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INFLUENCE OF SOIL TYPE AND HARVEST AGE
ON
TARO CORM DENSITY
(SECOND YEAR RESULTS)

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ABSTRACT

Little is known about production practices that may affect taro corm specific gravity. This study was conducted to determine which soil factors, other than fertility levels, influence corm specific gravity and weight for the Niue taro cultivar grown in volcanic soils of humid, tropical Samoa. Sixty-four plants were grown at each of 7 sites under similar conditions of fertilization, rainfall, and temperature. After 6 months, the taro was harvested and weight and specific gravity determined on individual corms using a double-weighing method: once in air and again in water. Comparing mean specific gravities and mean weights against soil test results failed to disclose any significant correlations, though there are unidentified site-specific factors which influence these parameters. Corm weight and specific gravity were found to be uncorrelated. Specific gravity values are dependent upon whether or not the petiole base is attached to the corm.

Taro (Colocasia esculenta (L.) Schott) is a major food throughout the Pacific. The corms are peeled, washed, boiled or baked and served with fish, poultry, pork or beef. In Hawaii Tahiti, and the Cook Islands, a paste 'poi' in Hawaii) is made from boiled and fermented taro. From a nutritional point of view taro compares well with other root crops such as yam, cassava, and sweet potato, as well as cereals, especially rice (Lambert, 1982). It has excellent potential in the snack chip and baby food markets, and in the production of taro flour (Yokoyama, et al., 1989). One impediment to expanding its commercial uses is a scarcity of information regarding taro corm quality.

For the Irish potato (Solanum tuberosum L.), specific gravity is the best single criterion of tuber quality (Teich and Menzies, 1964), since specific gravity is directly related to the total solids and starch content of tubers (Misra, 1983). Specific gravity also appears to be a good method for evaluating corm quality in taro (Bowers, et al., 1964)

Much attention has been given to the effects of the major plant nutrients on potato specific gravity. Only phosphorus fertilization has been shown to consistently increase tuber specific gravity, with nitrogen and potassium giving mixed results (Chaudhri, 1976; Munro, et al., 1977; Murphy and Goven, 1959; Teich and Menzies, 1964). Several cultural and environmental factors also influence potato tuber specific gravity, including soil type (Murphy and Goven, 1959)

In Samoa, it is commonly believed that the size of the taro corm is affected by the size of the planting hole. In Western Samoa, both corm yield and quality were found to be affected by the planting-hole size, with larger holes generally producing larger corms of better quality (Cable and Asghar, 1983). This suggests that soil structure may be an influencing factor.

From the first year's results of this study, when taro was grown at 3 sites and harvested at 6, 7, 8, and 9 month intervals, soil texture was tentatively thought to influence corm specific gravity[1] (Sagaga and Vargo, 1989). However, a full array of soil tests was not available then to help identify other possible contributing factors.

In order to investigate if soil texture and other factors of the basaltic soils of American Samoa may be influencing taro corm weight and specific gravity, taro was planted using a traditional approach, but with fertilizer amendments, at taro-producing sites selected on the basis of soil type, accessibility, and farmer cooperation.

MATERIALS AND METHODS

Taro, cv. Niue-ulaula (Whitney, <u>et al</u>., 1939), was planted at 7 sites on Tutuila, American Samoa (Fig. 1) using setts ('tiapula' in Samoa) consisting of a centimeter or so of the corm attached to 30 to 50 cm of the petioles with their leaf blades removed (Fig. 2).

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[1] In that year we reported taro corm density as grams per cubic centimeter. In this report, we have opted for the unitless expression, "specific gravity," which, at our level of precision, is synonymous with density.

Sett quality varied from site to site, depending upon available sources. Planting occurred at roughly weekly intervals between 27-OCT and 14-DEC-89 on level land with good drainage, cleared of vegetation, and exposed to full sun (Table 1)

At each site, 64 holes were made on an 8 by 8 grid, 60 cm apart and 25 to 30 cm deep, using a 1.5-m long pointed pole ('oso') 5 cm in diameter. The pole was repeatedly thrust into the ground and worked sideways to loosen the surrounding soil and to form a roughly conical hole 3 to 5 times wider at the top than at the bottom. Thirty grams of 12-8-16-17(S)-0.5(Zn) ammonium fertilizer were placed in each hole and covered with a few centimeters of soil (Navarro and Vargo, 1985). A sett was then dropped inside and its base lightly tamped into the soil. Ten grams of a soluble 10-52-8 fertilizer were placed along the brim of each hole and, together with some loose soil, were washed into the hole by rain within a few days. By 10 weeks the holes were thus filled with soil lacking structure. At 8 and 14 weeks 15 g of the 12-8-16 fertilizer were placed in a ring 2 to 5 cm from the petiole and covered lightly with soil. Sites were kept weed-free by passing a subsurface knifeblade hoe between rows and hand weeding around plants. Armyworms (Spodoptera litura) and giant African snails (Achatina fulica) were removed from the plants and rainfall recorded from a Tru-Check rain gauge of 150-mm capacity during weekly site maintenance.

Corm specific gravity measurement

Corms were harvested about 180 days after planting and separated into two groups: those from the outside, or border rows and those from the 6 by 6 interior rows. Traditionally, for subsistence purposes, corms are harvested by cutting just beneath the petiole base in order that the petiole moiety may serve as a sett. However, corms in this study were harvested with a centimeter or so of the petiole base attached in order to inhibit deterioration of the interior row corms during shipment to Hawaii for conversion into flour (Nip, et al., 1987

After washing with a nylon bristle brush under running tap water, each blotter-dry corm was weighed to the nearest gram on an Ohaus Port-O-Gram C3001 electronic balance, then again while suspended in water and attached by a velcro strap to a 700 g lead weight to counteract corm buoyancy. From these dual weighings and a reading of the specific gravity of the water used to suspend the corm (Durac hydrometer, 0.900 to 1.000 at 0.001 intervals), corm specific gravity was calculated as:

$$SG = W_a * SG_w / [W_a - (W_b - W_c)]$$

where

SG is corm specific gravity

W_a is corm weight, in grams

SG_w is specific gravity of the water

W_b is the sum of the corm, lead, and strap weights, in grams, while submerged in water

W_c is the sum of the lead and strap weights, in grams, while submerged in water

The petiole base was removed from the border row corms specific gravity again determined.

Soil tests

Eight to ten 20-cm deep soil cores were systematically taken and consolidated into a single sample for each site. Samples were air-dried, passed through a 2-mm sieve, and stored in air-tight containers. Unless otherwise specified, analyses were conducted on air-dried soil but with nutrient levels based on its oven-dry (105 °C) weight, recorded to the nearest tenth-gram on a Mettler PM400 electronic balance.

Soil texture was determined on oven-dried soil by the Bouyoucos method (Jacobs, *et al.*, 1971). Soil pH was measured with a Corning Model 5 pH Meter with combination electrode on a 1:1 soil: solution, where the solution was either distilled water or 0.01 M $CaCl_2$ (McLean, 1973). Neutral 1 N ammonium acetate was used to extract exchangeable cations (Thomas, 1982), and their concentrations determined on a Perkin-Elmer Model 2280 Atomic Absorption Spectrophotometer using an air-acetylene flame. Calcium (422 nm) and magnesium (285 nm) determinations were made by atomic absorption spectroscopy (Lanyon and Heald, 1982), while potassium nm) and sodium (589 nm) determinations were by atomic emission spectroscopy (Knudsen, *et al.*, 1982). Cation exchange capacity was measured by steam distilling an alkaline slurry of the ammonium acetate-saturated soil, collecting the distillate in 2% boric acid solution, and titrating with 0.10 N hydrochloric acid to determine the ammonia in the distillate (McLean, 1982). Soil phosphorous was determined by treating a modified Truog (0.02 N H_2SO_4, pH 2, 1:100 soil:solution) extract of the soil with ammonium paramolybdate and measuring optical density at 660 nm on a Bausch & Lomb Spectronic 20 Spectrophotometer (Ayers and Hagihara, 1952; Olsen and Sommers, 1982   Soil organic carbon was assayed by the Walkley-Black procedure on oven-dried soil (Nelson and Sommers, 1982). Soil nitrogen was determined using a permanganate-reduced iron modification of the Kjeldahl method to include nitrate and nitrite (Bremner and Mulvaney, 1982), with selenium as catalyst during digestion on a Kontes Rotary Kjeldahl Digestion Apparatus. Subsequent distillation was performed on a Kontes Kjeldahl Distillation Apparatus. Electrical conductance was measured using a Beckman Solu Bridge Soil Tester on a 1:2 soil:distilled water slurry.

Statistical analysis and graphs

Data were analyzed using MSUSTAT (Lund, 1988) or Data Desk (Velleman and Velleman, 1988), and graphs plotted using Data Desk.

RESULTS

About 60 days before its scheduled harvest, feral pigs destroyed the taro at site X. Consequently, this site was eliminated from the study

Of the corms sent to Hawaii for processing into flour, those from Site B had a higher specific gravity (Fig. 3). Yet when mean corm specific gravities were compared with soil test results (Table 2) other than nutrient levels (which were increased by the addition of fertilizer), no correlations were apparent. The nearest approach to a correlation was with percent sand values from soil texture measurements (Fig. 4).

Results for mean corm weights were likewise inconclusive (Fig. 5); though there are highly significant differences in corm weights among sites, soil tests cannot account for these differences. Nor was rainfall distribution markedly different among sites (Fig. 6)

In accord with the first year results, corm specific gravity and corm weight are uncorrelated (Fig. 7).

When the specific gravity of border row corms was measured with and without the petiole base, specific gravity increased by about 0.026 with the petiole removed (Fig. 8).

DISCUSSION

Though the sample variances for corm specific gravity of sites D and F far exceed that of site B and cannot be included in an analysis of variance (nor can the data be easily transformed to permit their inclusion), it is evident from Fig. 3 that site B corms have the highest mean specific gravity of all sites. However, mean corm specific gravities do not correlate with any soil test results. This suggests a number of possibilities: the soil tests may be inappropriate or inaccurate; an untested for soil factor(s) may be responsible for differences in specific gravity; a biological or environmental variable may be inconstant among sites.

Generally, several methods are available for analyzing soil parameters. Some, like the Bouyoucos method for determination of soil texture, are almost universally accepted for any soil type, while others are for explicit soil types. Every effort was made to conduct appropriate tests for the volcanic soils of Samoa, using a reference soil tested at other laboratories and fresh standards for instrument calibrations

Because no evidence suggests these soils are deficient in any micronutrient, their tests were omitted

As mentioned previously, setts were of varying quality, both within and among sites. Thicker, heavier setts were planted in the interior rows to increase yield (Wilson and Hamilton, 1987), since border row corms were not used in flour processing. Interestingly, at sites A, B, E, and F, mean specific gravity of interior row corms was lower than that of border row corms, but mean corm weight was higher for interior row corms at all sites except site A. Because plants at a 60-cm spacing produce corms of similar weight to plants at double that spacing (Navarro, et al., 1986) interior row plants should experience no more competition for soil and environmental factors than plants from the border rows. Heavier corms from the interior rows, then, are almost certainly due to heavier setts

Differences in corm weights among sites can be attributed, in part, to differences in sett quality. But site-specific factors are also involved because the heaviest batch of setts were planted at site F, yet this site did not produce the heaviest corms.

The greater specific gravity of border row corms at 4 of 6 sites is not statistically significant, (unlike for corm weights), according to the sign test for two related samples (Daniel, 1978), to suggest that thinner, lighter setts produce denser corms.

Figure 6 shows that each site received an adequate amount of rain more or less evenly distributed over the growing periods. Each site had good drainage with similar temperature, humidity and, presumably, solar radiation influx. All except site A received at least one fertilizer treatment following Hurricane Ofa. Inspections after the hurricane revealed little or no damage to the plants. This assessment was supported by the absence of suckers--which indicate corm catabolism due to severe upper-plant damage in this variety (Anon.)--at harvest.

Though each site received 3 amendments with commercial fertilizer, the soils may have widely varying fixing capacities for ammonium, potassium, or phosphate ions, which could account for differences in mean corm specific gravity or weight despite adequate fertilization. This was not investigated since the possibility is remote and no nutrient deficiency symptoms were observed.

The absence of correlation between corm specific gravity and corm weight (Fig. 7) suggests that factors which possibly influence specific gravity may be independent of those which influence the rate of starch accumulation. Otherwise, if both correlate with a common third factor, they must necessarily correlate with one another.

The difference in corm specific gravity with and without the petiole base (Fig. 8) is important in specifying which corm configuration specific gravity is measured in the future. Whether the petiole base is attached or removed influences the reported corm specific gravity value

CONCLUSIONS

Soil texture has only a minor effect on corm specific gravity and little effect, if any, on corm weight. Other common soil tests are also poor predictors of specific gravity and weight when adequate fertilization is used. Heavier setts produce heavier corms, but unidentified site-specific factors other than major nutrient levels and rainfall also influence corm weight. These factors probably do not affect corm specific gravity because it is uncorrelated with corm weight. The petiole base is of lower specific gravity than the corm, so future specific gravity measurements should be reported stipulating whether or not the petiole base is included.

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Table 1. Planting, fertilizing, and harvesting dates for taro.

Site	Activity	Date	Days
A	Planted	27-OCT-89	0
	Fertilized	26-DEC-89	60
	Fertilized	02-FEB-90	98
	Harvested	25-APR-90	180
B	Planted	06-NOV-89	0
	Fertilized	02-JAN-90	57
	Fertilized	12-FEB-90	98
	Harvested	04-MAY-90	179
C	Planted	09-NOV-89	0
	Fertilized	04-JAN-90	56
	Fertilized	15-FEB-90	98
	Harvested	07-MAY-90	179
D	Planted	16-NOV-89	0
	Fertilized	11-JAN-90	56
	Fertilized	22-FEB-90	98
	Harvested	14-MAY-90	179
E	Planted	27-NOV-89	0
	Fertilized	23-JAN-90	57
	Fertilized	05-MAR-90	98
	Harvested	24-MAY-90	178
X*	Planted	07-DEC-89	0
F	Planted	14-DEC-89	0
	Fertilized	08-FEB-90	56
	Fertilized	22-MAR-90	98
	Harvested	11-JUN-90	179

* Destroyed by pigs

Table 2. Test results on unamended taro-production-site soils.

Site	pHw[a]	pHs[b]	Percent sand/silt/clay	Texture class	P (mg kg^{-1})
A	5.75	5.59	25/45/30	clay loam	67
B	5.52	5.36	21/46/33	clay loam	56
C	6.05	5.63	48/37/15	loam	44
D	6.08	5.91	60/29/11	sandy loam	48
E	6.81	6.30	69/26/05	sandy loam	131
F	6.22	5.82	55/35/10	sandy loam	37
X	5.31	5.19	56/18/26	sandy clay loam	42

Site	Org. Carbon[c] (%)	Nitrogen (%)	Elec. Conductivity[d] (dS m^{-1})
A	2.6	0.19	0.12
B	3.1	0.24	<0.10
C	5.9	0.26	0.10
D	7.2	0.85	0.60
E	2.4	0.07	<0.10
F	9.7	0.78	<0.10
X	7.2	0.55	0.20

	Percent of Exchange Sites occupied by					
Site	Ca	Mg	K	Na	CEC[e](cmol$_c$ kg^{-1})	Base Sat'n[f] (%)
A	18.3	23.3	2.7	0.5	55	44.7
B	13.0	24.2	1.2	0.5	64	38.9
C	8.3	14.8	6.1	0.4	70	29.5
D	28.4	12.2	5.3	0.6	72	46.5
E	29.2	21.0	3.0	1.3	45	54.5
F	11.2	23.0	1.1	0.4	71	35.7
X	15.4	1.5	1.8	0.5	70	19.2

pHw is the pH taken in distilled water.

[b] pHs is the pH taken in 0.01 M $CaCl_2$.

[c] Org. Carbon is Soil Organic Carbon.

[d] Elec. Conductivity is Electrical Conductivity.

[e] CEC is Cation Exchange Capacity

Base Sat'n is Base Saturation

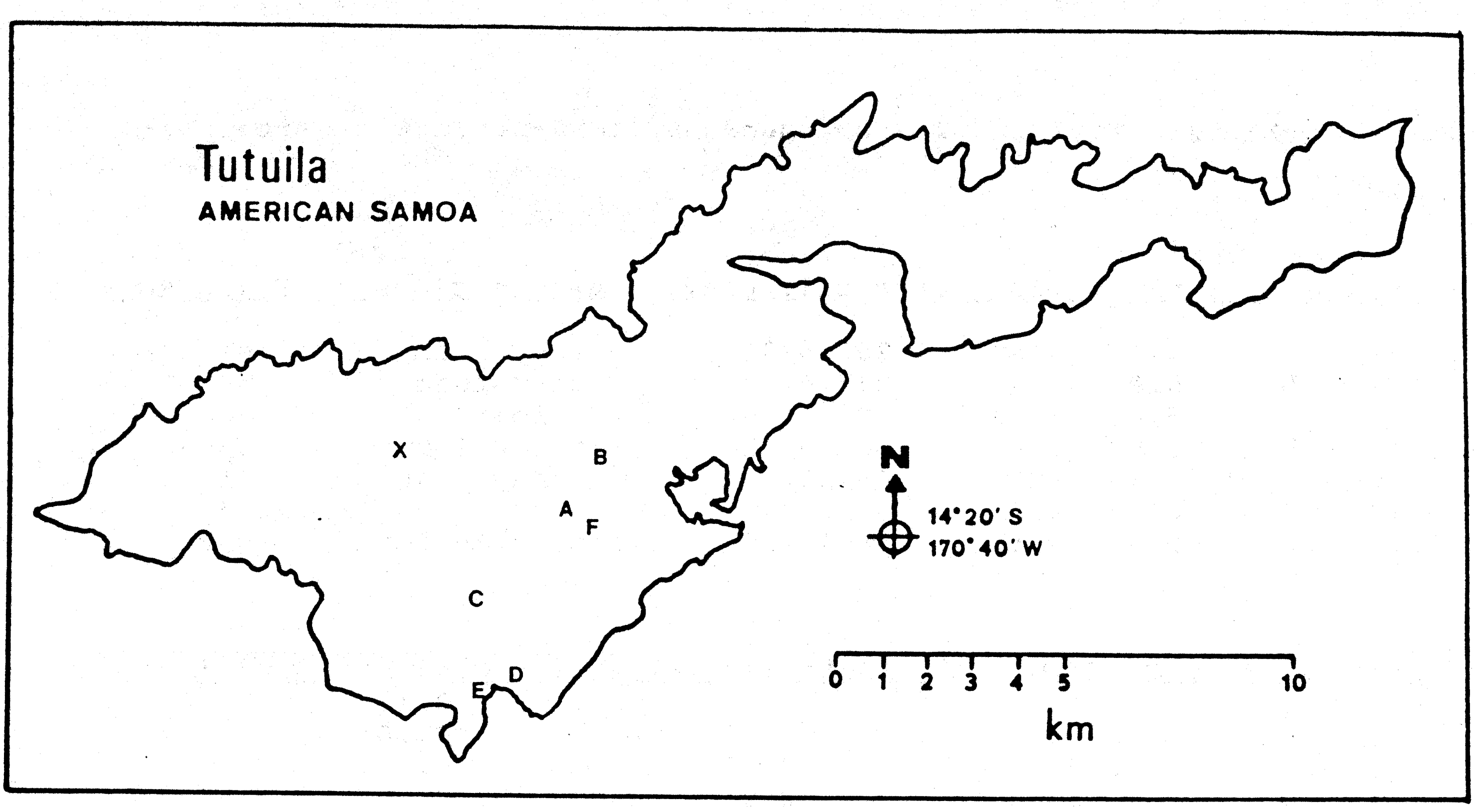

Fig. 1. Taro production sites, soil types, and approximate elevations.

Site	Series--Taxonomic Class	Elevation (m)
A	Pavaiai--medial-skeletal, Typic Dystrandepts	60
B	Leafu--very fine, mixed, Cumulic Hapludolls	60
C	Oloava--medial over cindery, Typic Dystrandepts	100
D	Puapua--medial, Lithic Eutrandepts	20
E	Sogi--medial, Udic Eutrandepts	50
F	Pavaiai--medial-skeletal, Typic Dystrandepts	60
X	Oloava--medial over cindery, Typic Dystrandepts	400

Adapted from Soils Western Tutuila map (Nakamura, 1984).
Taxonomic Class includes the term "isohyperthermic" for all soils.

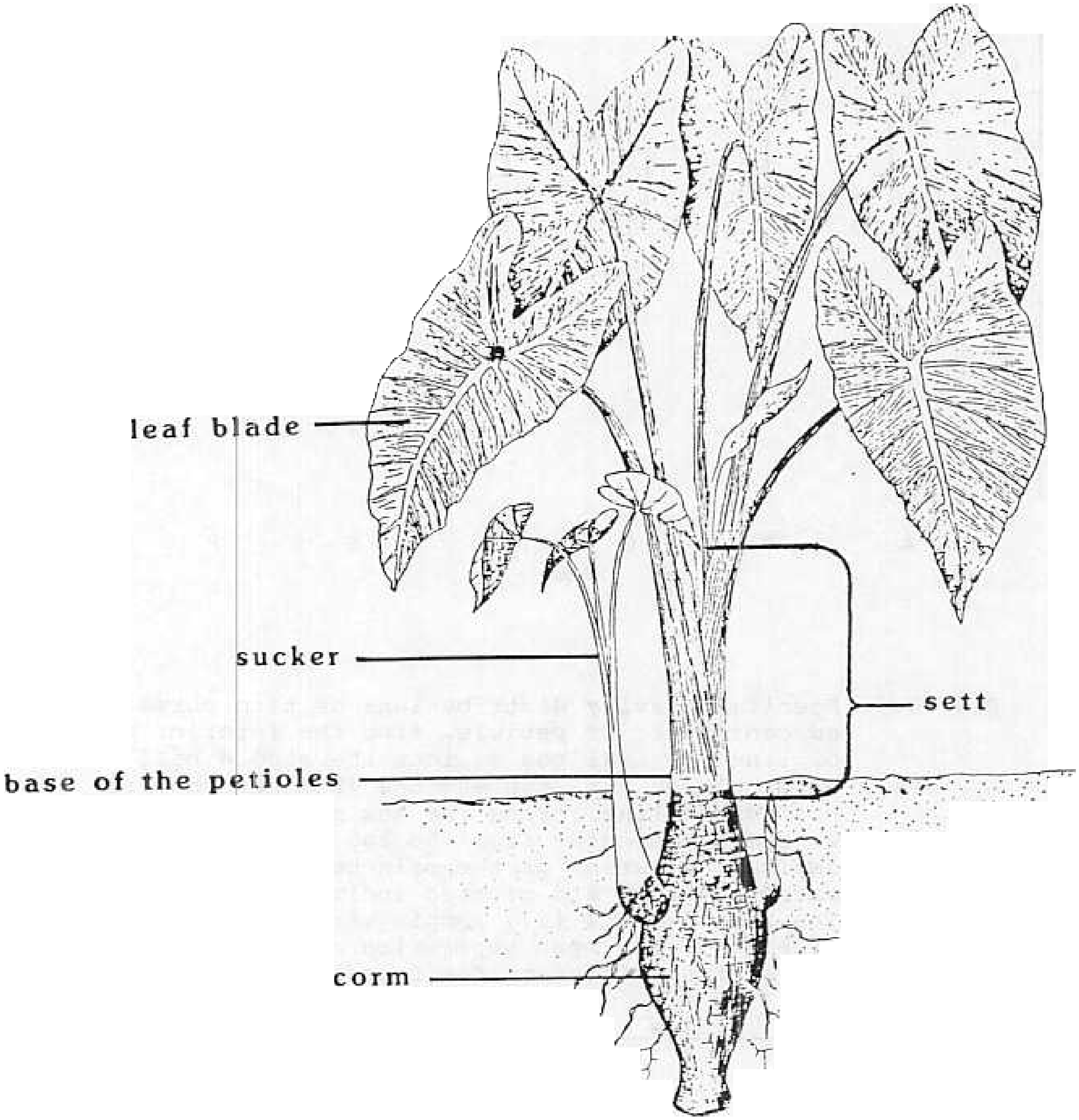

Fig. 2. **Illustration of taro plant.** Adapted and modified from "Growing Taro", Solomon Islands Agriculture Teaching Notes, according to Wilson and Hamilton, 1987.

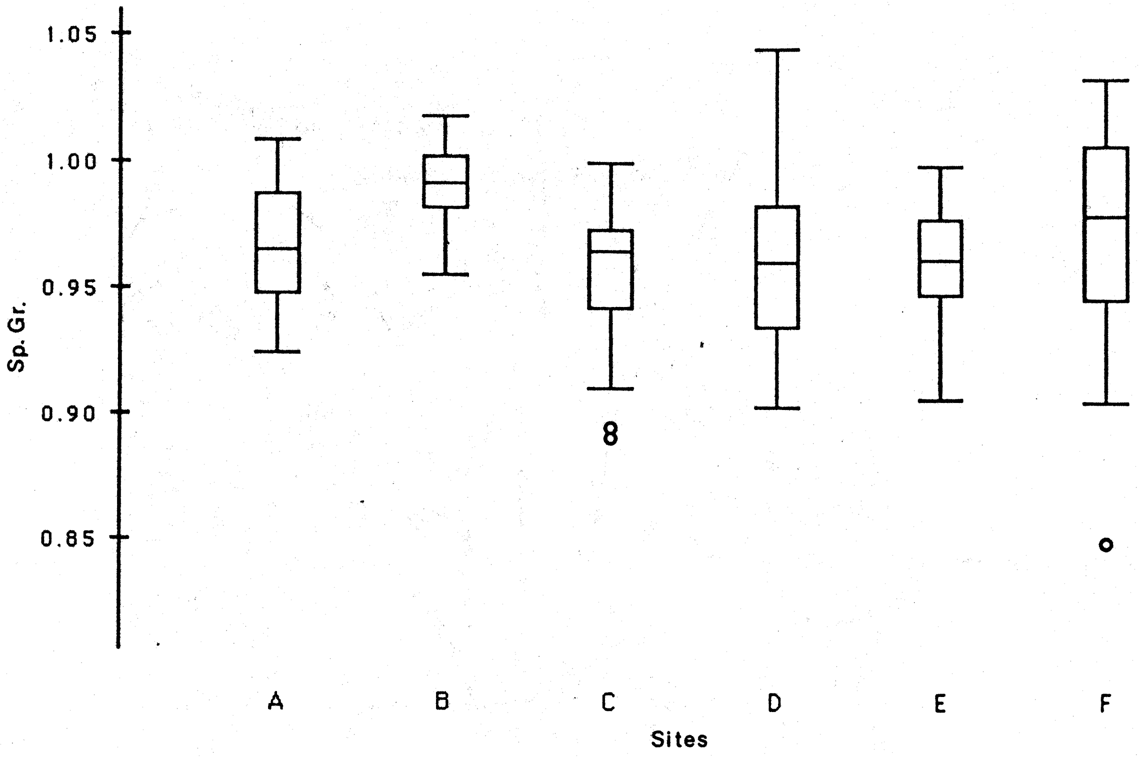

Fig. 3. **Specific gravity distributions of taro corms, with attached centimeter of petiole, from the interior rows.** The outlined central box depicts the middle half of the data between the 25th and the 75th percentiles. The horizontal line across the box marks the median. The whiskers extending from the top and bottom of the box depict the extent of the main body of the data, while extreme values are plotted individually with a circle. The sample means (x), sample variances (s^2), sample sizes (n), and mean separation categories (msc) at the 1% level of significance for Duncan's Multiple-Range Test are:

Site	x	s^2 x 10^3	n	msc
A	0.968	0.502	36	a
B	0.991	0.241	35	b
C	0.956	0.238	34	a
D	0.964	1.176	32	*
E	0.961	0.442	36	a
F	0.971	1.708	34	*

* Variance too large for inclusion in analysis of variance and mean separation tests.

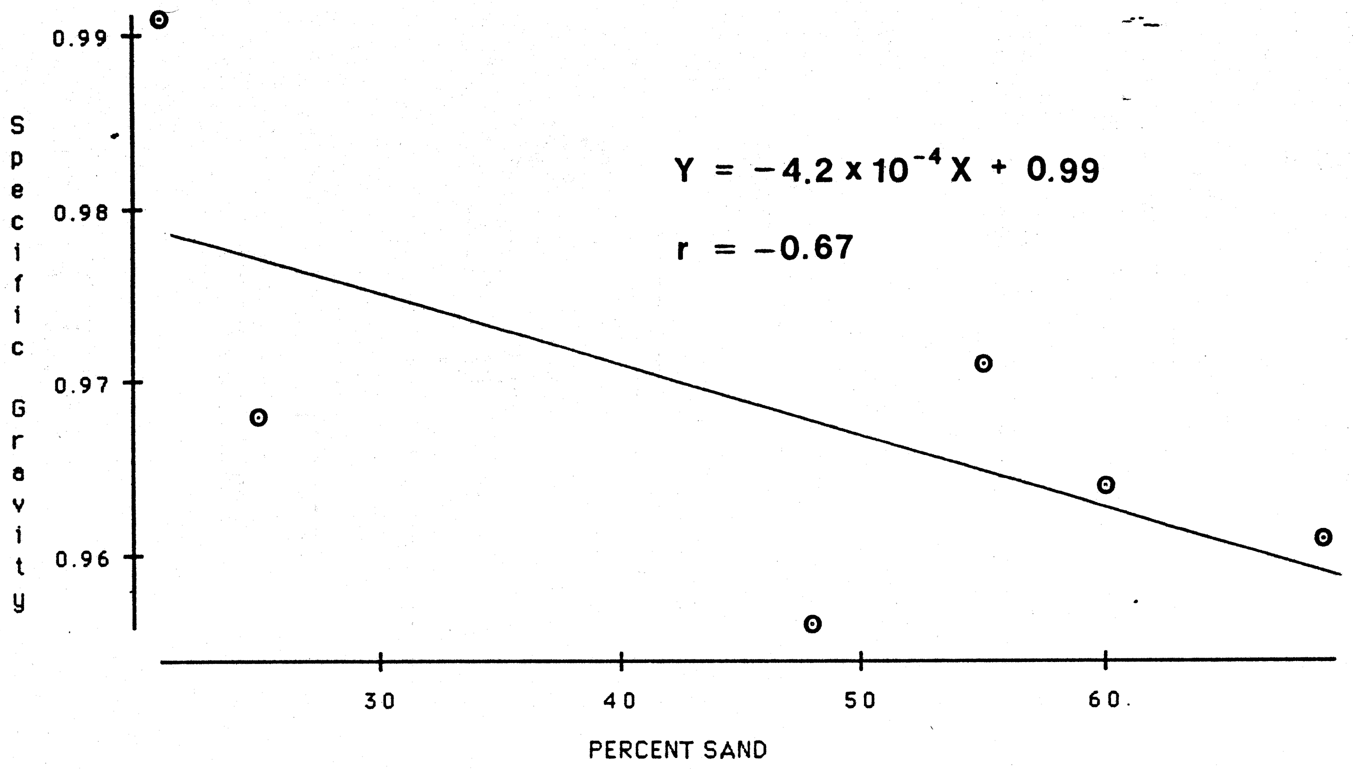

Fig. 4. Correlation between taro corm specific gravity and the percent sand in the soil. The corms have the petiole base attached and are from the interior rows. The correlation is not significant at the 5% level of significance.

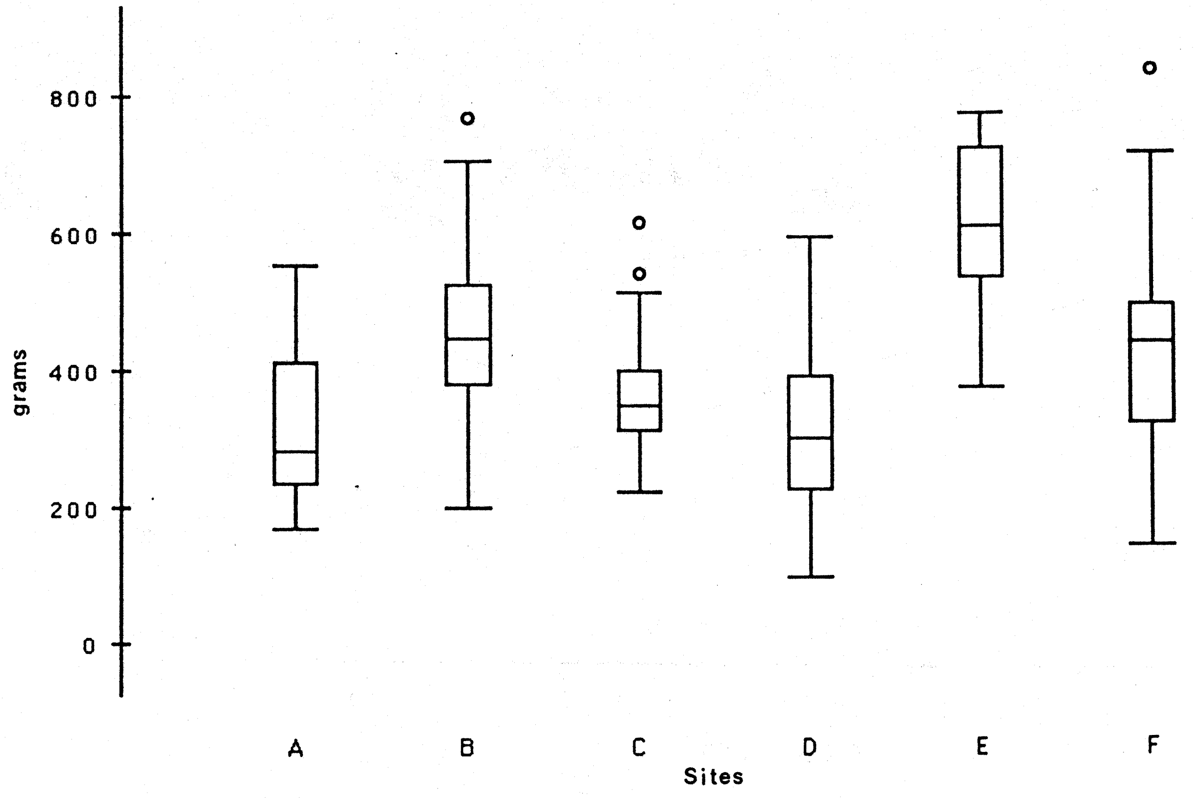

Fig. 5. **Weight distributions of taro corms, with attached centimeter of petiole, from the interior rows.** The outlined central box depicts the middle half of the data between the 25th and the 75th percentiles. The horizontal line across the box marks the median. The whiskers extending from the top and bottom of the box depict the extent of the main body of the data, while extreme values are plotted individually with a circle. The sample means (x), sample variances (s^2), sample sizes (n), and mean separation categories (msc) at the 1% level of significance for Duncan's Multiple-Range Test are:

Site	(x)	$s^2 \times 10^{-4}$	(n)	(msc)
A	321.2	1.072	36	a
B	465.5	1.674	35	b
C	364.6	0.775	34	a
D	310.9	1.483	32	a
E	617.1	1.224	36	c
F	422.8	2.000	34	b

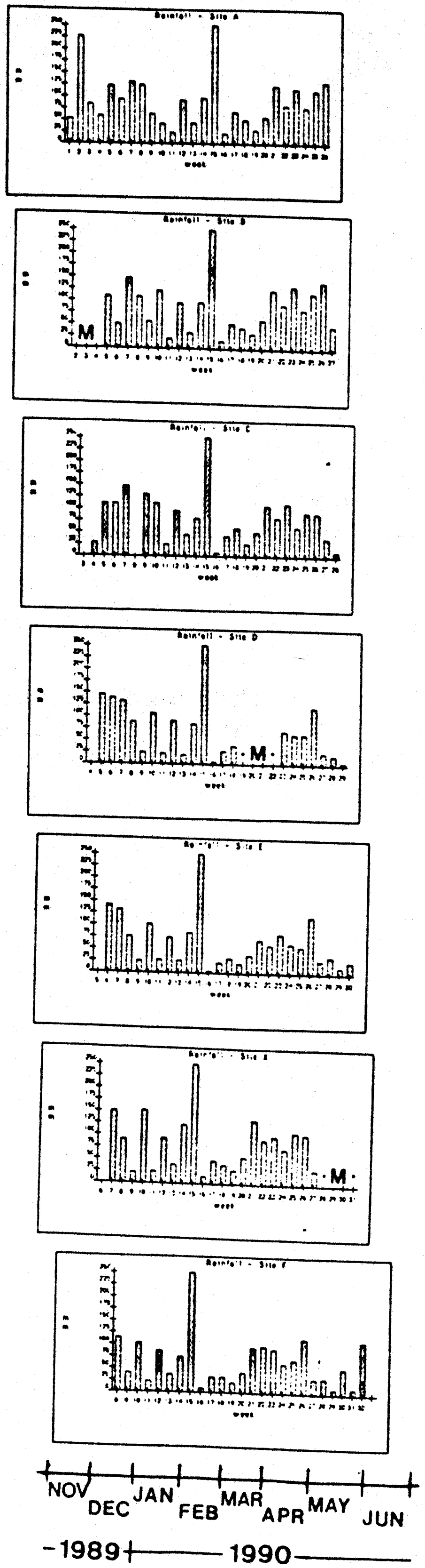

Fig. 6. Weekly rainfall records at the 7 taro production sites. Week 0 (not shown) marks when Site A was planted and week 32 when Site F was harvested. Production lasted 26 weeks at each site. The following data are missing (as indicated with a "M"): Site B: weeks 2 to 4; Site D: weeks 19 to 22; Site X: week 28 and beyond. During week 15 (FEB 2 to 4), Hurricane Ofa deposited 538 mm of rain at Site A. Assume a similar value for all sites during week 15 (listed, though, as 250 mm). The total amounts of rain recorded during the 26-week taro production period--minus values for week 15--are:

Site	mm
A	2108
B	1773*
C	1642
D	1269*
E	1334
X	1516*
F	1376

* Some data missing

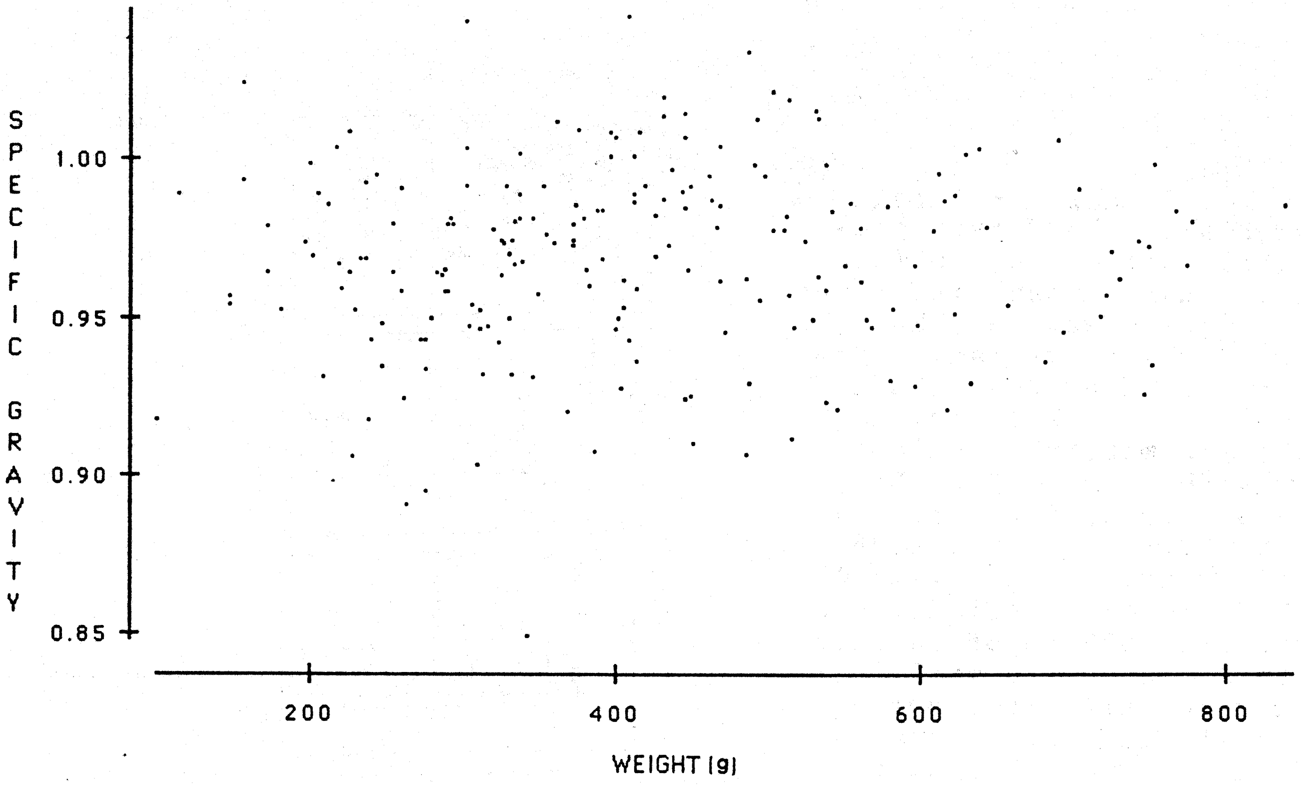

Fig. 7. **Scattergram of taro corm specific gravity and taro corm weight.** The corms have a centimeter of petiole attached and are from interior rows. Number of comparisons = 207.

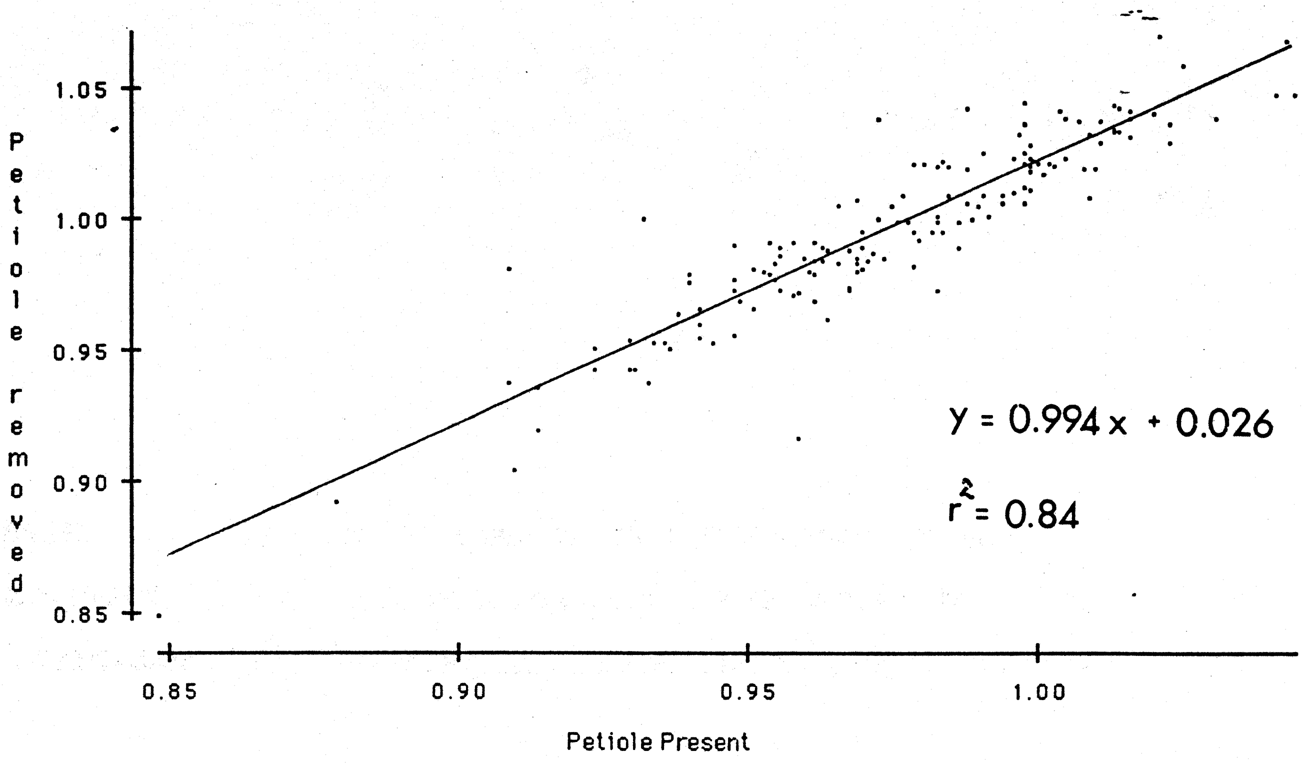

Fig. 8. **Correlation between taro corm specific gravity with and without the attached petiole.** Corms are from the border rows. Number of comparisons = 148.