culations to evaluate choices among superior alternative cultural practices. Construction of a benefit-cost index for the superior treatment practices (BP + TP; NP + TP; BP + DS) is facilitated by development of a partial budget.

A partial budget for the superior treatment practices was calculated (Table 2) using the control practice as a base. Individual entries in the budget were calculated as paired differences between the control and each respective experimental treatment. For example, treatments that included greater material, application, or harvesting costs than the control resulted in an entry under the "added cost" category. Benefit-cost index values were calculated (via formula) from entries made in the partial budget. The NP + TP treatment offered the greatest benefit-to-cost ratio among all alternative practices and resulted in $2.55 worth of benefits above each initial dollar invested. In comparison, a yield maximization strategy (BP + DS) offered a return on additional costs of $0.82 worth of benefits for each additional dollar invested. Although the BP treatments offered attractive returns when compared with the control practice, the benefits gained from switching to BP were much less lucrative than from switching to the NP + TP practice. Alternatively, the lower benefit-to-cost index associated with the BP treatments suggests that, all other things being equal, the investment in BP represented a greater risk for growers than adopting the TP practice. Benefit-cost criteria would indicate that, for the conditions and assumptions identified in this study, the preferred cultural practice for producers is to use transplanted muskmelons without plastic. However, these reuslts should be interpreted cautiously, since this study did not consider an individual grower's marketing practices or connections, product quality, management experience, and size of operation. In addition, price and yield information represent data from a single season, which makes recommendations difficult.

The use of NEV and benefit-cost ratios to evaluate cultural practice recommendations permits a grower several choices. Does he/she want to maximize marketable yields (BP + DS)?; to maximize gross returns (BP + TP)?; or to maximize the return benefit for a level of investment (NP + TP)? The long-term strategy would be for a grower to select the option that maximizes the return for each dollar of investment. However, short-term considerations and marketing strategies or price patterns different from the pattern assumed in this study may suggest that a grower maximize marketable yields, net economic value, or gross revenues. Consideration of all factors inclusive and exclusive of this study allows a grower to choose the treatment best suited to his or her particular needs from the three superior treatment practices. Over an extended period of time (several years), growers and researchers should select the treatment practice that maximizes net return on investment for an acceptable risk level; this study found that the NP + TP treatment best satisfied this criterion.

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Planting Dates Related to Tuberous Root Yield, Vine Length, and Quality Attributes of Yam Bean

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Additional index words. critical daylength, acidity, sugars, planting date, phenols, *Pachyrrhizus erosus*

Abstract. **Plant growth and tuberous root development in yam beans (*Pachyrrhizus erosus* L. Urb) were investigated using a series of 2-week plantings from April to December. Decreasing daylength at time of planting initiated tuberous root development, whereas increasing daylength inhibited tuberous root development and promoted vine and leaf growth. Once tuberous root formation and flowering began, stem and leaf growth ceased. At the time of planting, the critical daylength for tuberous root formation and flowering was 11 to 12 hr. The optimum planting date in Hawaii for maximum tuber yield of 24 $t \cdot ha^{-1}$ for yam beans was found to be September to October. Tuberous root development was sigmoidal, with dry matter percentage declining from 17.5% to 9%. There was little change in tuberous root acidity or total sugars during growth. Titratable acidity was about 20 $meq \cdot g^{-1}$ fresh weight if not induced to form tuberous roots, and ≈15 $meq \cdot g^{-1}$ fresh weight in plants forming tuberous roots. Total sugar was in the range of 30 to 50 $mg \cdot g^{-1}$ fresh weight during tuberous root growth of induced plants. Total phenols in the tuberous root declined during development, whereas roots from plants uninduced to form tuberous roots had an increased level of total phenols.**

Yam bean is one of a few leguminous root crops. It is native to Mexico and northern Central America, but now is cultivated widely in Southeast Asia (18). The plant also is known as Jicama (Mexico), sinkamas (Philippines), ge shu (Mandarin), or saa got (Cantonese). The light brownish tuberous roots are turnip-like (15) and have a white, crisp, succulent flesh with a pleasant flavor. They are eaten raw or lightly cooked (15). The range of crude protein in the tuberous roots varies between 3.9% and 14.1% on a dry-weight basis, but is low in methionine and cysteine (6). The leaves, stems, ripe pods, and seeds may contain the insecticide rotenone (3).

Suggested as a legume crop with potential for wider cultivation (12), numerous problems in its cultivation have been highlighted, including conflict over the photoperiodic response of the crop (2, 5). Since the crop is grown in Hawaii and available in Hawaiian supermarkets (5), information on optimum growing procedures and subsequent storage is needed. The objectives of this study were to develop information on optimum planting dates related to yields and to determine quality of yam beams for Hawaii. Root yield was determined from planting made at 2-week

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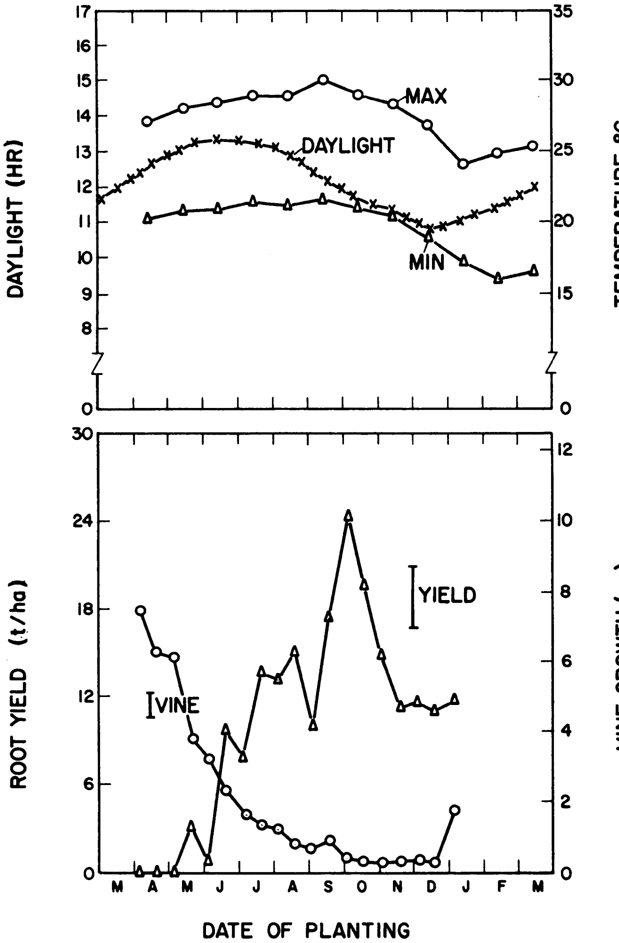

Fig. 1. Relationship between date of planting and yam bean vine growth and average tuberous root yield per plant (**A**) The average daylength and monthly minimum and maximum temperature during the period of growth. (**B**) Yield of yam bean tuberous root and length of vine. Vertical bars represents SE.

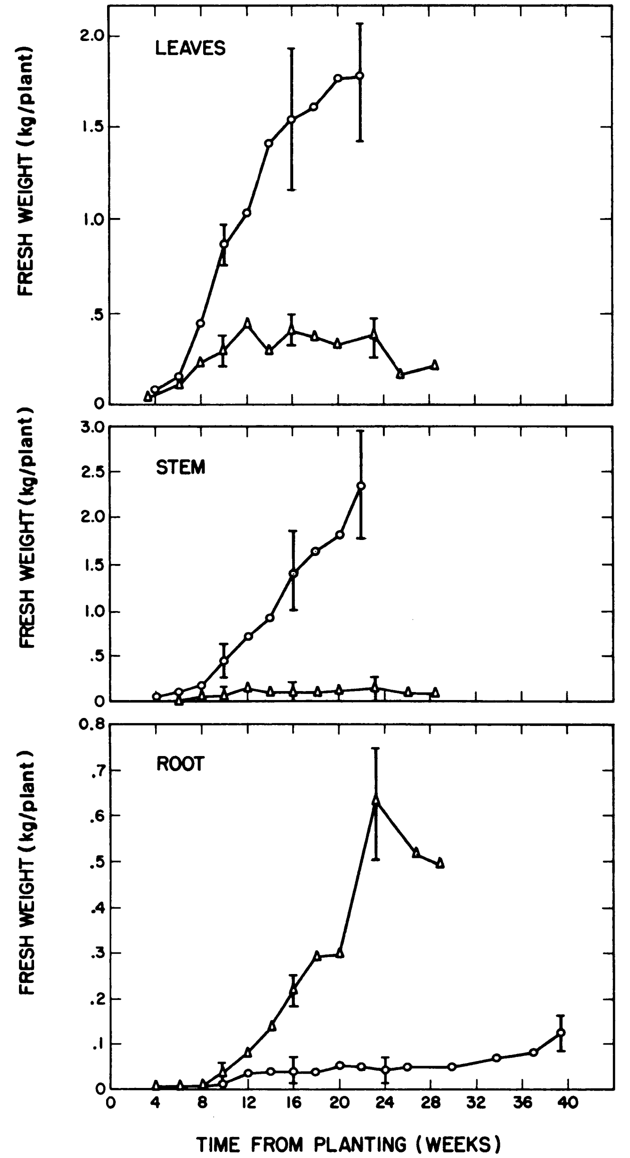

Fig. 2. Growth of yam bean at two planting dates [3 Apr. 1984 (○- - -○), Oct. 1984 (△- - -△)]. Growth of leaves (**A**), stem (**B**), and tuberous root (**C**). Vertical bar represents SE.

intervals from April through December. The growth and development of the plant top and root and, also, root quality attributes, were studied at two planting dates.

Yam bean seeds of a local low-growth, squat, tuberous-rooted cultivar selected from previous tests were planted at 2-week intervals from early Apr. to Dec. 1984 at the Waimanalo Experiment Station on the windward side of Oahu. Three rows, 40 m long and 0.92 m apart, received a preplant application of 57N–73.5P–47.3K ($kg \cdot ha^{-1}$). Plants were spaced 0.3 m apart within the row. Plants received a postplanting application of (51.3N–22.1P–42.6K ($kg \cdot ha^{-1}$) at 3, 6, 9, and 12 weeks after planting. Plants were harvested 5 months after planting for yield estimation. Flowers and pods were not removed if they developed. At the planting on 3 Apr. and 1 Oct., an additional area twice the size of the above plots were planted. This area was used for regular sampling to monitor plant growth and tuberous root development. Routine field preparation, irrigation, and weed and pest control were practiced.

Five plants were harvested from each of four replications at 2-week intervals. Dry weight was determined after drying for 48 hr at 60°C. A subsample (5 g) of fresh root tissue minus skin was homogenized in 10 ml of deionized water, and pH was determined. The homogenate was titrated with 0.1 M sodium hydroxide to pH 7.8, and results were expressed as micromoles per gram fresh weight of tissue. Total soluble solids of 100 µl of expressed juice were determined with a refractometer (Bausch and Lomb Abbe-3L) at 22°, with distilled water as the zero standard.

Fresh root tissue (2 g) was homogenized in 18 ml of 90% (v/v) ethanol. A portion of the cleared supernatant was used for analysis of total phenols and sugars (13). Total phenols were determined by the procedure of Singleton and Rossi (16), with catechol as the standard. Total sugars were determined by the phenol sulfuric acid procedure (4) with glucose as the standard.

After 5 months of growth, total root weight and total vine length were recorded from each 2-week planting. Each planting was replicated three times, with 10 plants per replicate.

Tuberous root development was initiated by decreasing day length at time of planting (Fig. 1 A and B). Increasing daylengths inhibited tuberous root development. For example, plantings in April, which were harvested 5 months later, failed almost completely to form tuberous roots, although considerable vegetative growth occurred (Figs. 1B and 2 B and C). Average minimum and maximum temperature (Fig. 1 A) did not seem to play a crucial role in root initiation. Plantings in early April that were allowed to grow for a longer period began to develop some tubers 9 months later (Fig. 2C).

Photoperiods of 14 to 15 hr prevent yam bean tuberous root formation in temperate regions (9). In the tropics, optimum period for planting is during the cooler part of the year, with December to January being recommended (2, 17). In Hawaii, a September planting is recommended (5). This recommendation was supported by our findings (Fig. 1B). The difference in recommendations probably lies in the wide diversity of characteristics shown by the plant now cultivated worldwide (12, 15).

Flowering also showed a photoperiodic response, with flowers beginning to appear

1 month after root tuberization began in the October planting. The April planting flowered in November (data not shown). This result agrees with reports from various parts of the northern hemisphere, where flowering occurs during the period from July to December (3). Our results (Fig. 1) suggested that the critical daylength for tuberous root formation and flowering was ≈11 to 12 hr, with decreasing daylengths at the time of planting. Many other root crops are induced to form tuberous roots by short days (10).

In the absence of tuberous roots and flower development, considerable vine and leaf growth occurred (Figs. 1B and 2 A and B). Plants that were not induced to form tuberous had roots and vines about 5 m long with 75 ± 16 leaves per plant after 6 months. Once plants were induced to form tuberous root and flowers, vegetative growth was greatly restricted (Fig. 1 A and B). Plants induced early to form tuberous roots developed 30 ± 8 leaves per plant after 6 months. At the time of tuberization (December) in the October planting, there were 24 ± 2 leaves per plant with 70 cm of stem length.

The pattern of plant development (Fig. 2) was similar to the environmentally sensitive phasic pattern described by Milthorpe (11) for sweet potato. A similar type of response is shown by radishes (14) and other root crops (8). This growth is in contrast to the relative environmental insensitivity of the balanced pattern of development between root and shoot in sugar beets. Once tuberous root formation and flowering are initiated in yam bean, the roots act as strong sinks (17). Flower head removal led to an increased tuberous root weight (19). Increased tuberization in response to pod removal has been reported for other tuberous-rooted legumes (1). Soon after tuberous root formation and flowering began, stem (Fig. 2B) and leaf growth (Fig. 2A) ceased.

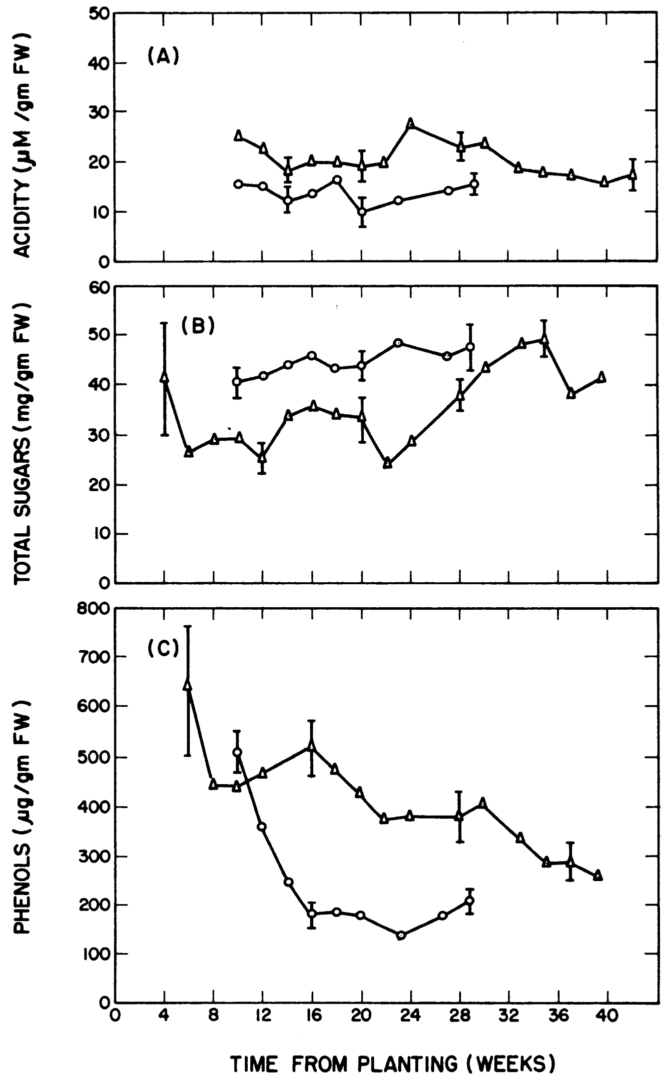

Fig. 3. Changes in root composition from plants sown at two planting dates [3 Apr. 1984 (○- - -○), 1 Oct. 1984 (△- - -△)]. (A) Acidity. (B) Total sugars. (C) Total phenols. Vertical bar represents SE.

Tuberous root growth was sigmoidal (Fig. 2C) when the plant was induced to form tuberous roots. Root diameter and root weight both showed the same sigmoidal pattern (data not shown), with the first planting showing little or no development of root (Fig. 2C). The percentage dry weight in the induced plants decreased rapidly from 17.5% during the initial phase of growth, then leveling at 9.5%. The final dry weight percentage agrees with published data of 10.5% (2). The plants not induced to form tuberous roots maintained a dry weight percentage of about 12.5%, significantly higher than those induced to form tuberous roots.

There was little change in tuberous root acidity or total sugar in the induced or uninduced plants (Fig. 3 A and B). The total phenol in the tuberous root declined in the plants induced and not induced to form tuberous roots. The greatest decline occurred in plants induced to form tuberous roots very soon after initiation (Fig. 3C). This decline could be associated with an overall increase in fiber formation and associated lignification. The uninduced plant tuberous root maintained a higher overall level of phenols. The young tuberous root would be expected to have a lower fiber content. Old roots tend to be fibrous (15). The low levels of phenols in induced and uninduced plants was not likely to impart any astringency to the tuberous root. The low concentrations of sugars and acidity and the small change during growth suggest that harvesting can occur at any stage of growth without affecting tuberous root flavor. The optimum planting date for yam bean in Hawaii was the September to October period. This gave maximum yield to tuberous roots meeting the size requirement (7) for Hawaii Grade A (340 g to 1.13 kg) in the shortest time. Planting date did not have a significant effect on quality if plants were induced to form tuberous roots soon after planting.

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Thermal Properties of Wraps Used for Freeze Protection of Young Citrus Trees

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Additional index words. Soil banks, frost, cold, *Citrus sinensis, Citrus aurantium*

Abstract. **Thermal properties of tree wraps commonly used for freeze protection of young citrus trees were measured in the laboratory using a newly developed method to determine which factors are most important in wrap design and performance. Thermal diffusivity was lowest for wet fiberglass and styrofoam wraps with water containers attached to their inner surface, intermediate for dry fiberglass, and highest for thin-walled polyethylene and polystyrene wraps. Thermal diffusivity was inversely related to freeze protection capacity observed under field conditions for the tree wraps tested. Addition of water, either throughout the wrap material or in containers inside wraps, decreased thermal diffusivity three- and ten-fold, respectively. Minimum trunk temperatures of 2-year-old 'Hamlin' orange trees [*Citrus sinensis* (L.) Osb.] were up to 2°C lower under ventilated tree wraps compared to similar nonventilated wraps on mild freeze nights. An ideal tree wrap should have low thermal diffusivity and lack free airspaces and ventilation holes, while allowing for gas exchange and expansion of the tree trunk.**

Traditionally, young citrus trees have been protected from freeze injury by banking soil around trunks during periods of cold weather (6). Following severe freezes, the tree canopy above the soil bank is often killed, but, after removal of the bank, trees sprout from the surviving wood and produce new canopies. Although an effective means of freeze protection, construction and maintenance of soil banks are labor-intensive and often result in mechanical or disease damage to trunks. Tree wraps were introduced into citriculture in the mid-1950s to circumvent the problems associated with soil banks while still providing freeze protection for young citrus trees (9). Tree wraps typically provide 4° to 6°C less protection than soil banks (7, 8, 15), but have proven effective during mild freezes in Florida (11) and Texas (5).

Despite lower potential for freeze protection, wraps are used widely because they inhibit sprouting and provide protection from herbicide, fertilizer, and mechanical injury (1). Furthermore, wraps increase the effectiveness of microsprinkler irrigation during freezes, providing greater freeze protection than microsprinkler irrigation or tree wraps alone (2).

The most commonly used tree wraps in Florida include 9-cm-thick foil-faced fiberglass, thin-walled polystyrene and polyethylene foam, and a thick-walled styrofoam wrap with water containers attached to the inner surface (14). These wraps provide 0° to 4°C protection, depending on the severity and duration of a freeze (2, 8).

Turrell (13) compiled a list of thermal properties of some materials used in wraps and suggested that thermal diffusivity is the single most important factor determining the freeze protection potential of a wrap. However, thermal diffusivity of tree wraps commonly used in Florida has not been determined. The objective of this study was to determine the thermal properties of commonly used tree wraps in situ and determine the effects of water, free airspaces, and ventilation on tree wrap performance.

Tree wraps chosen for analysis of thermal properties under laboratory conditions ranged from 34 to 40 cm in height and 8 to 13 cm in diameter when properly installed. A thick-walled (2.5-cm) styrofoam wrap was analyzed with and without its two plastic containers of water inside (≈420 ml of water) (14). Also tested were thin-walled (0.2-cm) polystyrene and thick-walled (1.8-cm) polyethylene foam wraps. These wraps had the smallest diameters (≈8 cm) and, like the styrofoam wrap, contained free airspaces between the inner wrap and trunk surfaces. The fiberglass wrap consisted of 9-cm-thick (R-11) aluminum foil-faced fiberglass building insulation held in place around the trunk with wire mesh, which, when newly installed, did not have an airspace between the trunk and inner wrap surface. Old fiberglass wraps that had been used for one season in the field and were somewhat weathered, and new fiberglass wraps wetted to a volumetric water content of ≈0.125, also were studied. Except fiberglass, other wrap materials do not absorb water when wetted, nor do they become significantly weathered after one season of use.

Thermal conductivity of various wraps was measured using an apparatus that consisted of a heating element inside a 4-cm-diameter tube filled with water (Fig. 1). The heating element drew power from a 28-V DC power source. Voltage (E) and resistance (R) across the heating element were measured with a multimeter (Keithley, Cleveland, Ohio), and energy flow into the heating element (Q) was calculated as E^2/R (watts). Temperature was measured with copper–constantan T-type thermocouples and a digital thermometer (Analog Devices, Norwood, Mass.). Temperatures of the tube (T_1) and outer wrap surface (T_2) were allowed to reach a steady state after the wrap was placed around the tube (≈24 hr), at which time the energy flow into the heating element equaled the heat flow radially outward through the wrap. Thermocouples also were placed on the inner wrap surface of those wraps with free airspaces to determine the thermal conductivity of the free airspace and the wrap material separately. The top and bottom of the wrap were insulated with 15 to 20 cm of fiberglass to minimize vertical heat loss, which would cause

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