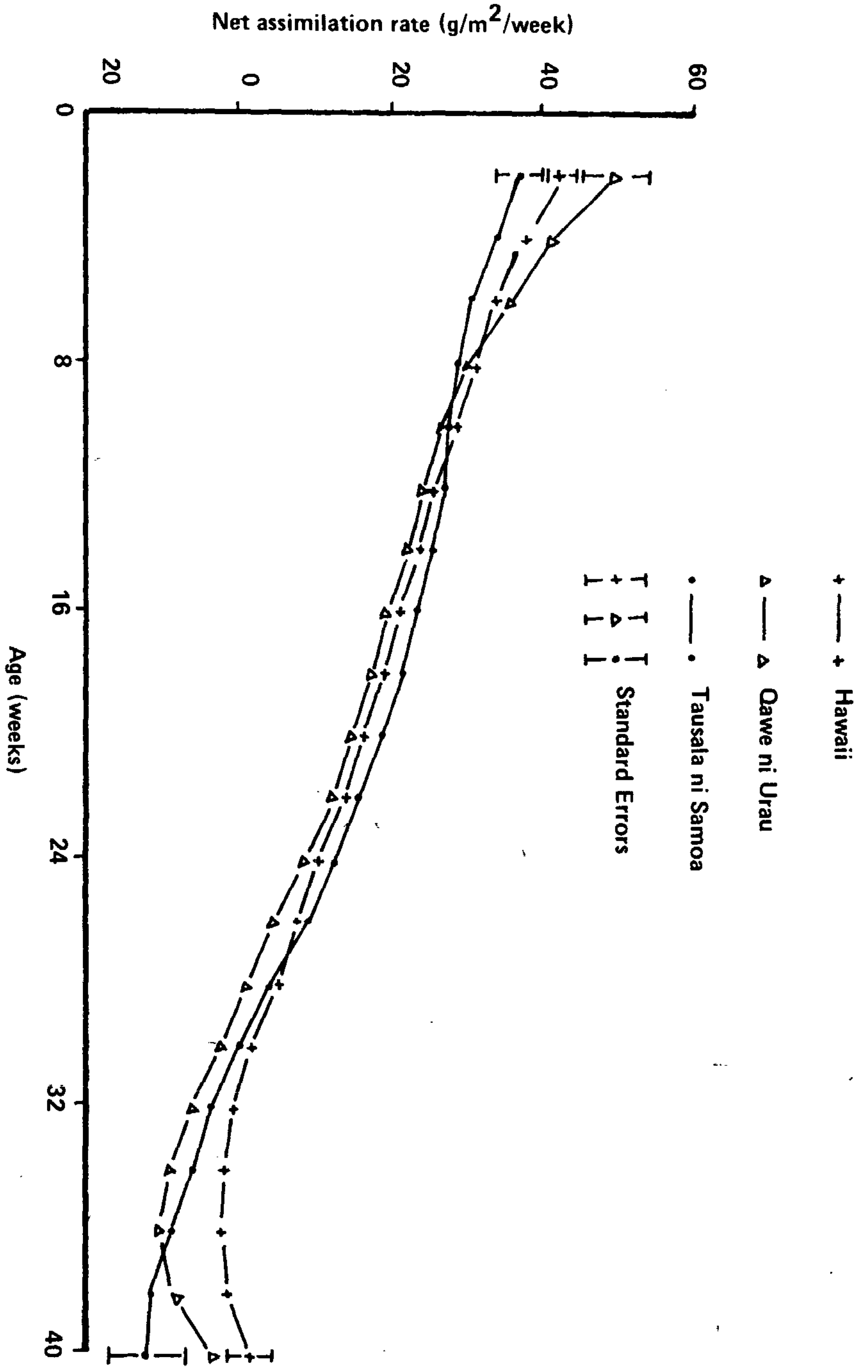

Fig. 3. Net assimilation rate of main plant plus suckers for the taro cultivars