tially shaded by deciduous oak trees. The rooted cuttings are pruned every few weeks during the growing season to insure a compact "twiggy" plant with reduced leaves 1.5 cm long, or less. New shoots, 7.5 to 15 cm long, are cut back so that one to three leaves remain.

After six months to a year in the can, the roots are pruned to encourage the development of a flat, bushy system, suitable for planting in a shallow container. The trees are then repotted in the same can, a bigger can, or a smaller can. Care is taken to plant the tree so that the top of the root system is at or slightly above soil level. This pruning and repotting procedure is continued from two to five years, resulting in a final product which varies from 5 to 40 cm in height.

The intensive pruning carried out on these trees results in a very dense, twiggy top growth which may cause some problems. Undirected overhead water tends to slide off to the side and may largely miss the pot. Hand watering with a hose overcomes this. If the cans are closely spaced, the lower limbs may not get enough light and die back. Obviously, spacing the cans and occasional rotation will fix this problem.

Catlin elm cuttings are taken any time during the year. However, those taken in the winter don't grow very much until the weather warms up. Other elms that have been grown as cuttings include the cork bark elm (*Ulmus alata*), *Ulmus davidiana*, and the tiny leaved Hokkaido elm. (3 mm long leaves)

EFFECT OF NITROGEN AND CLIMATIC FACTORS ON SEASONALITY OF BANANA PRODUCTION IN HAWAII[1]

R.M. WARNER AND R.L. FOX[2]

University of Hawaii
Honolulu, Hawaii 96822

Abstract. Planting material ("seed") of 'Williams hybrid' ('Giant Cavendish') was grown rapidly from frequent irrigation and nitrogen applications, using vigorous sword suckers, trimmed and heat-treated to control burrowing

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[2] Professor of Horticulture and Professor of Soils, respectively

nematode (*Radopholus similis*). Within 12 months each corm had produced 4 to 6 clean well-developed sword suckers.

Bananas grown with high levels of nitrogen produced more and heavier bunches. Production peaks were compared at low, medium and high nitrogen rates.

Growth rates were greatest from May through October when solar energy averaged 424 gram cal./cm^2/day and mean maximum-minimum temperatures were 28.5°C (83.4°F) and 22.8°C (73°F) respectively. Growth rates were lower from November through April when solar energy was 257 gram cal./cm^2/day and maximum-minimum temperatures were 26°C (79°F) and 18°C (66.9°F). Rainfall of about 1300 mm (42″) was supplemented by low-head sprinkler irrigation. Nitrogen, solar energy, and available water appeared to be the most critical factors under Hawaii conditions in banana production.

INTRODUCTION

This research was initiated with 'Williams hybrid' banana to determine critical levels for the principal nutrients under Hawaii conditions. Banana growers were shifting to 'Giant Cavendish' from 'Dwarf Cavendish' or 'Chinese' because it produced higher yields and the fruit had a longer shelf life. Banana uses large amounts of nitrogen and potash. Therefore, these elements were given primary attention in this study. Results from the first crop have been published (22). This report covers three years of harvest data.

In Australia, Summerville (16) found that the growth rate of banana from peepers on the corm to a fruiting plant ready to harvest was largely determined by the nutritional status of the plant during the first 3 months when the meristem was developing. The size of the meristem largely determined the size of the bunch produced. The corm expands into a mat over a period of 1 to 2 years, storing nutrients and carbohydrates. It is from this mat that suckers and shoots develop.

Bananas are propagated vegetatively from these young suckers. Sword suckers or large shoots make the best "seed" (5, 15). Figure 1 shows the 3 types of suckers. Peepers and water suckers have less stored food and smaller meristems and do not grow as fast as sword suckers. Propagating material was taken from virus-free mats and made free of burrowing nematodes (*Radopholus similus*) by trimming from the corms all discolored tissue and immersing the corms in hot water 50-55°C (122-130°F) for 15 to 20 minutes. Detail of the procedures have been published by Loos and Loos (12) and Trujillo (17). Figure 2 demonstrates the trimming procedure.

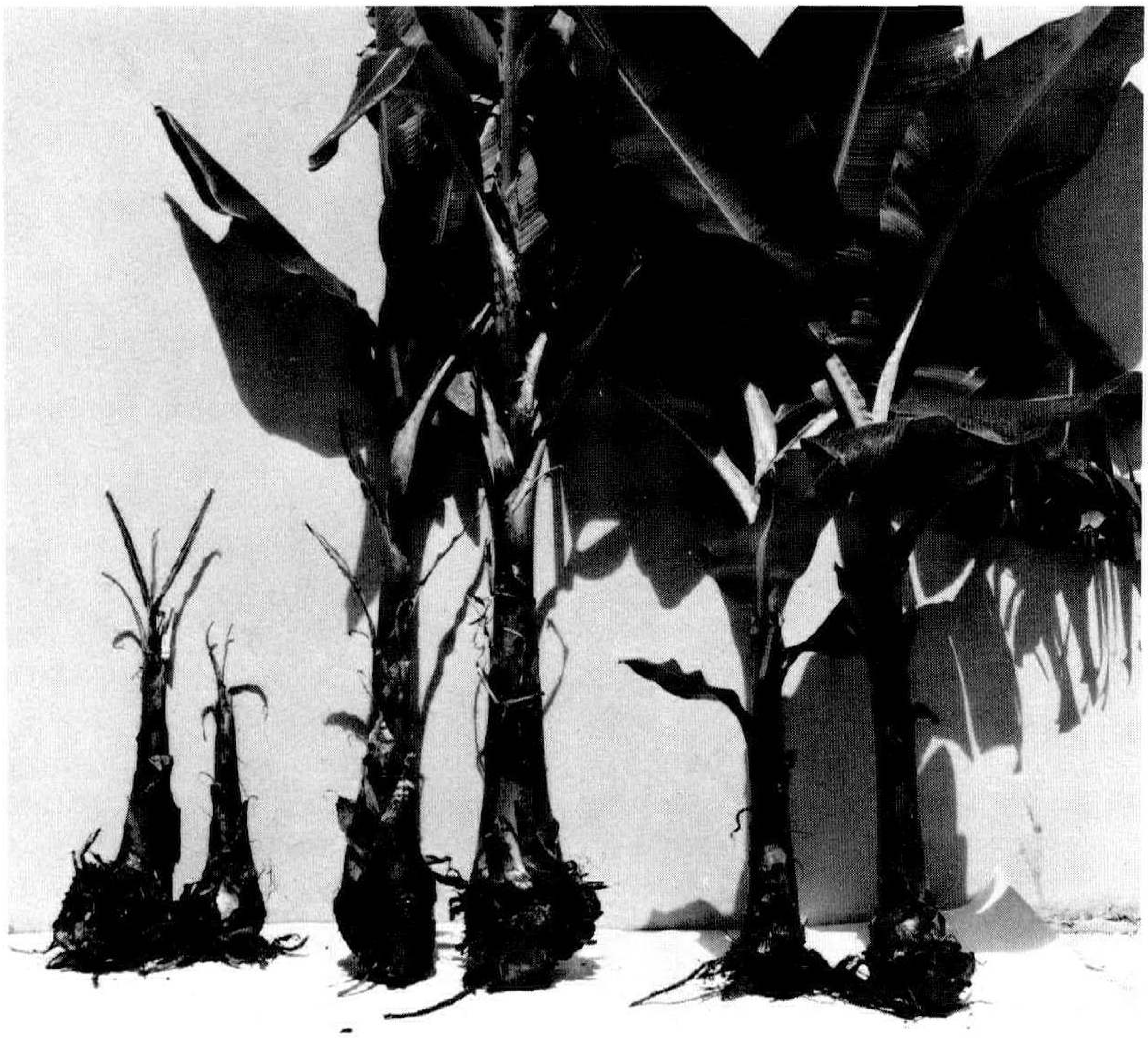

Figure 1. Banana propagating material, left to right: *Peepers*, suckers just starting to grow; *Sword Suckers*, with narrow leaves and enlarged corms; *Watersuckers*, broad leaves, slender pseudostems, and small corms. Sword suckers are the preferred planting material.

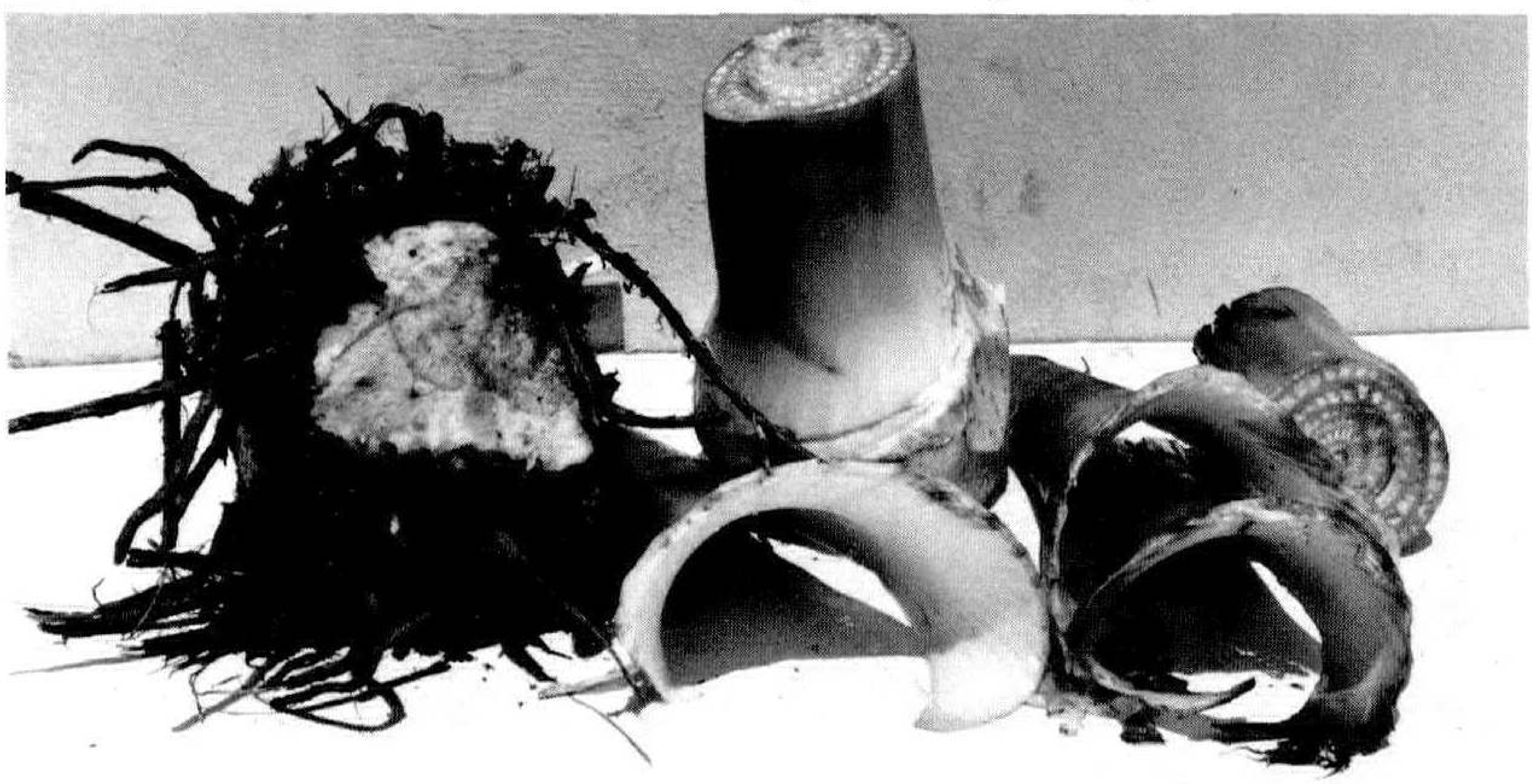

Figure 2. Banana corm (left) showing black lesions caused by the burrowing nematode. Corm (right) ready for hot water treatment for nematode control; all discolored tissue removed. Pseudostem cut back to 6"; 3 outer leaf sheaths removed.

REVIEW OF LITERATURE

Large amounts of nitrogen (N) and potassium (K) are used by the banana and lesser amounts of phosphorus (P), calcium (Ca) and magnesium (Mg) (16). During development of the fruit considerable K is taken up by the plant (16). Twyford (20) found a Cavendish plant crop produced, in 9 to 12 months, 100 to 150 tons per acre fresh weight of organic matter, including 8-14 tons of bananas. Nutrients taken up in a year, in pounds per acre, were: N, 400; P, 48; K, 112; Ca, 300; and Mg, 156. Croucher and Mitchell (6) working with 'Gros Michel' for 8 years, found responses to three major nutrients: N, P and K. Warner, *et al* (22) found that N fertilizer increased number of hands/bunch, finger length and weight and greatly reduced the days from planting to shooting. Butler (4) found yield responses only to nitrogen with 'Gros Michel' on exceptionally rich alluvia. In Jamaica, with other experiments, Butler found no advantage to organic manures. He found adverse effects from applying too much potash and saw no response from phosphate, even in low phosphate soils.

Twyford and Walmsley (21) found that fertilizer required by 'Robusta' bananas to be 2.5 kg/mat. of a 9:9:35 mixture. They recommended that applications be frequent and large the first year to rapidly attain high yields (50T/ha).

The number of leaves is important for filling the bunch. To produce a 50 lb. bunch 35 to 40 leaves are needed during the life of the shoot (2). Yields are depressed and delayed by loss of leaves from wind or leaf spot disease (*Mycosphaerella musicola*). In Hawaii, Black leaf streak disease (*Mycosphaerella fijiensis*) can be just as destructive (13).

Leaf analysis has been a useful tool in plant nutrition. Workers investigating 'Dwarf Cavendish', 'Poyo' and 'Lacatan' (Jamaica) have sampled the third fully expanded leaf at shooting (9, 10, 14). Others report work with the 'Giant Cavendish' banana (3, 18, 19). From these reports, critical concentrations of some nutrient elements can be tentatively set as percentage of dried leaf samples, as follows: N, 2.6%; P, 0.20%; K, 3.2%; Ca, 0.55%; and Mg, 0.40%.

Climatic factors have an influence on growth and production of bananas. Temperature affects rate of growth. Daudin (7) from Martinique showed the effect of altitude on time from planting to shooting; sea level up to 450′, 6-7 months; 600 to 1200′, 9-10 months; temperature 2°F lower; 1300 to 2,100′, 11-13 months, temperature drop 5°F. In winter, fewer leaves are produced and the rate of flower emergence is much slower.

Bananas need a continuous supply of water for good production. Two inches per week is considered essential. Berril (2) reported periods of drought or low temperatures reduced growth rate and flowering. Best yields were obtained with soil at 75% of moisture holding capacity (1).

MATERIALS AND METHODS

Our experimental planting was made in July, 1971. The first crop was harvested in May and June, 1972. Before planting, the corms were pared and heat-treated to control the burrowing nematode (*Radopholus similis*) and planted in a clean nursery. Figure 2 shows a nematode-infected corm and one trimmed and ready for heat treatment. A year later when good sword suckers had developed, they were dug and planted in a continuous function experimental design (8).

Forty-eight corms were planted in blocks of 6 × 8 plants. Nitrogen applications were made in 6 increments in one direction and potassium in 8 increments at 90° to the N. Thus every plant was an experimental plot and received a different combination of N and K. There were 8 blocks; 4 received P and 4 did not.

The relative amounts of fertilizer added for the various treatments were always in a fixed ratio. For N, the relative amounts were 0, 0.1, 0.3, 0.5, 0.7 and 0.9 (Table 1). Relative amounts of K were 0, 0.1, 0.3, 0.5, 0.7, 0.9, 1.1 and 1.3. The plant in each block with treatments N4K5 was used as a control. Monthly leaf samples were taken from the 3rd youngest fully expanded leaf of the dominant sucker of this mat. A 10 cm strip was taken from each side of the leaf at its center. The samples were dried, ground and analyzed for N and K. When the leaf content of N or K dropped near the critical level, more N and/or K was applied. The critical levels were 2.6% for N 3.2% for K.

Table 1. *Banana leaf nitrogen percentage. Average of 30 monthly means from 6 N treatments, and yields in metric tons/hectare.*

N Treatments	Low		Medium		High	
	N_1	N_2	N_3	N_4	N_5	N_6
Relative N rates	0	1	3	5	7	9
Urea, g/mat	0	40	120	200	280	360
Leaf N% z/	2.15	2.18	2.31	2.45	2.55	2.69
MT/ha/Mo y/	4.2	4.6	6.1	6.5	7.3	7.5
MT/ha/yr y/	50.1	55.2	73.2	78.5	87.4	90.3

z/ All treatments total 3,069 shoots, 30 months.
y/ All treatments total 4,111 bunches, 36 months.

Leaf samples were also taken from each plant at shooting. When the bunch was mature, 3 to 5 months later, it was harvested and weighed (22). Measurements of new shoots and the harvest data of mature bunches were recorded weekly.

Solar energy, rainfall and temperatures at Waimanalo fall into six month periods; summer, May to October; and winter, November through April. Solar energy averaged 257 gram calories/cm²/day in winter and 424 in summer. For the same periods 5 year mean rainfall was 215 mm (0.15") and 734 mm (29.1"). The maximum and minimum six month temperature means for 5 years are listed in Table 2. The differences are not great but for bananas, a few degrees is important especially around 20°C (68°F) as was shown above by Daudin (7).

Table 2. Waimanalo, Hawaii; summer-winter temperatures in degrees Celsius.

Year	May-Oct.		Nov.-Apr.	
	Max	Min.	Max	Min.
71-72	28.5	21.9	25.7	19.2
72-73	29.0	22.0	26.1	19.0
73-74	28.2	21.0	26.9	19.9
74-75	29.6	22.0	25.7	19.8
75-76	28.1	21.7	25.7	19.8
Avg.	28.7	21.7	26.0	19.6

Rainfall in Hawaii often is limited to tradewind showers. The clouds reduce solar energy without producing effective precipitation. Most effective rainfall comes from 2 or 3 tropical storms per year which come from the south. The irrigation used to supplement rainfall is usually adequate but is not always available. The summer months of 1974 were very dry and sufficient supplemental water was not available. Less than 95 mm (3.8") of rainfall was received in July, August and September that year. This was reflected in the banana yields shown in Figure 3 and reduced the uptake of nitrogen in the leaves (Figure 4). Growth was reduced and fewer new leaves were produced.

RESULTS AND DISCUSSION

The nitrogen treatment data is summarized in Table 1. The relative rates and actual rates per application in grams of urea are presented. The mean N content of all leaf samples for each treatment shows gradual increase from $N_1$to N_6 but the control plants often fell below the 2.6% N critical level. This indicated our nitrogen applications were not frequent enough. Likewise the yields were less than anticipated. Treatment N6 was to be an excessive rate, which it was during the first year of production. Technical problems with obtaining foliar analyses promptly delayed the treatment applications.

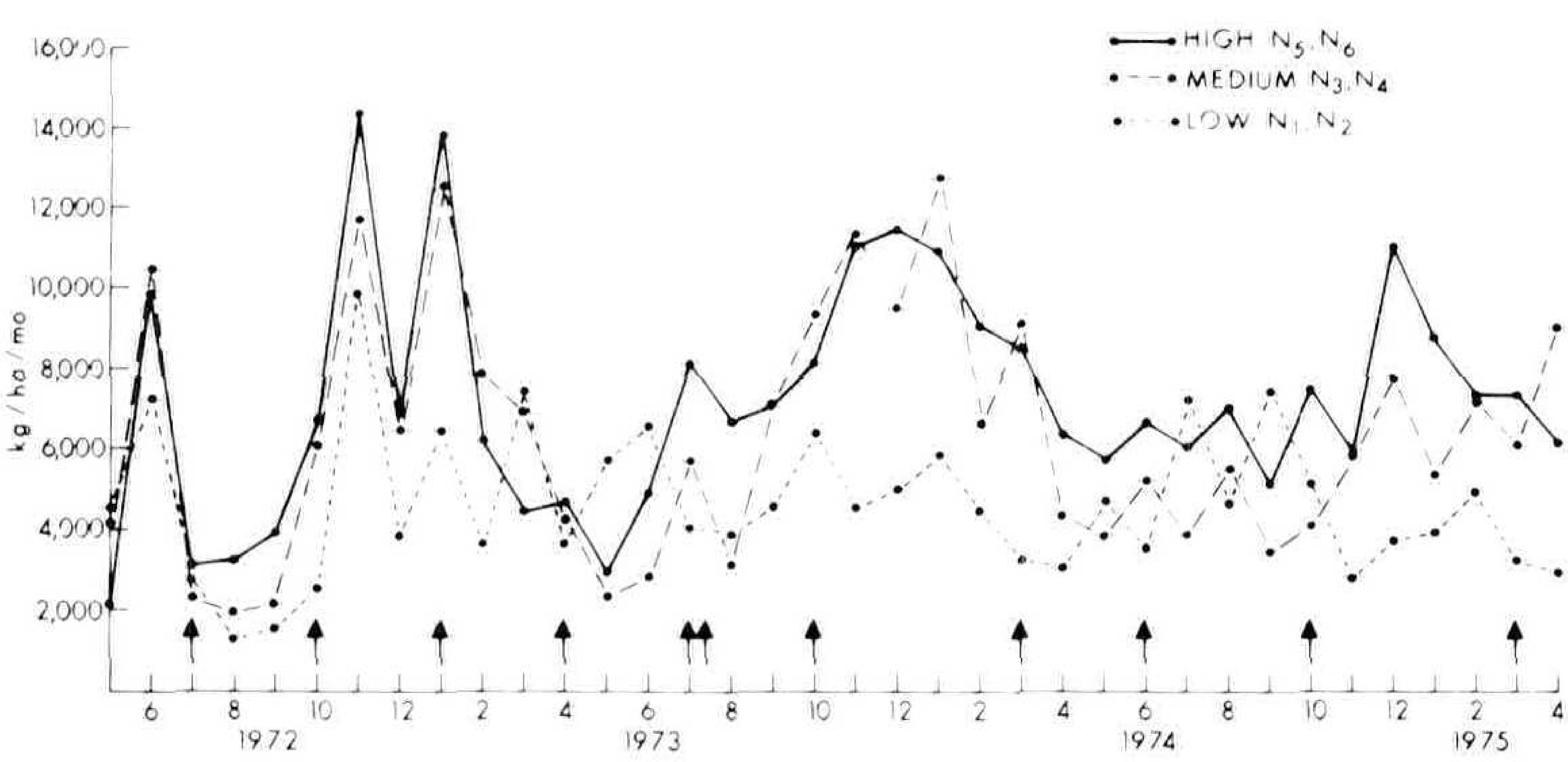

Figure 3. Yields of bananas during 3 years as influenced by levels of nitrogen fertilization. Each level of fertilization is the mean of 2 nitrogen rates. Arrows indicate time of nitrogen applications. Earlier nitrogen applications were made in August and December, 1971, and April, 1972.

The harvest data of each treatment were totaled monthly. Nitrogen treatments, N_1 and N_2 were combined as *low* treatment, N_3 and N_4 as *medium*, and N_5 and N_6 as *high*. The results are shown for 36 months in Figure 3. The arrows at the bottom indicate the time of nitrogen fertilizer applications. The production peaks of all three N treatments for the first 18 months were similar with high N treatment showing highest production and low N the lowest. The peak of June 1972 was not unexpected since the corms were all planted 11 months before. The double peaks in November, 1972 and January, 1973 were artificial because of uneaven harvests. They should be one peak because November and January each had 5 harvest dates and December only 3. After November, 1972 the low-N treatment plants had exhausted residual fertility in the soil and production peaks were smaller and irregular. The summer of 1974 was very dry and irrigation water was inadequate, as mentioned above. The soil was so dry that the plants were not able to take up nitrogen effectively. This was evident from Figure 4 where the leaf N content in August and September dropped sharply at all 3 N levels.

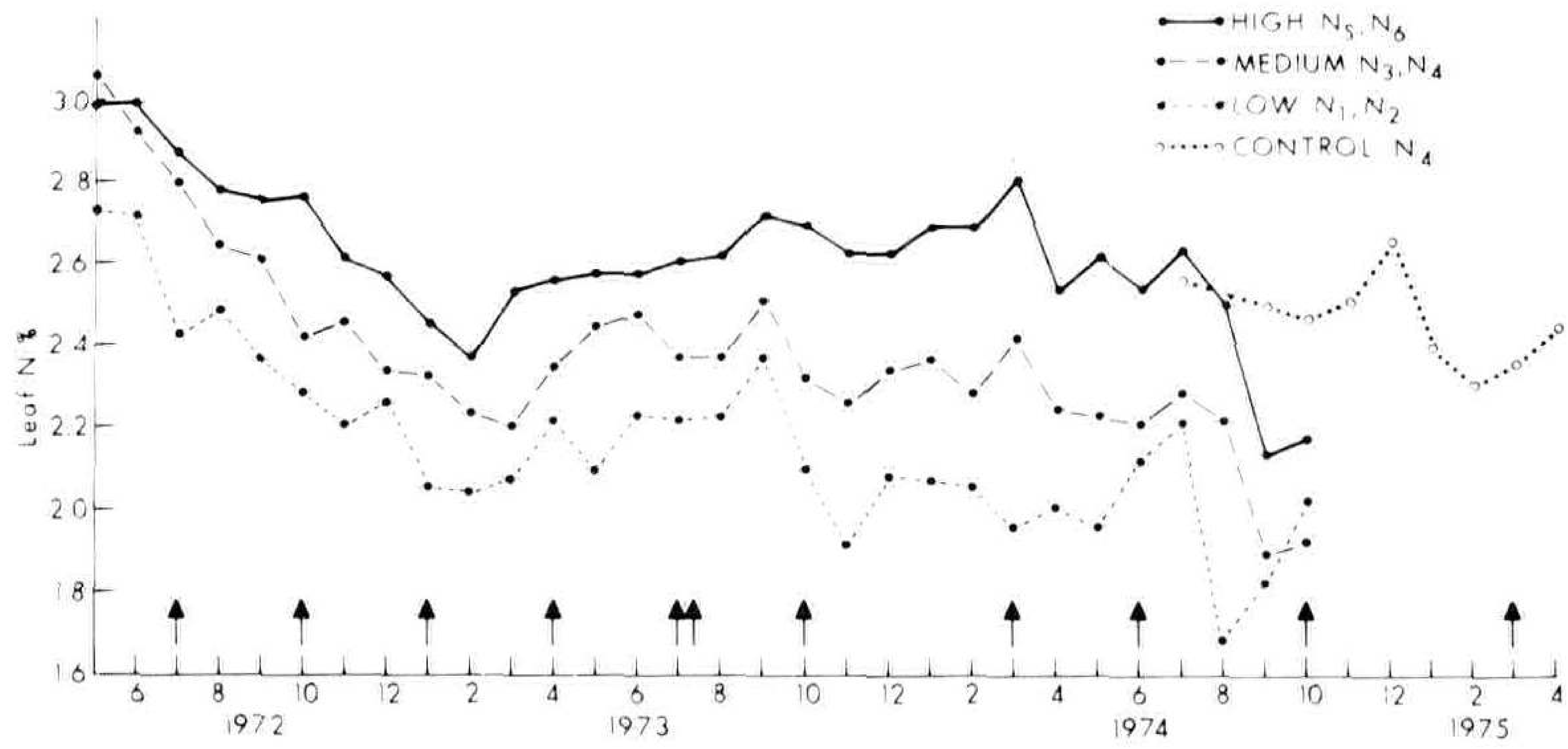

Figure 4. Banana leaf nitrogen percentages during 2 1/2 years as influenced by level of nitrogen fertilization. Each level of leaf nitrogen is a mean leaf N content of two application rates. Leaf samples taken at shooting are plotted as of the harvest date of the bunch some 3-6 months later. Leaf sampling was discontinued June 30, 1974, except for 8 monthly control samples of the N_4K_5 which are plotted on the dates the leaf samples were taken. Arrows indicate time of fertilizer applications.

The higher N treatments increased the number of bunches produced, the weight per bunch, and the total weight of fruit. Table 3 shows this clearly. The high number of bunches in N Rate 1 reflects border effects. Guard rows have since been planted to reduce it. The kg/bunch increased from 15.6 in N Rate 1 to 33.5 kg in N Rate 5 and decreased in N Rate 6.

Table 3. Effect of nitrogen rate on bunch weight.

N Rate	No. bunches	Kg total	Kg/ bunch
1	707	11,002	15.6
2	594	12,377	20.8
3	687	19,601	28.5
4	668	21,813	32.7
5	700	23,444	33.5
6	767	24,179	31.5

The number of healthy leaves a banana plant has affects the vigor of the plant and the size of the bunch. After the dry summer in 1974, plants had lower vigor and fewer leaves. October and November had moderate rains which favored buildup of banana leaf streak disease. December was very dry but January had 275 mm (11") of rain. No fungicide control measures were taken and the disease became severe. Leaf counts at harvest in early 1975 are compared with those of January to April, 1974 in Table 4. In 1975 the leaf numbers continued to decline to about 2.7/plant compared to over 9 leaves in 1974. The leaf count was lowest in the low N treatments. The 1975 yields were considerably lower in January and February, than in 1974. However, the cause and effect needs more study.

Table 4. Healthy banana leaves/pseudostem at harvest vs N rate. (1975).

N rate		Jan.	Feb.	Mar.	Apr.
1974	Low	9.1	9.2	9.2	8.3
	Med.	9.4	9.8	9.7	9.3
	High	10.4	10.1	10.1	9.3
1975	Low	6.0	3.9	3.1	2.6
	Med.	6.4	4.7	4.1	2.8
	High	7.6	5.3	5.1	2.9

It has been demonstrated that rates of nitrogen fertilization are of primary importance in banana production in Hawaii but may be limited by inadequate moisture, low temperature and insufficient solar radiation. A biotic factor, such as the fungus disease, Black leaf streak, may also limit the effects of N fertilization.

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