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# TARO CORM WEIGHT AND SPECIFIC GRAVITY RESPONSES
# TO
# SETT SIZE AND FERTILIZER AMENDMENTS

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# ABSTRACT

Fertilizer N generally increases root crop yield but decreases specific gravity, a measure of crop quality. This study examines the effects of sett size, sett root length, N, P, K, and Ca on upland taro [Colocasia esculenta (L.) Schott] corm weight and specific gravity. Planting setts of taro cv. Niue were grouped by weight and were grown for 6 months on an Oloava silt loam (medial over cindery, isohyperthermic Typic Dystrandept) in humid, tropical Samoa. Select setts received a total of 336 kg N $ha^{-1}$, 206 kg $P_2O_5$ $ha^{-1}$, 297 kg $K_2O$ $ha^{-1}$, 0.27 Mg Ca $ha^{-1}$, or a combination of any 3 of these amendments. N significantly increased corm weight, the incidence of sucker formation, and plant mortality. P, K, and Ca were less effective than N for increasing corm weight. Like N, they had no effect on specific gravity. Corm weight correlated positively with planting sett weight, but specific gravity correlated negatively. Sett size at planting did not influence sett size at harvest. Fertilizers may increase taro corm weight without lowering corm specific gravity, but the choice of planting sett size favors one at the expense of the other.

After yield, crop quality is a major factor influencing the income of farmers. It also affects properties of products made from a crop. Yet little is known of production factors affecting the quality of taro, <u>Colocasia</u> <u>esculenta</u> (L.) Schott, a staple crop of subsistence farmers throughout the tropics and subtropics with expanding commercial uses.

For the white potato, <u>Solanum</u> <u>tuberosum</u> L., specific gravity is the best single criterion of tuber quality (Teich and Menzies, 1964). Increasing specific gravity also appears to increase the corm quality of taro (Bowers, <u>et</u> <u>al</u>., 1964).

Studies on the potato show an antagonistic effect between yield and specific gravity with N-P-K fertilizer amendments. While all increase yield, nitrogen and potassium generally decrease tuber specific gravity, while phosphorus may raise, lower, or have no effect on it (Murphy and Goven, 1975; Teich and Menzies, 1964).

Fertilizer amendments also increase taro yield (Pluckett, <u>et</u> <u>al</u>., 1970; Pena, 1967) But in upland taro, nitrogen was found to lower corm specific gravity significantly, potassium to raise it, and phosphorus to have no effect (Pena, 1967)

Earlier we found a nearly negligible positive correlation between taro corm specific gravity and corm weight (Sagaga and Vargo, 1991). We surmised that factors influencing corm weight would have little, if any, effect on corm specific gravity.

To test our hypothesis that fertilizer amendments would influence corm weight but not specific gravity, we fertilized taro with combinations of N, P, K, and Ca. To improve precision, setts were grouped according to weight, since larger setts reportedly produce larger yields (Bourke and Perry 1976; Ching 971) The effects of the various combinations of N, P, K, and Ca on corm weight and specific gravity were examined by ANOVA. Correlations of corm weight and specific gravity with planting sett weight were also examined. Other aspects studied were the influence of planting sett size on harvest sett size; the influence of planting sett size and fertilizer amendments on plant mortality; the influence of fertilizer amendments on sucker development; the influence of planting sett root length on corm yield; and the feasibility of a border row in taro trials.

## MATERIALS AND METHODS

Fresh cormel setts ('lauvai' in Samoa) of taro cv. Niue were trimmed to 40, 50, and 60 cm from petiole base to tip. Each was weighed to the nearest 5-g increment and its petiole base circumference measured to the nearest millimeter. It was noted as having either short, medium, or long roots.

The following day (25 Jan. 1991) conical holes were made along a 10 by 20 grid, 60 cm apart and 25 to 30 cm deep, using a long pointed pole. The area was hand-weeded and the thatch used as mulch. The soil was a well-drained Typic Dystrandept of the Oloava silt loam series (Table 1). The field comprised 24 randomized blocks with 6 setts each, based on petiole length and weight, and 56 setts of assorted lengths and weights forming a border around the blocks. Within blocks, setts were randomly assigned the following fertilizer treatments: N-P-K-Ca, N-P-K, N-P-Ca, N-K-Ca, P-K-Ca, and no fertilizer. All border row setts received the N-P-K-Ca treatment.

Amendments were made as follows: dolomitic limestone, 100-mesh, was applied prior to planting by broadcasting on the sloping walls of the holes at a rate of 25 g per hole (0.67 Mg ha$^{-1}$) At 10 g each, urea (120 kg N ha$^{-1}$) and triple superphosphate (128 kg $P_2O_5$ ha$^{-1}$) were placed in holes and covered lightly with soil before inserting setts. On alternate weeks the following were placed in rings 3 to 6 cm from the petioles at a rate of 2 g each per plant: urea (24 kg N ha$^{-1}$) between weeks 2 to 18; triple superphosphate (26 kg $P_2O_5$ ha$^{-1}$) between weeks 2 to 6; and potassium chloride (33 kg $K_2O$ ha$^{-1}$) between weeks 8 to 18.

By 6 weeks holes were completely filled with loose soil. The plot was kept free of weeds and pests, and rainfall recorded from a 150-mm capacity gauge, during weekly inspections.

Corms, including a centimeter of the petiole base, were harvested at 188 days while noting the number of suckers. Weight, specific gravity, and petiole base circumference were recorded for each washed corm. Specific gravity was determined using a modified air and water method (Sagaga and Vargo, 1991). ANOVA, including missing value estimations, were performed using a multi-factor analysis of variance program, AVMF (Lund, 1988). Missing value estimation employed a least squares fit to the available plot means. Of the 24 blocks, 8 had all six treatment values, 9 had one missing value, and 6 had two missing values. One block had 3 missing values and was excluded from the ANOVA. Observations from this block were used elsewhere, however. The 21 missing values were within the limitations imposed by AVMF for handling missing values.

## RESULTS AND DISCUSSION

Earlier studies of the effect of planting sett size on taro yield partitioned setts into 3 broad categories based on petiole base diameter (Bourke and Perry, 1976; Ching, 1971). Because petiole bases are only approximately circular, having axes of varying lengths rather than a true diameter, we measured the petiole base circumference and calculated a radius. Although less uncertain than measuring a single "diameter," measuring the circumference of a beveled petiole base involves a degree of subjectivity. We chose, instead, to measure sett size by weight after trimming sett tops to within 40, 50, or 60 cm of their bases. A plot of petiole base radii against sett weights shows good linear correlation despite sett length (Fig. 1). Regression improves slightly ($r^2 = 0.82$) if the radii are replaced by their squares. The radius-squared is proportional to the petiole base cross-section area which, for a given length, is approximately proportional to sett volume.

For the 6 fertilizer treatments, the standard deviations of the corm weight sample distributions are proportional to their means (Fig. 2). A logarithmic transformation to obtain independence between these statistics, followed by a test for homogeneity of variances (Little and Hills, 1978), was performed prior to the ANOVA. Nitrogen is the most influential fertilizer for increasing corm weight; phosphorus, potassium, and calcium contribute only marginally compared with the unamended soil. In contrast, an ANOVA of the specific gravity data (Fig. 3) shows no differences between treatments (Table 2).

Examining each fertilizer combination individually, corm weights display a significant positive linear correlation (one-tailed test) to planting sett weight for 2 of the

6 treatments and in the border row plants, 40 of which survived (Fig. 4). Positive correlations are also noted for the other 4 fertilizer treatments, though not at significant levels. A similar comparison for corm specific gravity is different in that, except for the unfertilized treatment, a negative correlation exists between corm specific gravity and planting sett size (Fig. 5). The heterogeneous correlation coefficients for corm weight (Fig. 4) and corm specific gravity (Fig. 5) suggest fertilizer treatments interact with planting sett weight. Why some coefficients are highly significant and others not significant is not readily understood. But even for the largest coefficients, less than half the variability in corm weight or specific gravity is explained by the planting sett weight.

Planting sett radii do not significantly influence harvest sett radii (two-tailed test) for any fertilizer treatment (Fig. 6). An interaction again exists between fertilizer treatments and planting sett size since some slopes are positive and others negative. Interaction was confirmed by a test for the homogeneity of regression coefficients (Gomez and Gomez, 1984). Interestingly, 84% of the 161 observations result in harvest setts with larger radii than their planting setts.

Planting sett size influences the final stand, with larger setts being generally more reliable (Wilson, 1984). Our data confirm this but show that risk does not fall solely on the smallest setts. Instead, mortality afflicts a subgroup whose mean is shifted toward smaller sett size (Fig. 7).

Examined in detail, the addition of fertilizers, especially nitrogen, increases plant mortality (Fig. 8). This may be due to an increase in soil acidity, since the mortality rate is reduced when calcium is also added. Calcium carbonate may partially neutralize hydrogen ions generated during nitrification of urea. Nitrogen also might induce a physiological change in the plant resulting in increased sucker formation (Table 2). This may stress the plant, rendering it more vulnerable. Though rates of fertilizer amendments are high, they do not exceed recommended rates (Pena, 1978).

An alternative explanation for sucker formation proposed by some farmers is plant density. Wider spacing between plants is thought to encourage the formation of suckers. Though plant spacing is a constant 0.6 m in this trial, border row plants inherently experience less competition than plants from interior rows. Omitting plants with missing neighbors, a comparison of the number of suckers of border row plants (3.90 ± 2.05 for the mean and standard deviation, respectively, of 21 plants) with the number of suckers formed on interior row plants given the N-P-K-Ca treatment (4.25 ± 2.89 for 12 plants) does not result in a significant t-test.

The same plants selected above were examined to determine if differences in corm weight and specific gravity can be attributed to plant density. Because planting sett size might influence corm weight and specific gravity, t-test precision could improve by performing an analysis of covariance with sett weight as the independent variable (Cochran and Cox, 1957). Results show no significant difference in either corm weight or corm specific gravity between border row and interior row plants receiving the same fertilizer treatment (Table 3). Also, precision is increased about 10% in both analyses by considering the effect of planting sett weight. This modest increase does not justify the time and labor needed in measuring and monitoring each planting sett.

Setts often have root systems largely intact depending, presumably, on soil texture and moisture at harvest. Could setts with well-developed roots have an advantage over setts with missing or truncated roots? We investigated if root lengths of planting setts influence corm weight at harvest. Setts were noted as having either short, medium, or long roots at the time of planting. Corm weight is plotted against planting sett weight after grouping fertilizer treatments according to the level of significance of the linear correlation coefficients of Fig. 4 (Fig. 9), with the status of the planting sett roots included. The results show a somewhat random distribution of points based on root length, suggesting corm weight is independent of the initial level of root development of planting setts.

Over 2115 mm of rain was recorded during the 27-week growing season, ranging from 6 to over 150 mm during a given week, with no less than 33 mm during two consecutive weeks. Generally, surface applications of N, P, and K were rapidly dissolved and transported into the soil profile. Frequent applications of fertilizers were necessary to minimize leaching--especially of nitrogen under conditions favoring rapid nitrification--on the coarse-textured soil

## SUMMARY AND CONCLUSIONS

The best measure of planting sett size is weight. Sett size has a positive influence on corm weight and a negative influence on corm specific gravity. The level of regression does not warrant an accounting of individual planting sett sizes for subsequent covariance analysis for improved precision, but setts should be grouped by size when possible. Nitrogen increases corm weight, sucker formation, and plant mortality. Neither added nitrogen, phosphorus, potassium, nor calcium significantly affects corm specific gravity relative to levels of these elements in the unamended soil. Calcium appears to mitigate the effect of added nitrogen on plant mortality. Care should be taken when reporting taro yields in nitrogen fertilization studies since the treatment may affect plant stand. It is commonly accepted that larger setts survive better than smaller setts But mortality does not fall predominantly on the smallest setts. Instead, a distribution of setts with a mean weight less than the total mean sett weight is afflicted. Sett size at planting does not affect sett size at harvest, nor does the root status of the planting sett influence corm weight. The corm weight and specific gravity distributions, and the incidence of sucker formation of border row plants are indistinguishable from those of interior row plants receiving the same fertilizer treatment. For such studies, labor and material may be saved by eliminating the border row without compromising the results.

The disagreement between our results and those of earlier research on the effects of N, P, and K on corm specific gravity (Pena, 1967) echoes similar discord in potato tuber research. Clearly, minimizing variability is the major obstacle to explaining the effects of production practices on specific gravity for both crops. This may be exceedingly difficult for the potato, since a single plant may bear several tubers ranging widely in weight and specific gravity (Meredith, 1988). We believe taro, with its single mature corm, offers the better hope for reaching this goal

## ACKNOWLEDGEMENT

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Table 1. Soil analysis of the Oloava silt loam.

sand: 38%
silt: 58%
clay: 4%
pH: 6.0 [a]
Organic carbon: 4.5%
Kjeldahl nitrogen: 0.46%
Available phosphorus: 120 mg $kg^{-1}$ [b]
CEC: 55 $cmol_c kg^{-1}$ [c]
Ca: 15.4% [d]
Mg: 3.2% [d]
K: 21.0% [d]
Na: 0.3% [d]

[a] 1:1 soil:distilled water
[b] 1:100 soil:0.01 N $H_2SO_4$, pH 2, 30 min
[c] 1 N $NH_4OAc$, pH 7
[d] Percent of CEC

Table 2. Multiple comparisons of treatment means based on LSD (Student's t).

| Treatment | log(corm weight) | corm sp. gr. | log(suckers + 1) |
|---|---|---|---|
| No Fertilizer | 2.219 a | 0.9761 a | 0.19 a |
| P-K-Ca | 2.282 ab | 0.9785 a | 0.28 a |
| N-P-K-Ca | 2.415 abc | 0.9782 a | 0.64 b |
| N-P-Ca | 2.512 bc | 0.9753 a | 0.69 b |
| N-K-Ca | 2.565 c | 0.9820 a | 0.57 b |
| N-P-K | 2.628 c | 0.9884 a | 0.70 b |

Means not followed by a common letter differ at the 0.01 level of probability. Corm specific gravity means did not differ significantly at the 0.05 level of probability.

Table 3. Results of analysis of covariance t-tests on taro corm weights and corm specific gravities between border row and interior row plants receiving N-P-K-Ca.

| | Corm Weight | Corm Specific Gravity |
|---|---|---|
| Unadjusted mean | | |
| Border | 445 g | 0.986 |
| Interior | 322 g | 0.975 |
| Adjusted mean | | |
| Border | 450 g | 0.986 |
| Interior | 315 g | 0.976 |
| Unadjusted std. dev. | | |
| Border | 205 g | 0.026 |
| Interior | 195 g | 0.025 |
| Slope | 0.77 | $-8 \times 10^{-5}$ |
| Relative efficiency | 1.11 | 1.08 |
| df | 30 | 30 |
| t | $0.345^{ns}$ | $0.192^{ns}$ |

$^{ns}$ Not significant at the 0.05 level of probability.

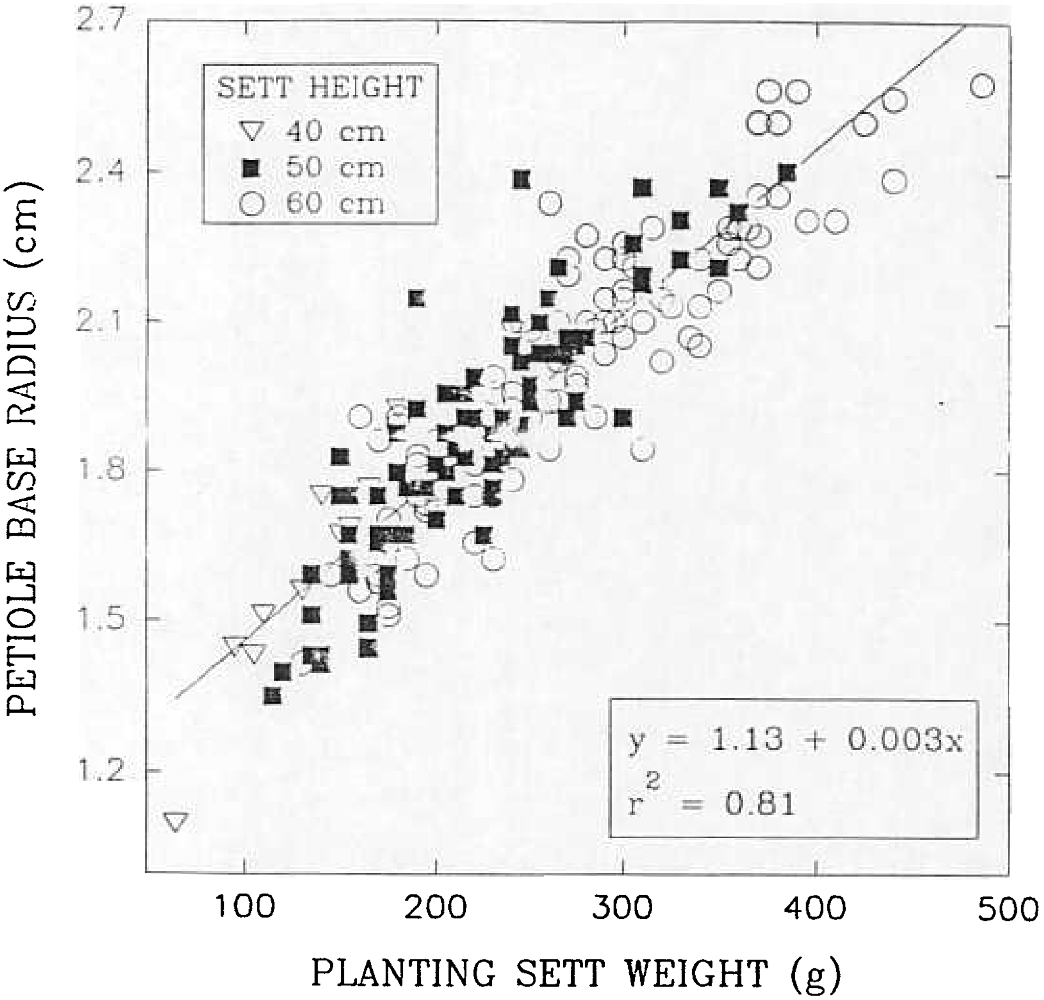
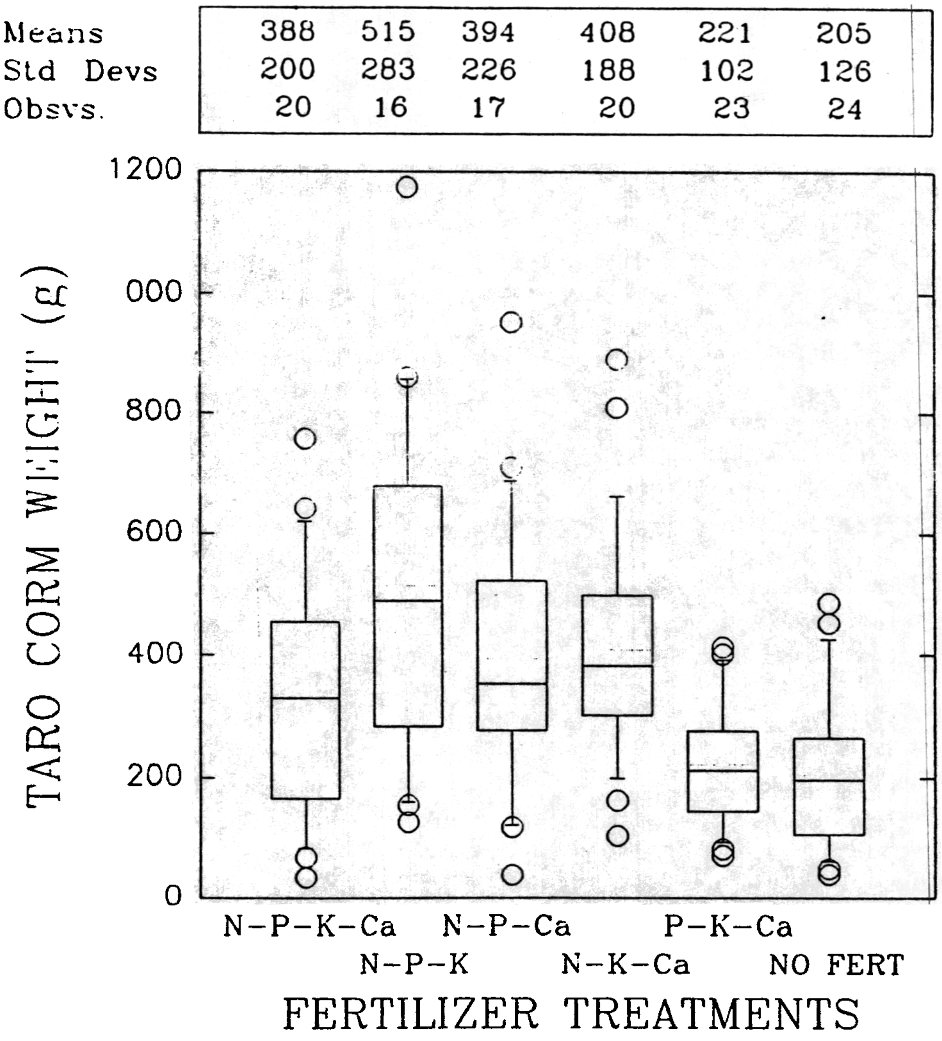


**Fig. 1** **Relationship between planting sett weight and petiole base radius.** The data comprise 12 setts 40 cm high, 85 setts 50 cm high, and 109 setts 60 cm high.



|  | N-P-K-Ca | N-P-K | N-P-Ca | N-K-Ca | P-K-Ca | NO FERT |
|---|---|---|---|---|---|---|
| Means | 388 | 515 | 394 | 408 | 221 | 205 |
| Std Devs | 200 | 283 | 226 | 188 | 102 | 126 |
| Obsvs. | 20 | 16 | 17 | 20 | 23 | 24 |

Fig. 2 Distributions of taro corm weight for six fertilizer treatments. Each outlined central box depicts the middle half of the data between the 25th and the 75th percentiles. The dark horizontal line across the box marks the median, and the light horizontal line marks the mean. The whiskers extending from the top and bottom of the box depict the extent of the main body of the data between the 10th and the 90th percentiles, while extreme values are plotted individually with a circle.

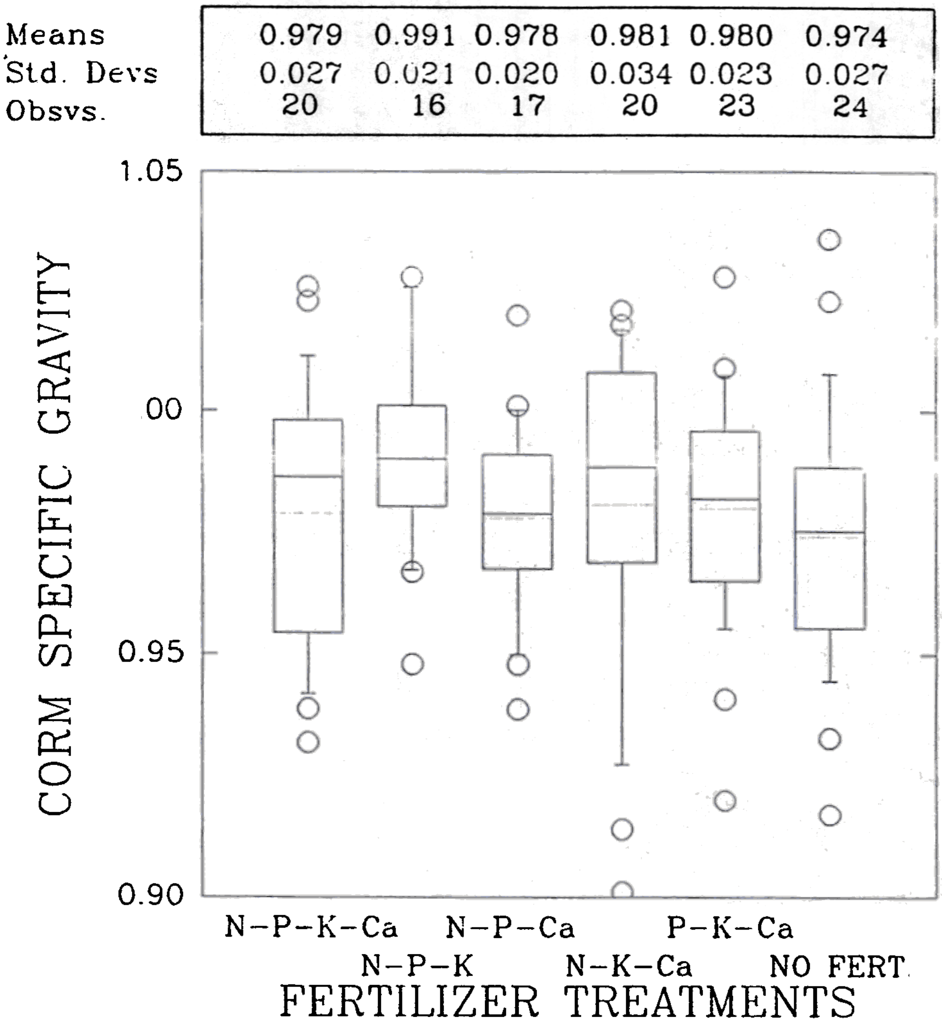


Fig. 3 **Distributions of taro corm specific gravity for six fertilizer treatments.** Each outlined central box depicts the middle half of the data between the 25th and the 75th percentiles. The dark horizontal line across the box marks the median, and the light horizontal line marks the mean. The whiskers extending from the top and bottom of the box depict the extent of the main body of the data between the 10th and the 90th percentiles, while extreme values are plotted individually with a circle.

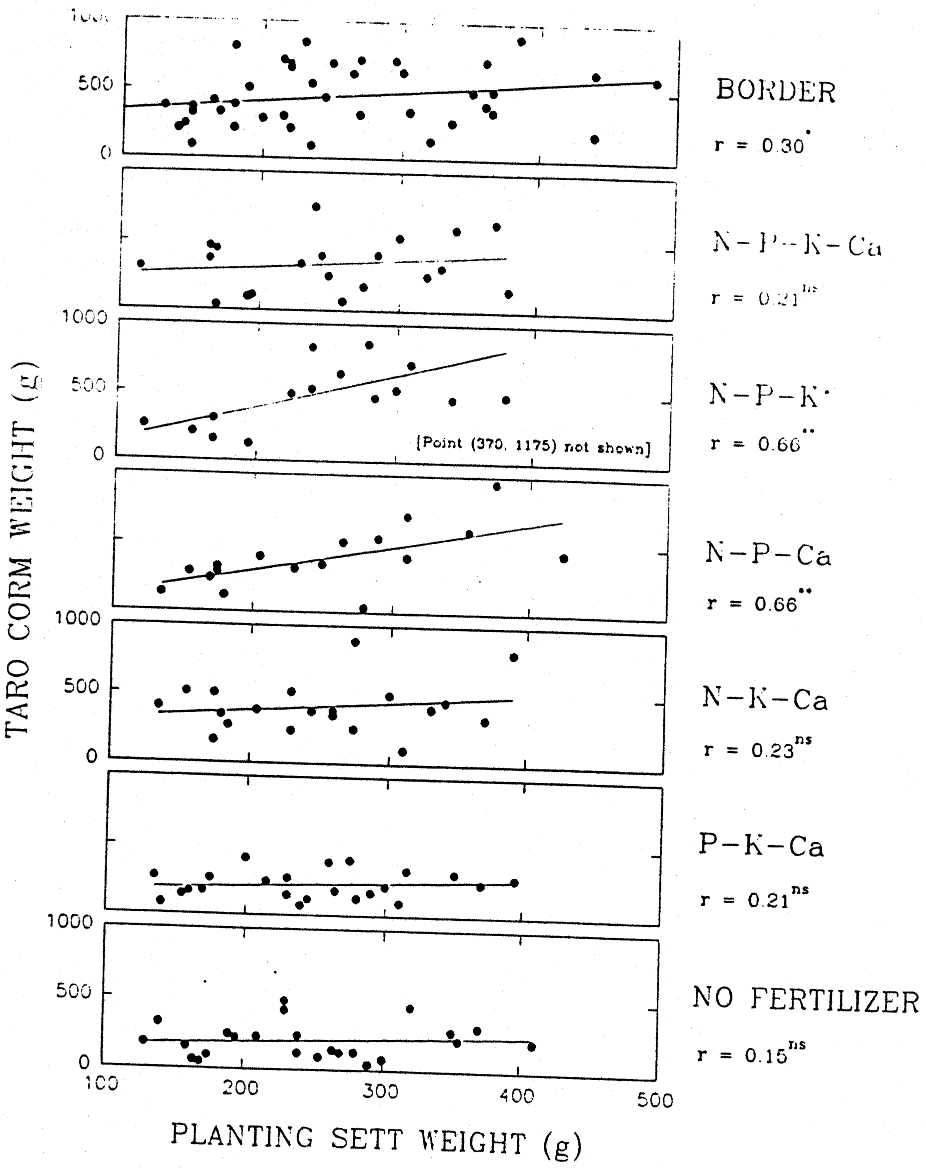


Fig. 4 **Relationships between taro corm weight and planting sett** weight for six fertilizer treatments and for border row plants. The superscript above each linear correlation coefficient indicates if the coefficient is significant at the 0.05 (*) or 0.01 (**) probability level, or is not significant (ns).

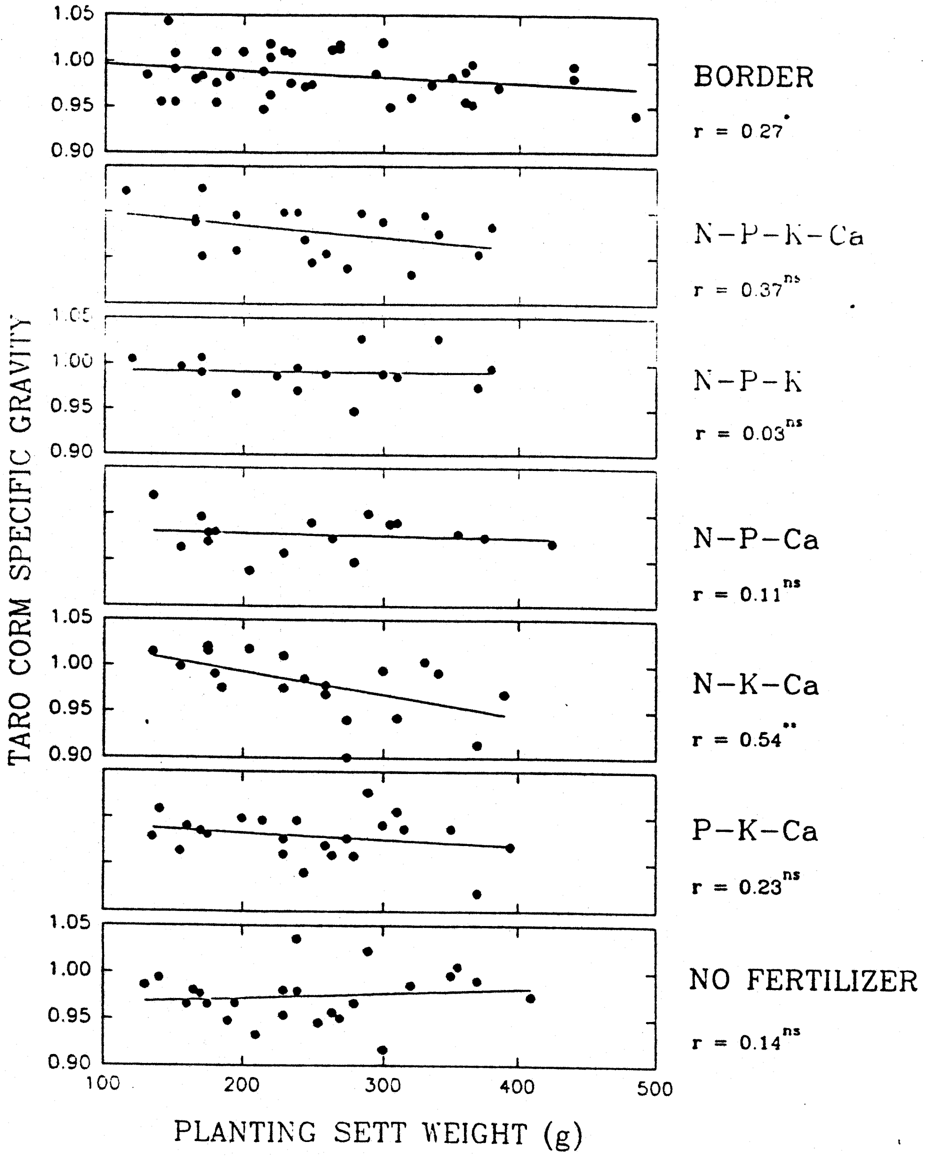


Fig. 5 Relationships between taro corm specific gravity and **planting sett weight for six fertilizer treatments and for border row plants.** The superscript above each linear correlation coefficient indicates if the coefficient is significant at the 0.05 (*) or 0.01 (**) probability level, or is not significant (ns).

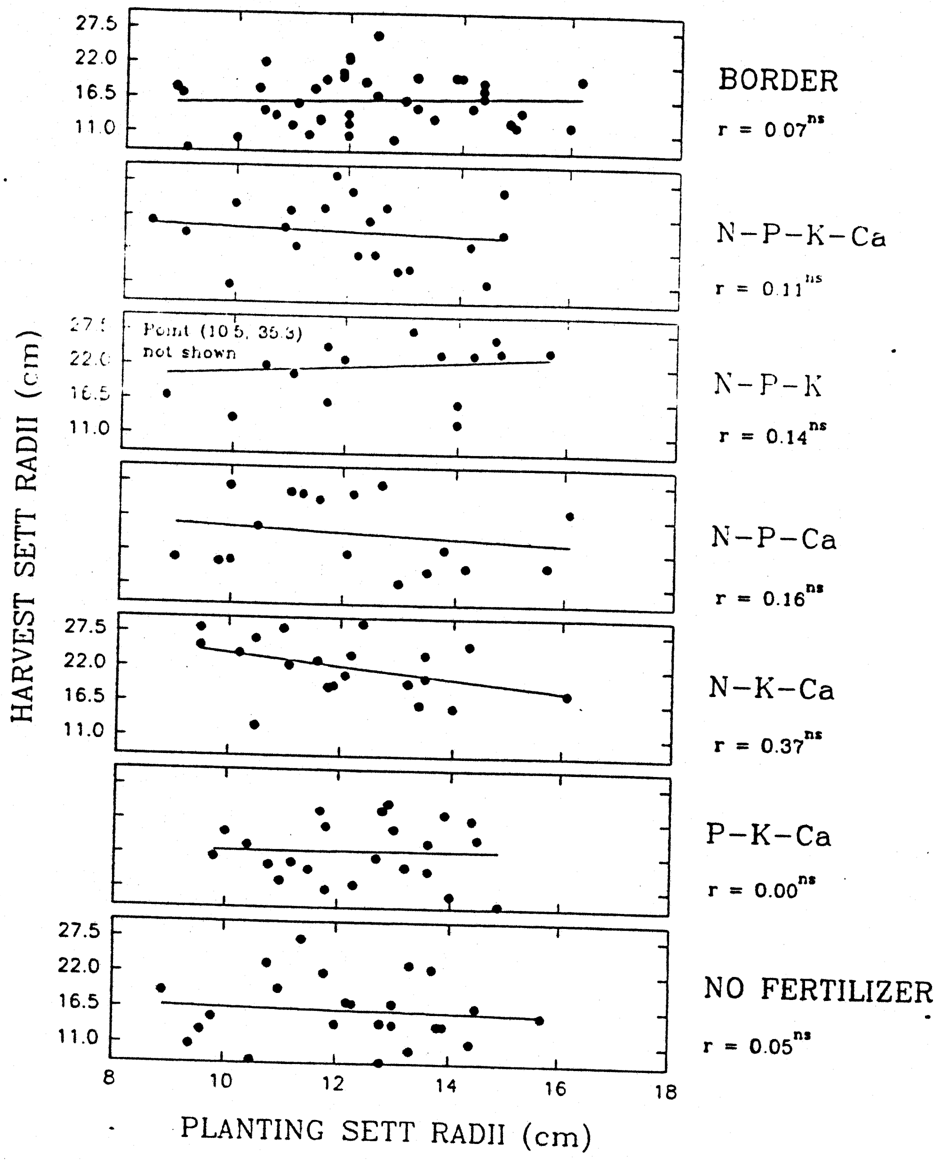


Fig. 6 Relationships between planting sett radii and harvest sett radii for six fertilizer treatments and for border row plants. The superscript above each linear correlation coefficient indicate that all are not significant (ns).

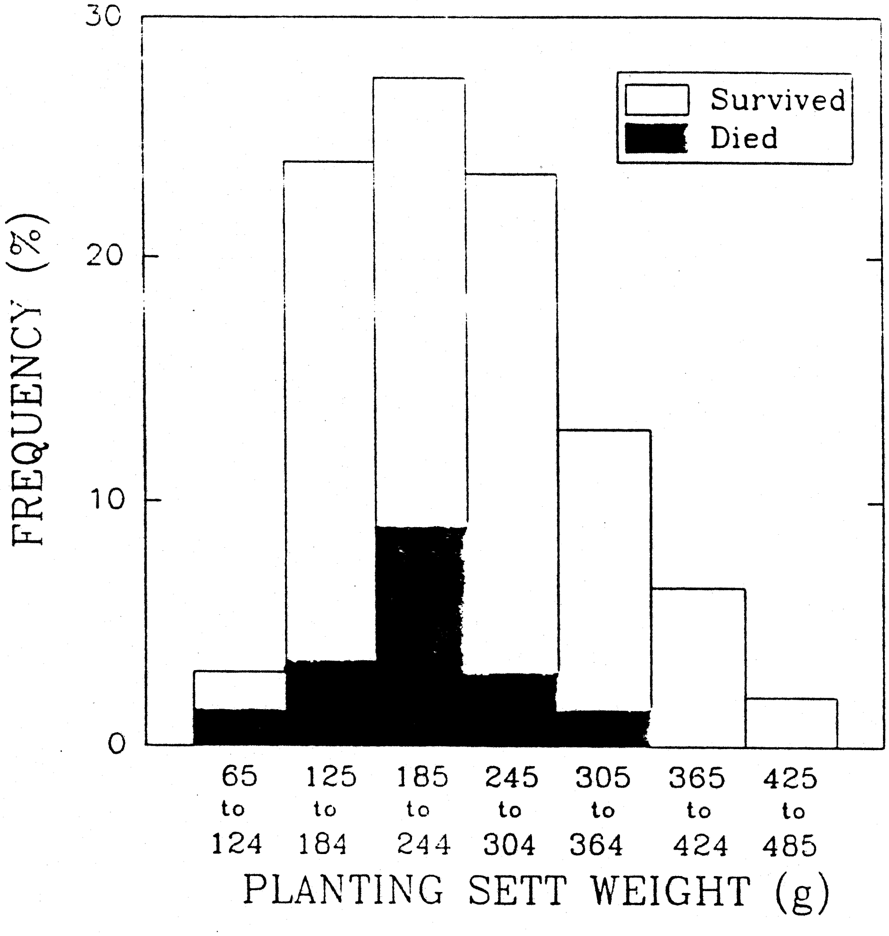


Fig. 7 **Frequency distribution of planting setts based on weight.** The dark histogram indicates the distribution of 37 of the original 200 setts that died, most within 2 months after planting.

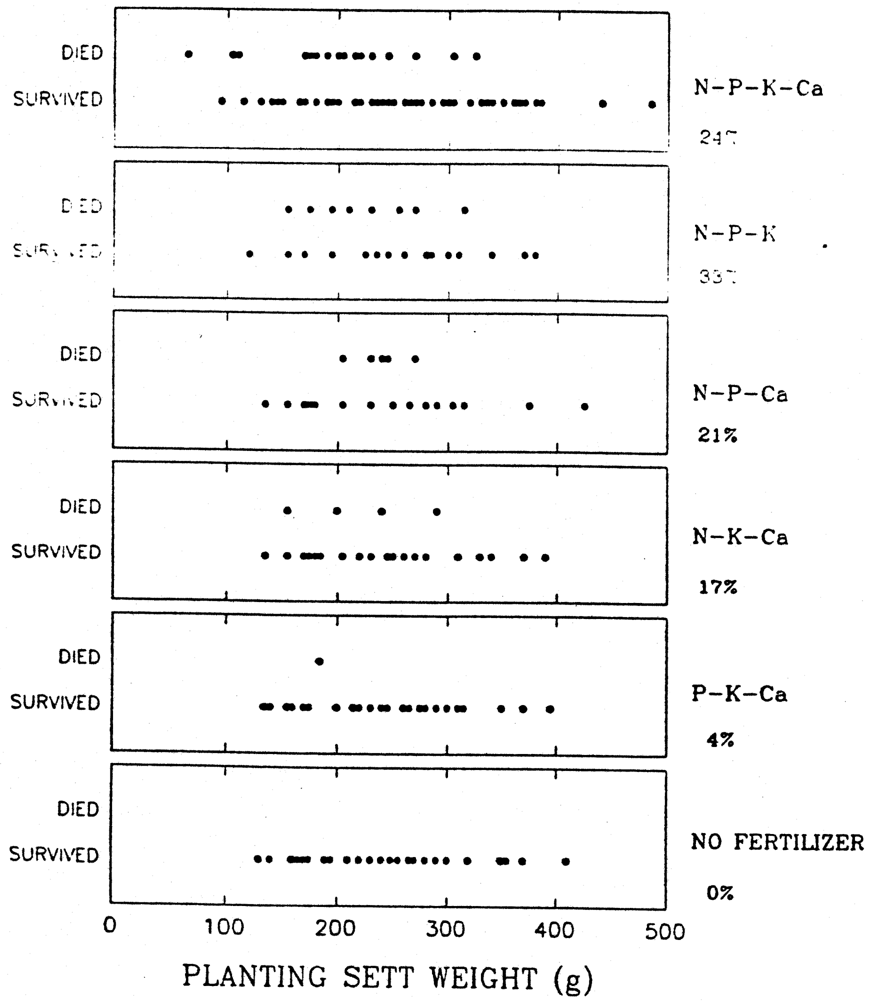


Fig. 8 Dot plot distributions of the fate of planting setts **based on sett weight and on fertilizer treatment.** Data from the border row plants and the interior row plants receiving the N-P-K-Ca treatment are combined. Percentages beneath fertilizer labels are mortality rates.

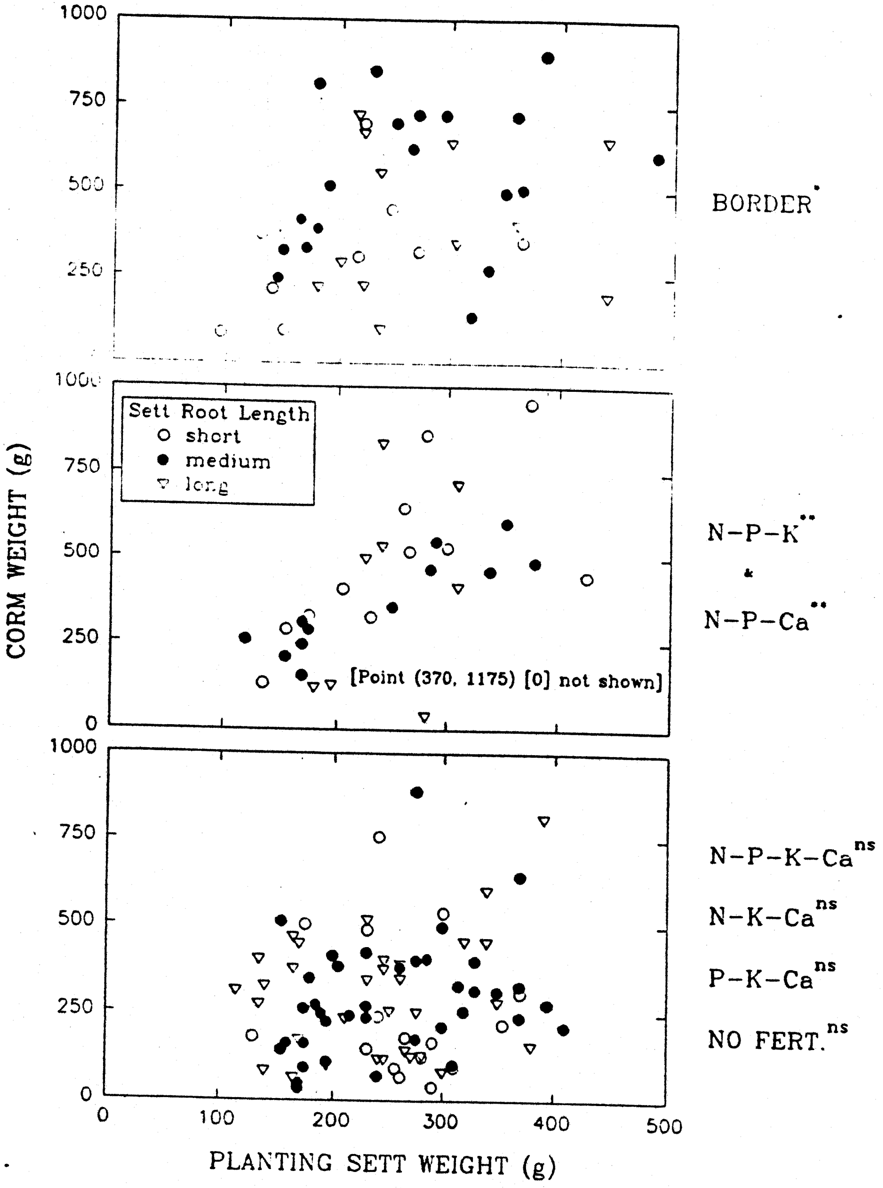


**Fig. 9** **Relationship between taro corm weight, planting sett weight, and planting sett root length.** Data from Fig. 4 were grouped according to the level of significance of their correlation coefficients.