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

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ABSTRACT

Little is known about how production practices influence taro (Colocasia esculenta) corm density. This study was conducted to determine the effects soil type and harvest age have on corm density. Niue taro variety was grown on 3 soil types on Tutuila, American Samoa, and harvested 6, 7, 8, and 9 months after planting. Corm densities were measured using a double-weighing method: weighting the corm first in air, then again while suspended in water. Corm density was greatly influenced by soil type, suggesting that lighter soils produce lower density corms. Harvest age also influences corm density, but whether corm density increases or decreases with harvest age depends upon the soil type. Corm density was found to be independent of corm weight.

Taro (*Colocasia esculenta* (L.) Schott) is an ancient crop of the Araceae family thought to have originated in India (Plucknett *et al.*, 1970). Though it is important in the diet of many people throughout the tropics and subtropics, its potentia for commercialization remains underexploited. One way to diversify and increase its use is to process it into precooked taro flour. Its acceptance as a processed flour depends upon several factors, one of which is corm density. For instance, flour recovery increases with an increase in corm density (Bowers *et al.*, 1964), since higher density corms contain a larger percentage of starch (Takahash and Ripperton, 1941)

Little is known of the influence of various production practices on corm density This report addresses the effects soil type and harvest age have on taro corm density

MATERIALS and METHODS

The Samoan taro cv. Niue was planted at 3 sites on Tutuila, American Samoa using setts ('tiapula' in Samoa) consisting of the lower 30 to 50 cm of the petiole with the leaf blade removed, together with the top centimeter or so of the corm. Planting began and was completed during the first half of October 1988. The sites were cleared by slashing. Holes were made about 0.6 m by 0.6 m apart and 15 to 25 cm deep using a sharpened stick ('oso'). Each sett was placed in a hole and its base tamped ightly with soil. Subsequent weed control was applied as needed.

The sites were selected because they represent 3 soil taxonomic classes on which taro is commonly grown (Table 1) They are also accessible by vehicle, and the cooperating farmers have a record of achievement and support of agricultural research

At 6, 7, 8, and 9 month intervals after planting, 115 kg of corms, including a centimeter or so of the petiole, were harvested at each site. After washing, every tenth corm was selected for density measurement. The remainder were dipped in 1% sodium hypochlorite (Jackson *et al.*, 1979) and placed in polyethylene bags. Half were air-shipped within 3 days to Honolulu for processing into taro flour, and half were stored under ambient conditions for 2 weeks prior to shipping.

Corm density was measured by weighing the corm twice using an Ohaus Port-O-Gram Model C3001 electronic balance: first the standard way by placing the blotter-dried corm on the balance pan and recording its weight; then by suspending it in water while attached to a 700 g lead weight with a velcro strap to counteract corm buoyancy. Using an hydrometer to measure water density, corm density was calculated as

$$D = W_A D_W/[W_A - (W_B - W_C)] \qquad \text{[Eq. 1]}$$

where D is the corm density, in g cm^{-3}

W_A is the corm weight in grams

D_W is the water density, in g cm^{-3}

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 weight, in grams, while submerged in water

With a balance precision of ± 1 g and hydrometer precision of ± 0.001 g cm^{-3}, the uncertainty in corm density, delta density (ΔD), was determined from its total differential (Larson and Hosteller, 1982):

$$\Delta D = [\delta D/\delta W_A]\Delta W_A + [\delta D/\delta D_W]\Delta D_W + [\delta D/\delta(W_B - W_C)]\Delta(W_B - W_C) \qquad [Eq. 2]$$

where

$$[\delta D/\delta W_A] = -[(W_B - W_C)D_W]/[W_A - (W_B - W_C)]^2$$

$$[\delta D/\delta D_W] = W_A/[W_A - (W_B - W_C)]$$

$$[\delta D/\delta(W_B - W_C)] = W_A D_W/[W_A - (W_B - W_C)]^2$$

$$\Delta W_A = 1 \text{ g}$$

$$\Delta D_W = 0.001 \text{ g cm}^{-3}$$

$$\Delta(W_B - W_C) = 2 \text{ g}$$

Following the density measurements, these corms were also dipped in sodium hypochlorite solution, placed in polyethylene bags, and held at 4°C (refrigeration), 25°C (air-conditioned room), and at 25 to 31°C (ambient temperatures) to assess corm storage at the 3 temperature levels.

The data were analyzed using a two-way analysis of variance (ANOVA) to study the combined effect of site and harvest age on corm weight and on corm density (Koosis, 1972). This procedure also checks for interaction between sites and harvest ages. The procedure requires a constant number of multiple replications from each combination of site and harvest age (John, 1971) For this reason 15 random samples were used from each treatment combination, since this is the minimum sample size among the 12 treatment combinations. Because no provision is made for missing values, the data from A-7, *i.e.*, site A, harvest age 7 months, is used though it includes data of corms inadvertently harvested from an adjacent field. Results of the ANOVA are interpreted using corroborative evidence from corm density and corm weight distributions, or histograms.

RESULTS and DISCUSSION

The ANOVA for corm density data indicates that all "Between Groups" sources of variation are highly significant (Table 2). From the average corm densities (Table 3) and the corm density histograms (Figure 1) it is obvious that taro grown at site B is of consistently lower density than taro grown at the other sites. Soi tests (Table 1) show that site B has an organic carbon content and, by implication, a soil nitrogen content that lies between the organic carbon contents of sites A and C. Its potassium, calcium + magnesium, base saturation, and cation exchange capacity (CEC) values are similar to those of site A: The major differences between soil properties at site B and the two other sites are the intensity factor of soil acidity, or pH, and the soil texture. Soi at site B is about 8 times less acidic than at site A, and about 25 times less acidic than at site C. Soil texture at site B is 50% sand, while it is mainly clay at site A (50%) and silt at site C (40%). Of these two major differences soil texture is, perhaps, the more important in influencing corm density. The lighter soil at site B may allow for easier expansion of the growing corm, resulting in ts decreased density

The "Between Months" source of variation is more difficult to interpret. From the corm density histograms (Figure 1) and the average densities for each treatment combination Table 3), the corm density for taro grown at site A does not change appreciably from month to month (excluding treatment combination A-7 for the reason stated earlier). Beginning at 7 months, though, corm density gradually decreases with harvest age at site B, but increases at site C. The reason for these observations is not readily apparent but probably accounts, in part, for the highly significant "Month x Site" interaction.

Rainfall was not recorded at the sites because rain gauges were unavailable and the sites were far from the farmers' homes. Rainfall was recorded at the Land Grant Agricultural Experiment Station at Malaeimi using a RainWise automatic recording rain gauge (Figure 2). Because rainfall in American Samoa is thought to be highly variable within a few kilometers, this rainfall record may be useful in suggesting relative monthly rainfal variability rather than absolute rainfall rates for the taro production sites.

Rainfall probably has a greater influence on biomass accumulation, or corm weight, than on corm density. ANOVA of corm weights (Table 4), the average corm weights (Table 3), and the corm weight histograms (Figure 3) all indicate no significant differences in corm weights among the 3 sites. This suggests that biomass accumulation at all 3 sites was more or less equal, implying that the combinations of rainfall and soil fertility were similar. Furthermore, the distributions of both corm weight and corm density do not change appreciably with harvest age; heavy and light, high density and low density corms are found in similar numbers at 9 months as at 6 months. The significance of the "Between Months" source of variation for corm weights (Table 4) is between the 7 and 8 month harvest ages, with average corm weights of 668 g and 506 g, respectively. Yet corms harvested at 6 months are not significantly different in weight from those harvested at 9 months, nor are they significantly different in weight from corms harvested at either 7 or 8 months. The significant differences in weight between corms harvested at 7 months and those harvested at 8 months must be attributed to chance alone.

The histograms of corm weights show a broad spectrum between 200 g and "greater than 1000 g", with a modal range between 400 to 599 g at each site

The data also indicate an absence of correlation between corm density and corm weight (Figure 4). The size of the corm is no indicator of the corm density. There is correlation, however, between the measure of the uncertainty of corm density, *i.e.*, delta density, and corm weight (Figure 5). Heavier corms give a more precise measure of corm density, a consequence of the differential equation used to determine delta density (Eq. 2). Corms weighing about 200 g have a ± 1% error in their density measurement, while corms weighing over 1000 g have about a ± 0.3% error. This level of precision makes the double-weighing method a viable alternative to the floatation method (Bowers *et al.*, 1964) when an exact measurement of corm density is required.

Corms stored for 28, 35, and 42 days at the three temperature levels were examined for decay. Almost half of the corms stored under ambient conditions had symptoms of decay after 28 days (softness and brown rot, usually accompanied by a fermentation odor), with all corms affected by 42 days (Figure 6). Corms stored in an air-conditioned room fared almost as badly as those under ambient conditions. But corms stored at 4°C showed little evidence of decay, even after 42 days. These results are in accord with earlier observations that corms may store for up to 30 days in polyethylene bags (Jackson *et al.*, 1979), with many probably unpalatable after 1 or 2 weeks (Gollifer and Booth, 1973; Siki, 1979). The optimum storage temperature is about 4°C (Watson, 1979).

In addition to rotting, corms spout roots during storage. What effect this may have on corm quality is uncertain.

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Table 1. Taro production sites and their soil properties.

		SITES	
	A	B	C
FARMER	Siufaga Fanene	Siaumau Samatua	Sosene Asifoa
LOCATION	Malaeimi Valley	Fagama'a Crater	Aoloau
SOIL TAXONOMY	Cumulic Hapludol	Lithic Eutrandept	Typic Dystrandept
pH	5.2	6.1	4.7
SAND/SILT/CLAY	16/34/50	50/28/22	36/40/24
TEXTURE CLASS	Clay	Sandy clay loam	Loam
ORGANIC CARBON	2%	5%	8%
POTASSIUM	3%	3%	8%
CALCIUM	24%	49%	10%
MAGNESIUM	47%	22%	35%
BASE SAT'N	74%	74%	53%
CEC (cmol (+)/kg)	31	35	29

Table 2: Analysis of variance of taro corm densities.

SOURCE OF VARIATION	SUM OF SQUARES	DF	VARIANCE EST.	F-VALUE
TOTAL	0.3384	179		
BETWEEN GROUPS	0.2017	11		
BETWEEN MONTHS	0.0169	3	0.0056	6.925**
BETWEEN SITES	0.1401	2	0.0700	86.072**
MONTHS X SITES	0.0447	6	0.0075	9.166**
WITHIN GROUPS	0.1367	168	0.0008	

**indicates the results are significant at the 1% level.

Table 3: Harvest dates, average corm weights and densities, standard deviations for weights and densities, and sample sizes for each combination of site and harvest age.

CODE	HARVEST DATE	AVE. WGT. ($x \pm s$)	AVG DENSITY ($x \pm s$)	n
A-6	13-APR-89	492 ± 207	1.008 ± 0.024	21
B-6	20-APR-89	655 ± 198	0.937 ± 0.034	18
C-6	28-APR-89	506 ± 242	0.997 ± 0.028	22
A-7	11-MAY-89	737 ± 284	1.060 ± 0.040	15
B-7	18-MAY-89	594 ± 175	0.961 ± 0.034	17
C-7	25-MAY-89	672 ± 223	0.994 ± 0.026	23
A-8	08-JUN-89	476 ± 105	1.015 ± 0.014	21
B-8	15-JUN-89	499 ± 173	0.957 ± 0.023	21
C-8	22-JUN-89	542 ± 160	1.015 ± 0.032	20
A-9	06-JUL-89	631 ± 168	0.989 ± 0.031	20
B-9	13-JUL-89	626 ± 261	0.952 ± 0.030	17
C-9	20-JUL-89	511 ± 205	1.026 ± 0.014	18

Under the CODE heading, A, B, and C are the sites, while 6, 7, 8, and 9 are the harvest ages, in months. For AVE. WGT. and AVG DENSITY, the weights are in grams and the densities in g cm^{-3}, with "x" as the sample averages and "s" as the sample standard deviations.

Table 4: Analysis of variance of taro corm weights.

SOURCE OF VARIATION	SUM OF SQUARES	DF	VARIANCE EST.	F-VALUE
TOTAL	9 133 202	179		
BETWEEN GROUPS	1 126 973	11		
BETWEEN MONTHS	758 239	3	252 746	5.304**
BETWEEN SITES	8 578	2	4 289	0.090
MONTHS X SITES	360 156	6	60 026	1.260
WITHIN GROUPS	8 006 229	168	47 656	

**indicates the results are significant at the 1% level.

Figure 1. Histograms of taro corm densities for each combination of site and harvest age. Each histogram is partitioned into four cells ranging in densities (g cm^{-3}) from 0 to 0.999, 1.000 to 1.024, 1.025 to 1.049, and 1.050 and greater. The Y-axis of each histogram denotes the frequency of each cell as a percent.

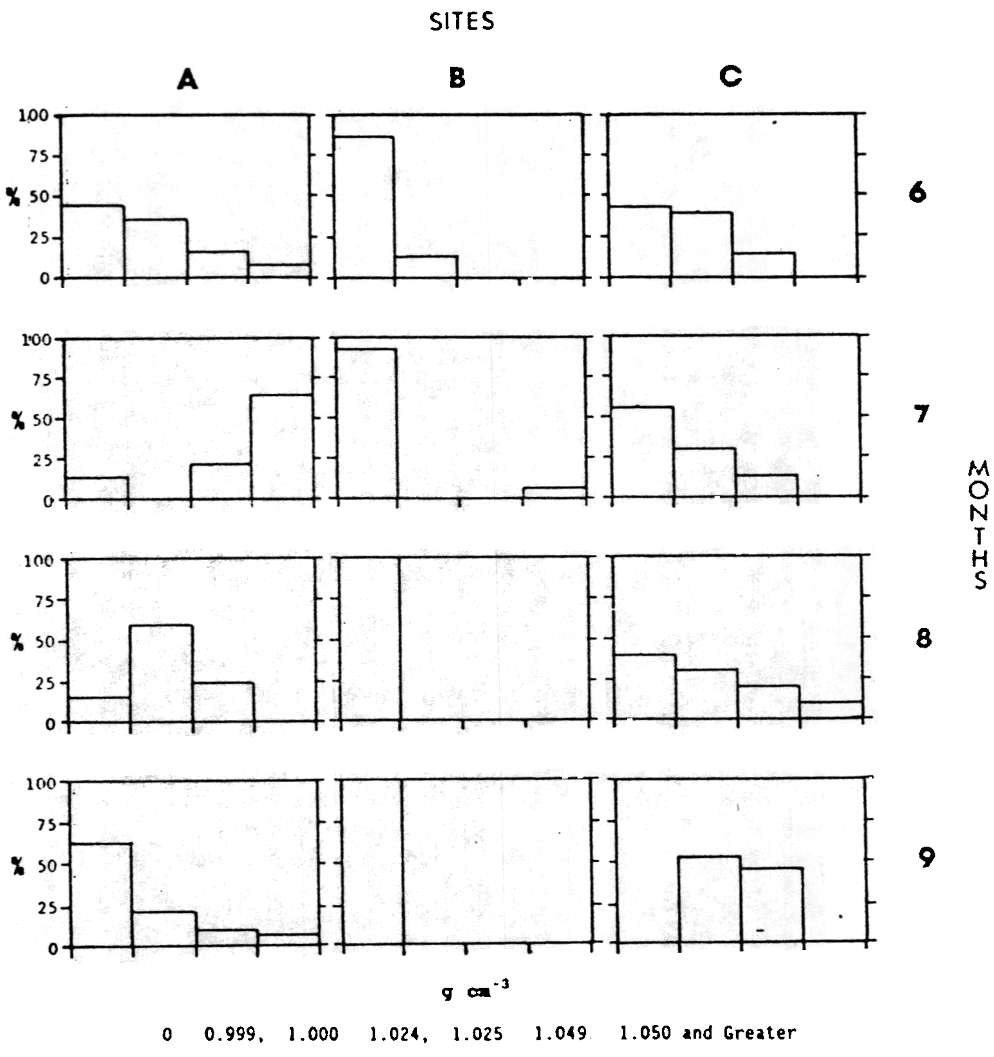

Figure 2. Rainfall record at the American Samoa Community College Land Grant Agricultural Experiment Station.

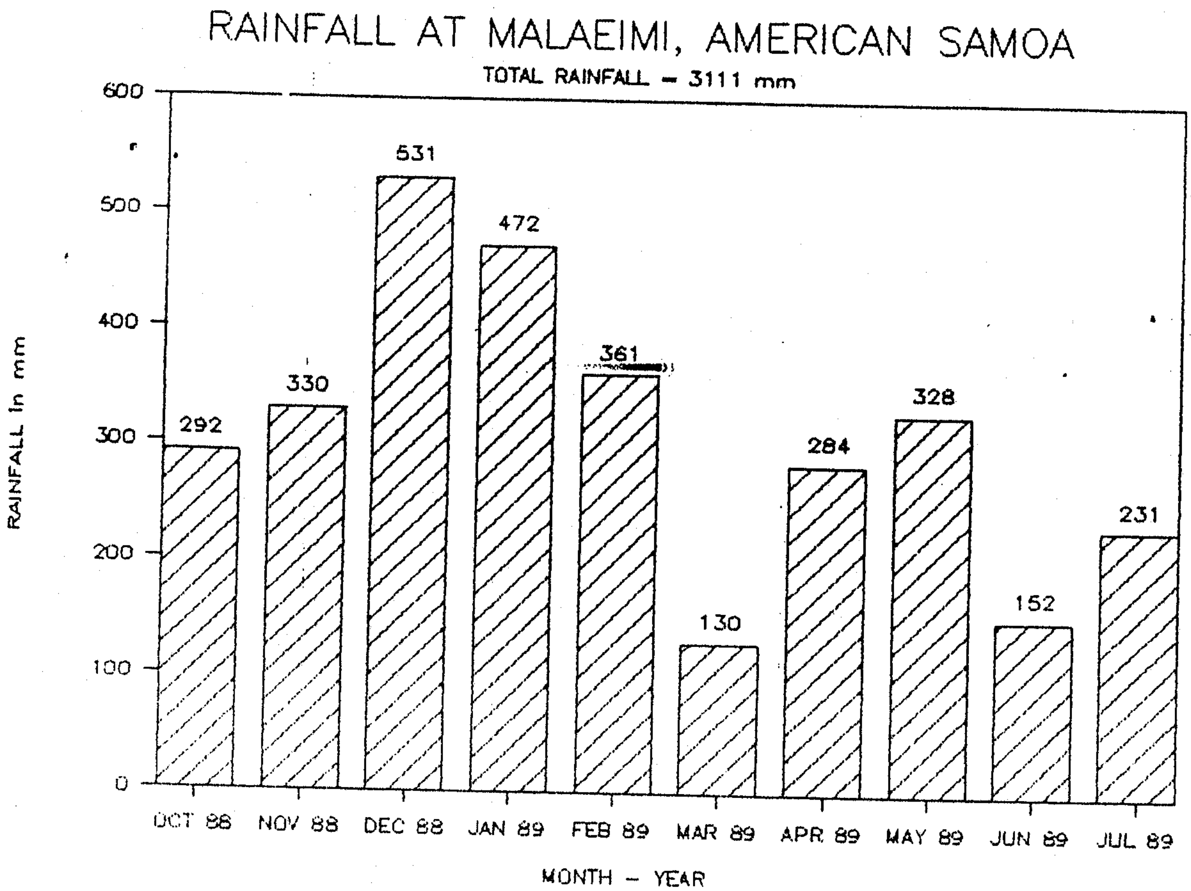

Figure 3. Histograms of taro corm weights for each combination of site and harvest age. Each histogram is partitioned into five cells ranging in weights from 200 to 399 g, 400 to 599 g, 600 to 799 g, 800 to 999 g, and 1000 g and greater. The Y-axis of each histogram denotes the frequency of each cell as a percent.

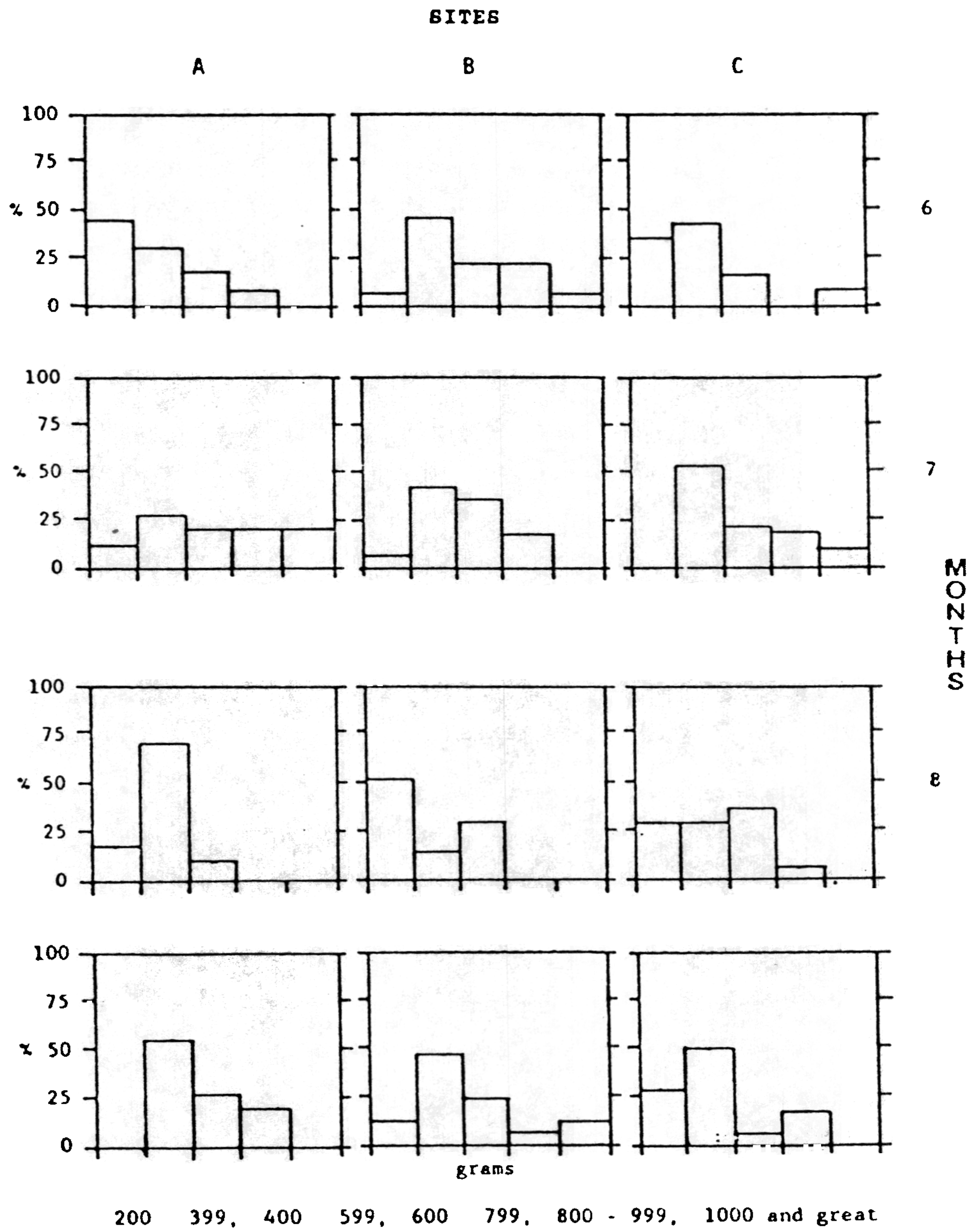

Figure 4. Taro corm densities compared to corm weights for corms sampled from all combinations of site and harvest age. Number of samples is 217.

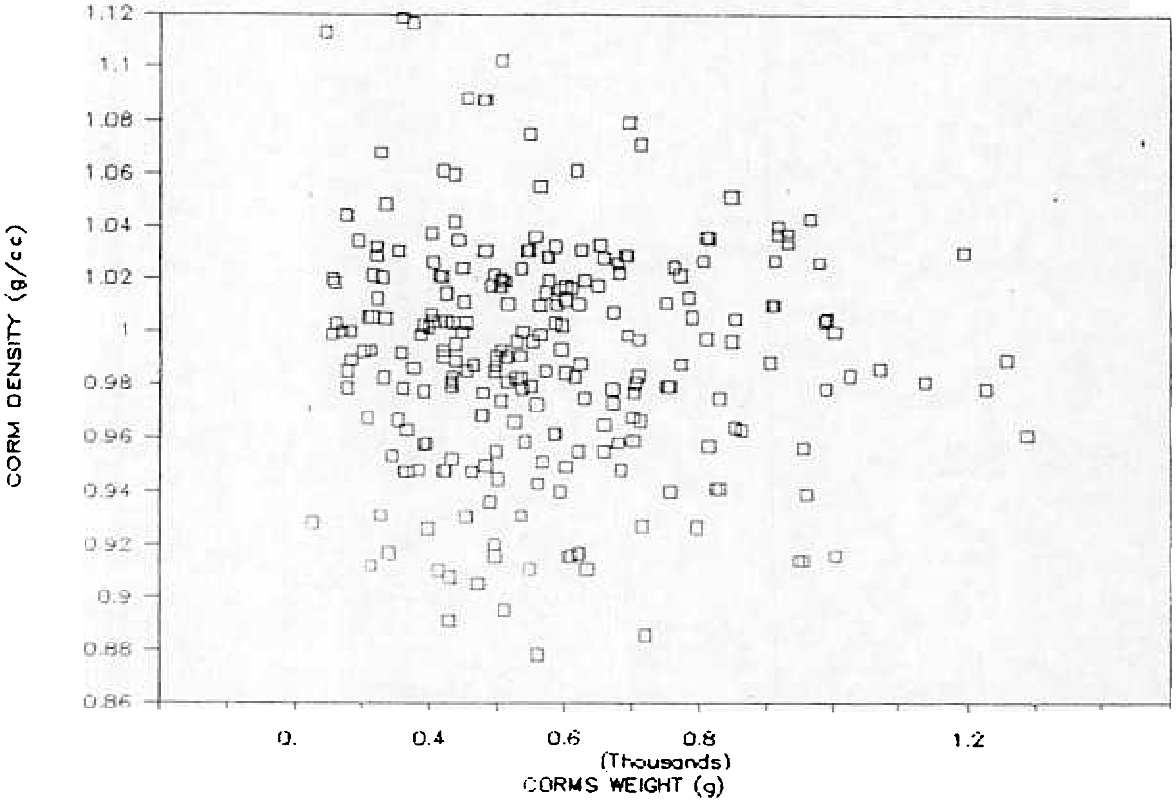

Figure 5. Delta densities, (ΔD), compared to taro corm weights for corms sampled from all combinations of site and harvest age. Number of samples is 217.

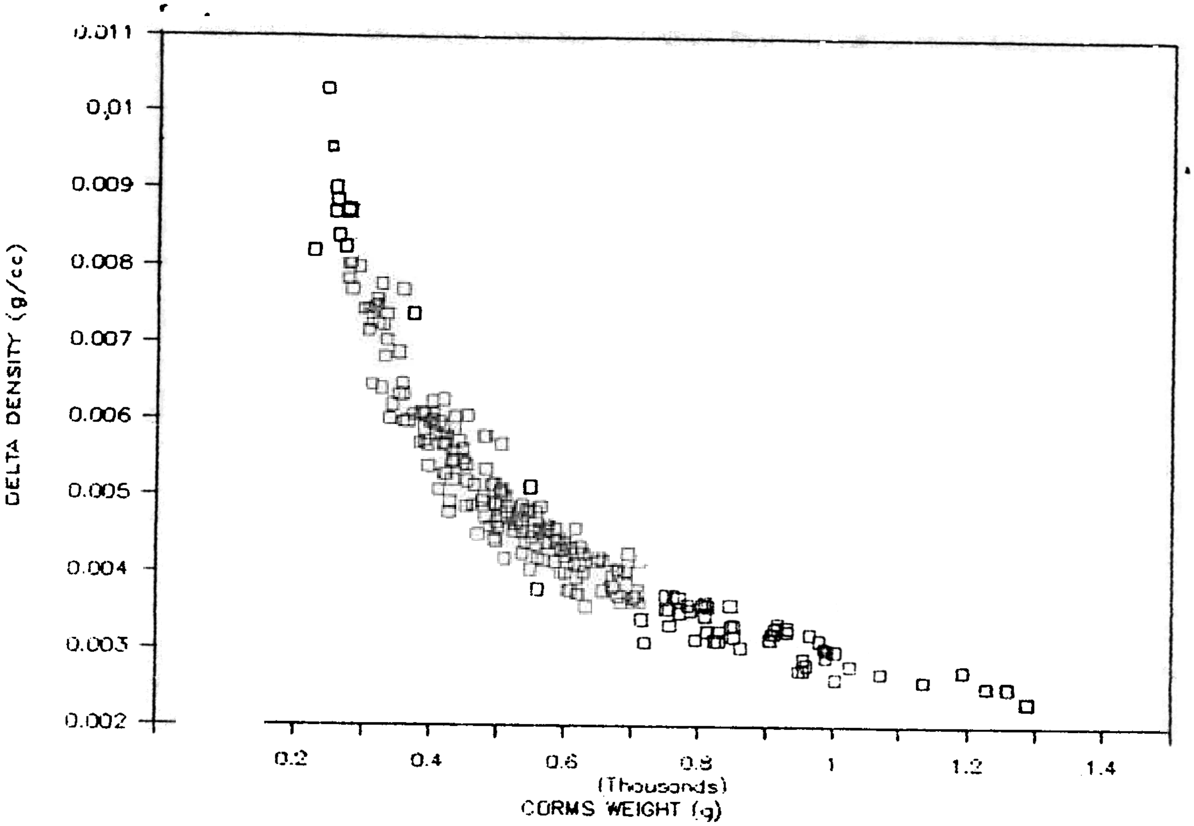

Figure 6. Frequency of rot for taro corms stored at three temperature levels: ambient (25 to 31°C), air-condition (25°C), and refrigeration (4°C). Storage periods were 28, 35, and 42 days.