THE EFFECT OF DIFFERENT LEVELS AND INTERVALS OF APPLICATION OF AMMONIUM SULPHATE ON THE GROWTH, CHEMICAL COMPOSITION AND YIELD OF CAYENNE AND QUEEN PINEAPPLE PLANTS UNDER FIELD CONDITIONS

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1. INTRODUCTION

The fertilisation of pineapples in the Eastern Cape Province is still a relatively new practice which started approximately twelve years ago. Even after this time many growers still insist that pineapples can be grown without fertilisation on virgin soils. As the available virgin soil decreased, however, so the interest in fertiliser application increased. Very little basic research on the fertiliser requirements of pineapples in the Eastern Cape was done to serve as a guide to growers. The available advisory literature by le Roux (1951), Malan (1954) and Lewcock (1956) were based on overseas experience.

When pineapple research was started on a large scale, in 1955, it was realised that emphasis should be placed on the nutritional requirements on virgin as well as replanted soils. From initial experiments it was clear that the main response in plant growth and yield was obtained from nitrogenous fertilisers. In this initial research programme it was decided, therefore, that it was important to establish what role nitrogen played in the nutrition of pineapples. Notwithstanding the results, however, the exact fertiliser quantities had not been clearly defined. One of the main reasons may have been the contrasting climatic conditions in the pineapple producing areas of the Eastern Cape.

It was realised, at the outset of this research programme, that it was of primary importance to establish what method could be used, with reasonable accuracy, in assessing the nitrogen requirements of the plants.

Nitrogen deficiency was described by Nightingale (1942a), Cannon (1954), Kanapathy (1959), Cibes and Samuels (1961) and Teiwes and Gruneberg (1963), as a chlorosis of the entire leaf surface. These symptoms were found throughout the Eastern Cape. The extent of this nitrogen deficiency varied considerable in different localities which made uniform recommendations practically impossible. Individual plantings, therefore, had to be inspected by experienced persons to assess the necessity of fertiliser application. Although reasonable accurate diagnosis was possible, the lack of uniformity in plant material and consequent plant growth as well as variable climatic conditions complicated the recommendations. The standard quantity of ammonium sulphate was $11\frac{1}{2}$ gm per plant per application which was

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mainly based on the overseas practice. This application is equivalent to 12.5 tons ammonium sulphate per one million plants per application at a cost of approximately R450.00 excluding labour and transport costs. These figures serve to indicate what the grower lost if he gave one unnecessary application and emphasises the importance of an accurate method of establishing the nitrogen requirements of the plants.

The indicated method was through leaf analyses. Leaf-colour in combination with leaf-N was established as a reliable method by Nightingale (1942a). The possibility existed, therefore, that leaf-N or the easier method of leaf-chlorophyll could be used to establish a reliable index under our own conditions.

In order to establish the effect of the increasing 3 levels of nitrogen on the leaf-N and the yield it was necessary to vary the frequency of these applications. At the same time it was hoped this ~~will~~ would indicate the influence of smaller and larger quantities of ammonium sulphate, at different times of the year, on the plant and yield.

The practice in the past was to apply a standard four or five applications from planting to plant crop mainly to spread them evenly through the seasons.

Fertiliser mixtures such as 10:6:10 and 15:0:15 (N:P:K:) are used by certain growers mainly based on the advise from overseas practices. There was, however, no information available in literature on the effect of the mixtures under South African conditions. This information is very essential in view of the fact that we are still planting on virgin and relatively newly cultivated soils, whereas, in most other countries pineapples had been grown on the same soils for 30 to 70 years. At the outset of this research programme, however, it was decided that it is of primary importance to establish what effect nitrogen, at increasing levels, will have on the major elements in the plants. Any addition of other fertilisers may complicate the work as we have no information under natural conditions.

2. REVIEW OF LITERATURE ON NITROGEN NUTRITION.

No literature is available on the fertilisation of the Queen pineapple. The following discussion will, therefore, only be applicable to the Cayenne cultivar.

Ammonium sulphate is used as the main source of nitrogen fertilisation. Sideris, Krauss and Young (1939), and Pennoch (1949)

/ proved .... 3.

proved that ammonium nitrogen was more acceptable in pineapple nutrition than nitrate nitrogen. These findings were later confirmed by Py, Haendler, Huet and Silvy (1956). Py (1962) also showed that urea did not give the same favourable growing conditions and weight of fruit compared with ammonium sulphate.

The beneficial effect of nitrogen fertilisation on the pineapple yield is wellknown and proved by research workers such as Su (1961); Teiwes et al (1963), Cook (1949), Py, et al (1956). The fertiliser programmes with nitrogenous fertilisers recommended by authors such as Py et al (1956), Mitchell and Cannon (1953), Su (1961), Malan (1954), le Roux (1951) and Lewcock (1956) have very little in common. The main conclusion by most research workers wat that each individual case must be treated on its own merit. Su, Kang, Yow and Chow (1957) worked out exact quantities of fertiliser on a profit and loss basis with yield increases and also by the growth response of the plants. The most profitable rate, by calculation of net profit from harvest, was 16 gm N, 0 gm P_2O_5 and 16 gm K_2O. The rates established through growth measurements were 14.4 gm N, 0 gm P_2O_5 and 20.8 gm K_2O. In Puerto Rico Samuels, Landrau and Olivencia (1955) concluded that 168 lb of N per acre gave the highest yields per acre. Samuels, Alers-Alers and Jackson (1958) showed, however, that 480 lb of nitrogen per acre gave the highest yields.

Nightingale (1942a) and Sanford (1962) established the crop log system which included the method of assessing nitrogen requirements of pineapple plants with the aid of leaf-colour standards. Four leaf-colour standards, which cover a range from yellow to black-green, were used to establish the relation between carbohydrate and protein-nitrogen in the plants. These observations were correlated with the yield, that is, for a maximum yield an adequate reserve of nitrate was essential and sufficient carbohydrates must be availablefor oxidation as nitrate is reduced. In the early stages of growth nitrate may be allowed to become temporarily deficient in relation to carbohydrate, provided that nitrate is again applied in sufficient time before flower differentiation so that inorganic nitrogen is available for protein synthesis. On the other hand, however, if the nitrate is too high in relation to the carbohydrate at this time, the yield may also be adversely affected. These results indicate, therefore, that the timely application of nitrogen is most important particularly to have a

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correct balance at flower differentiation.

When this information is applied to the Eastern Cape it must be kept in mind that ~~these~~ pineapples here are grown at a lower latitude compared to any other country in the world. The winters are longer and cooler which prolongs the dormant season immediately preceding flower differentiation. According to Nightingale (1942a) some evidence was found to indicate that soil temperatures of 68°F or lower result in limitation of absorption of nitrate by the roots. The average soil temperature at 20 cm depth, 8 a.m., for the months of April to November ~~were~~ was lower than the specified 68°F (Annexure A). Therefore, it is normally experienced that although the leaf-colour may appear adequate before the winter, according to Nightingale (1942a) leaf standards, ~~they~~ it will be inadequate after the winter when flower differentiation takes place. For this reason leaf-colour may not be a reliable index under our conditions and it is felt that a more accurate standard should be found.

According to Magistad (1934) and Teiwes <u>et al</u> (1963), soil analysis can assist to provide information on soil reaction and relative levels of the major nutrients in the so l. (Sanford (1962) stated that these soil indices do not necessary reflect accurately how much of these nutrients are absorbed by the plants. Furthermore, soil analysis for nitrogen had not been successful as a guide to nitrogen fertilisation, and therefore, plant indices are a very important part in his crop log. In support of using leaf-colour standards he goes on to say that as a whole, correlation between any nitrogen fraction in the plant and response from nitrogen fertilizer applications had been poor. Samuels <u>et al</u> (1955) came to the conclusion that leaf-N values 8 months after planting of below 1.66 per cent would be indicative of a nitrogen deficiency and of the probability that the application of nitrogenous fertilisers will produce increased yields. Samuels <u>et al</u> (1958) concluded that leaf-nitrogen values showed a significant correlation with relative yield of pineapples. None of these workers have, however, set up any index of correlation between leaf-N and yield for the complete growth period.

A further possible method of determining the nitrogen requirements of the plants is by means of the chlorophyll content of the leaves. Tam and Magistad (1935) have shown that with few

/ exceptions .... 5.

exceptions, an increase in the amount of nitrogen applied resulted in a corresponding increase in the total chlorophyll concentration. They considered this as an indication that, in pineapple leaves, the amount of available nitrogen present determines to a large degree the amount of chlorophyll formed. Sideris and Young (1947) found that the chlorophyll concentrations in leaf tissues were considerably greater for the high-N than low-N cultures. It appears, however, that factors such as iron deficiency and inadequate light (Sideris, 1947) may affect the chlorophyll content of the leaves. Sideris and Young (1944) established that chlorophyll and carotenoid pigments were higher in the leaves of plus-iron than minus-iron cultures. Sideris and Young (1946a) found that iron deficiency could also reduce the total nitrogen in the leaves. Sideris and Young (1956) confirmed that chlorophyll, carotenoids and protein increased simultaneously in the green leaves of plants with iron sufficiency, but decreased in the chlorotic leaves with iron deficiency. It appears, therefore, that although iron deficiency may affect the chlorophyll content there is still a possibility of using it as an index to nitrogen requirements.

Sanford (1962) stressed the importance of D-leaf weight and plant weight in the assessment of the nitrogen requirements of pineapple plants. The effect of increasing nitrogen levels on the plant growth was also studied by Su et al (1957). They found no growth response to nitrogen applications at 8 and 12 months after planting or at flower differentiation except for an increase in the number of leaves at 12 months. Cibes and Samuels (1961) have found that ~~the~~ a ~~absence~~ lack of nitrogen had the greatest influence in retarding plant growth at 11 months. Py et al (1956) showed that nitrogen promotes the general development of the leaves and hence the weight of the plant. It also produced an increase, significant at 0.01, in the height of the plant. Slip and sucker production are important considerations because an optimum of each is required. Slips are considered to be the best plants for planting but it is expected that an excess may affect the development of the plant and ratoon suckers. Sucker production is important for the number of fruit that will be produced in the ratoon crop. Cibes et al (1961) found in sand culture experiments that a minus-nitrogen treatment was responsible for a reduction in slip and sucker production. Samuels et al (1955) established an increased slip production with increasing nitrogen.

Fertiliser mixtures are recommended by several authors such as Cannon (1957a), Cannon (1957b), Su et al (1957), Py et al (1956), Mitchell et al (1953), le Roux (1951), Malan (1954) and Lewcock (1956). No detailed studies were presented, however, on the actual effect of nitrogen on the absorption of the other major nutrients. In this respect, the importance of leaf analysis in the interpretation of nutrient requirements by pineapple plants was stressed by Sanford (1962). He also stated that the application of ammonium sulphate, urea or potassium sulphate to attain the critical level of either nitrogen or potassium, can induce calcium or magnesium deficiencies. From annexure B it is clear that the Ca and Mg content of the soils in East London are very high in relation to the K content. A study of the effect of nitrogen on these major nutrients is, therefore, of primary importance before further work can be continued on their requirements by pineapple plants in the Eastern Cape.

Frequency of application of nitrogenous fertilisers will probably play a most important part in the accuracy of the index that is to be established, not only because of the variable requirements in different soils but the time of application will also be affected by climatic conditions. Nightingale (1942a) and Sanford (1962) have established that the nitrogen utilization or protein synthesis, is a function of the amount of carbohydrate available to the plant. The synthesis of the latter is primarily a function of the amount of temperature, carbon dioxide supply, and sunlight intensity. Samuels et al (1955) concluded that 168 lb of N per acre gave the highest yield whether applied in two or three applications. It was found by Samuels and Gandia-Diaz (1958) that one application at the time of planting was equal to, or better than, splitting the same quantities of fertiliser into two or three applications. It is clear, therefore, that there must be outside factors which cannot be controlled, that will affect the time and number of applications. Under the extreme variable climatic conditions at the latitude of the Eastern Cape ~~these factors will be important to be established.~~ further investigation of the effect of these factors is of importance

3. PROCEDURE

3.1: EXPERIMENTAL PROCEDURE AND FIELD LAYOUT OF THE PROJECTS.

Two projects were planted out for the Cayenne and two for the Queen cultivar. For each cultivar one project was planted in virgin soil and one in old pineapple land.

CAYENNE CULTIVAR:-

(i) Project (A)T.-Bh. 3:

Soil type: Red sandy loam soil. Second replanting with Cayennes.

Situation: Bathurst Agricultural Research Station.

Experimental design: Split plot design with six main treatments, and three subtreatments replicated three times.

Date of planting: 2nd December, 1960.

Planting material: Slips

Plot size: The plants were planted in double rows with a spacing of 4' X 2' X 9", having 72 plants per sub plot and an equivalent of 19,355 plants per acre.

Treatments:

Main treatments

0 Kg $(NH_4)_2SO_4$ - Control

200 Kg $(NH_4)_2SO_4$ per 10,000 plants per annum

400 Kg $(NH_4)_2SO_4$ per 10,000 plants per annum

600 Kg $(NH_4)_2SO_4$ per 10,000 plants per annum

800 Kg $(NH_4)_2SO_4$ per 10,000 plants per annum

1000 Kg $(NH_4)_2SO_4$ per 10,000 plants per annum

Sub-treatments

Main treatments applied in 2 applications per annum

Main treatments applied in 4 applications per annum

Main treatments applied in 6 applications per annum

Fertilising dates from planting to flower differentiation:

2 Applications: 22/3/61, 13/9/61, 30/3/62.

4 Applications: 2/1/61, 14/4/61, 13/9/61, 4/11/61, 13/1/62, 28/4/62.

6 Applications: 2/1/61, 22/3/61, 9/5/61, 26/7/61, 13/9/61, 14/11/62, 30/3/62, 10/5/62, 5/7/62.

(ii) Project (A)T.-Bh. 3C:

Soil type: Reddish-brown ~~clay~~ loam virgin soil.

Situation: Pineapple Research Sation, Fort Grey.

Experimental design: Split plot design with six main treatments and three sub-treatments replicated 12 times.

Date of planting: 19th December, 1960.

Planting material: Slips.

Plot size: The plants were planted in double rows with a spacing of 3'6" X 18" X 9", having 50 plants per sub plot and an equivalent of 23,226 plants per acre.

Treatments:

Main treatments

0 Kg $(NH_4)_2SO_4$ - Control

200 Kg $(NH_4)_2SO_4$ per 10,000 plants, from planting to flower differentiation.

400 Kg $(NH_4)_2SO_4$ per 10,000 plants, from planting to flower differentiation.

600 Kg $(NH_4)_2SO_4$ per 10,000 plants, from planting to flower differentiation.

800 Kg $(NH_4)_2SO_4$ per 10,000 plants, from planting to flower differentiation.

1000 Kg $(NH_4)_2SO_4$ per 10,000 plants, from planting to flower differentiation.

Sub-treatments

Main treatments applied in 2 applications

Main treatments applied in 4 applications

Main treatments applied in 6 applications

Fertilising dates from planting to flower differentiation:

2 Applications: 6/3/61, 4/10/61.

4 Applications: 6/3/61, 4/10/61, 4/12/61, 5/2/62.

6 Applications: 10/1/61, 6/3/61, 30/8/61, 1/11/61, 28/12/61, 5/2/62.

QUEEN CULTIVAR:-

(i) Project (A)T.-Bh. 3A:

Soil Type: Grey sandy soil. Second replanting with queens.

Situation: Bathurst Agricultural Research Station.

Experimental design: Split plot design with six main treatments and three sub-treatments replicated three times.

/ .... 9.

Date of planting: 29th December, 1959.

Planting material: Stumps, graded to have 3 or 4 suckers of approximately 6 inches in length, each.

Plot size: The plants were planted in double rows with a spacing of 3'6" X 18" X 12", having 100 plants per sub plot and an equivalent of 17,424 plants per acre.

Treatments:

Main treatments

0 Kg $(NH_4)_2SO_4$ - Control

200 Kg $(NH_4)_2SO_4$ per 10,000 plants per annum

400 Kg $(NH_4)_2SO_4$ per 10,000 plants per annum

600 Kg $(NH_4)_2SO_4$ per 10,000 plants per annum

800 Kg $(NH_4)_2SO_4$ per 10,000 plants per annum

1000 Kg $(NH_4)_2SO_4$ per 10,000 plants per annum

Sub-treatments

Main treatments applied in 2 applications per annum

Main treatments applied in 4 applications per annum

Main treatments applied in 6 applications per annum

Fertilising dates from planting to flower differentiation for the first crop year:

2 Applications: 14/3/60, 26/9/60, 23/1/61.

4 Applications: 29/1/60, 2/4/60, 26/9/60, 22/11/60, 21/3/61, 25/4/61

6 Applications: 29/1/60, 14/3/60, 13/5/60, 12/7/60, 26/9/60, 22/11/60, 7/1/61, 21/3/61, 10/5/61, 25/7/61.

Fertilising dates for the second crop year:

2 Applications: 19/9/61, 26/3/62.

4 Applications: 19/9/61, 14/11/61, 31/1/62, 28/4/62.

6 Applications: 19/9/61, 14/11/61, 31/1/62, 26/3/62, 10/5/62, 5/7/62.

(ii) Project (A)T.-BH. 3B:

Soil type: Reddish brown clay virgin soil.

Situation: Pineapple Research Station, Fort Grey.

Experimental design: Split plot design with six main treatments and three sub-treatments replicated 12 times.

Date of Planting: 5th December, 1960.

Planting material: Stumps, graded to have 3 or 4 suckers of approximately 6 inches in length, each.

/ .... 10.

Plot size: The plants were planted in double rows with a spacing of 3'6" X 18" X 12", having 50 plants per sub plot and an equivalent of 17,424 plants per acre.

Treatments:

Main treatments

0 Kg $(NH_4)_2SO_4$ - Control

200 Kg $(NH_4)_2SO_4$ per 10,000 plants, from planting to flower differentiation.

400 Kg $(NH_4)_2SO_4$ per 10,000 plants, from planting to flower differentiation.

600 Kg $(NH_4)_2SO_4$ per 10,000 plants, from planting to flower differentiation.

800 Kg $(NH_4)_2SO_4$ per 10,000 plants, from planting to flower differentiation.

1000 Kg $(NH_4)_2SO_4$ per 10,000 plants, from planting to flower differentiation.

Sub-treatments

Main treatments applied in 2 applications

Main treatments applied in 4 applications

Main treatments applied in 6 applications

Fertilising dates from planting to flower differentiation for the first crop year

2 Applications: 1/3/61, 4/10/61.

4 Applications: 1/3/61, 4/10/61, 4/12/61, 4/2/62.

6 Applications: 10/1/61, 1/3/61, 30/8/61, 1/11/61, 28/12/61, 6/2/62.

Fertilising dates for the second crop year:

2 Applications: 1/10/62, 14/10/63.

4 Applications: 1/10/62, 4/12/62, 5/3/63, 14/10/63.

6 Applications: 7/9/62, 12/11/62, 3/1/63, 5/3/63, 19/9/63, 14/10/63.

3.2: METHOD OF FERTILISATION.

The ammonium sulphate used in all the experiments contained 21% N.

Cayenne cultivar: For the first six months from planting the ammonium sulphate was applied on the soil but against the plants. This resulted in some fertiliser remaining on the soil and the balance falling into the lower leaves of the plants. After this period all the ammonium sulphate was placed in the axils of the lower leaves.

/Queen cultivar .... 11.

Queen cultivar: From planting to flower differentiation for the first crop year the ammonium sulphate was applied into the axils of the lower leaves of the larger suckers on the plant. It was applied in such a way so as to ensure a uniform distribution of the fertiliser to these suckers. After flower differentiation of the larger suckers the ammonium sulphate was applied to the suckers that were mature enough to go through flower differentiation for the next crop year.

General: Specially made stainless steel spoons were used for the application of the ammonium sulphate. The spoons were made to take the exact quantity of ammonium sulphate applied per plant for each sub-treatment. To ensure that no fertiliser will remain in the spoons after application they were made in a conical shape.

Fertiliser application was made immediately after any leaf sampling to ensure that no contamination of leaf samples will result.

No other forms of fertilisers were used in any of the treatments.

3.3: LEAF SAMPLING.

The term D-leaf was applied to the fourth whorl of leaves by Sideris, Krauss and Young (1938). These leaves are, at the time of sampling, the active growing leaves and are recognised by being the longest leaves on the plant. These leaves were used for analytical purposes in accordance with the methods established by Sideris, Krauss and Young (1938), and later confirmed by Nightingale, (1942) and Steyn (1957).

Only one leaf was pulled per plant per sampling by placing the hands around the leaves and pressing them together, the longest leaf was taken. One leaf was taken from each plant in every data plot in the Cayenne cultivar. For the Queen cultivar one leaf was pulled from the largest sucker of each plant in every data plot. The reason why only one leaf was pulled per plant was to avoid excessive damage to the plants which might have influenced the yield.

According to Samuels, Landrau and Olivencia (1955) it appears that the best time of leaf sampling is about 3 to 4 months after fertilising the plants. Therefore, all fertiliser applications were made immediately after leaf sampling. This allowed 3 to 4 months from fertilising to sampling.

/ 3.31: .... 12.

3.31: D-LEAF LENGTH MEASUREMENTS.

A dowel stick, ½" in diameter, was sharpened at the lower end and marked off in inches. This stick was placed, without using force, in the centre of the plant. All the leaves were then pressed tightly against the stick and the length of the longest leaf recorded as the D-leaf length. A total of 50 plants were measured in each sub plot, and the average of these measurements was regarded as the average length per D-leaf for each treatment.

3.32: D-LEAF WEIGHT.

After the D-leaf lengths were recorded, the longest leaf was removed from the plant. This was done by carefully pulling the leaf sideways until it comes free from the stem to ensure that all the basal white portion of the leaf is removed. All the leaves from each treatment were tied together and immediately taken to the laboratory to be weighed. The total weight of the leaves was recorded and the average weight per D-leaf calculated.

3.4: PREPARATION OF LEAF SAMPLES FOR ANALYSIS.

The cutting of fresh leaf material was done in all instances with a stainless steel knife on a marble block.

3.41: Green chlorophyllous section.

Immediately after recording the D-leaf weights, the centre one-third green portion of each leaf was cut out. These centre portions were washed in distilled water with teepol (1% solution). The leaves were then washed twice in polythene beakers containing pure water.

This leaf material was then cut transversely in one-eight inch strips which were mixed thoroughly before a representative sample was taken for chlorophyll analysis. This analysis was carried out immediately but if a delay of longer than two hours was unavoidable, the material was stored in a refrigerator.

3.42: Basal non-chlorophyllous section.

The basal non-chlorophyllous white sections of the leaves were cut off at the same time as the green chlorophyllous sections. The whole white portion was then taken for analysis of the major elements. The first step was to wash the leaf samples in pure water with Teepol (0.1% solution). After this the leaves were washed twice more in polythene beakers containing pure water. These leaf samples were then placed in small paper bags, placed in a forced-draught oven and dried for 72 hours at 50 C. The dried leaf material was afterwards powdered by grinding with an agate mortar and pestle ready for chemical analysis.

3.5: ANALYTICAL PROCEDURE.

The methods adopted for leaf analysis were adaptations of those established by Steyn (1957) and the standard methods used at the Pineapple Research Institute of Hawaii which were obtained by the Author through private communication. These methods are given in Annexure C for chlorophyll, Nitrogen, Na, Ca, K and Mg.

3.6: PROCEDURE IN THE TAKING OF FRUIT DATA.

The fruits were harvested in baskets and transferred to crates which were accurately marked with the treatment number. These crates were then taken to a central examining shed for the data to be taken.

3.61: Fruit weight per plot.

Each fruit was weighed separately for each treatment and recorded together with the stage of ripeness of the fruit. The total weight of the fruit per plot was determined from this data. The weights were taken with the tops on and the tops off in order to obtain the weight of the tops. The actual weights of fruits presented in this work represents that with the tops off, in other words, the weight of the fruit as delivered by the farmers to the Canneries.

3.62: Number of fruit per plot.

The total number of fruit harvested on each harvesting date was recorded and at the harvesting period totalled to represent the number of fruit per plot.

3.63: Average weight per fruit.

The average weight per fruit was determined by dividing the total weight of fruit per plot by the total number of fruit per plot.

3.64: Determination of the degree of translucency.

Points were allocated to each of the four stages of translucency as follows:

0 = Opaque fruit with no translucency

1 point = Only lower half of the fruit translucent.

2 points = Whole fruit translucent without cracking open.

3 points = Whole fruit translucent and cracking open.

/ Each .... 14.

Each alternate fruit was cut open after weighing and the degree of translucency recorded. At the end of the harvesting season the points allocated to the fruits in each treatment were added and divided by the number of fruit examined. This figure will represent the average degree of translucency per fruit.

3.7: NUMBER OF SLIPS AND SUCKERS. CAYENNE CULTIVAR.

The slips were left on the plants after the plant crop was harvested, according to normal procedure, and pulled off during the Spring. The slips from each plot were pulled off separately and counted.

The suckers were counted, irrespective of size, during the Spring following the plant crop. Each plot was counted separately and recorded as the total number of suckers per plot.

3.8: PROCEDURE FOR STATISTICAL ANALYSIS.

The method used for the statistical analysis of the results is given in Annexure D.

4. RESULTS

4.1: (A)T. - Bh. 5:

THE EFFECT OF DIFFERENT LEVELS AND INTERVALS OF APPLICATION OF AMMONIUM SULPHATE ON THE GROWTH, CHEMICAL COMPOSITION AND YIELD OF CAYENNE PINEAPPLE PLANTS UNDER FIELD CONDITIONS: BATHURST, RED SANDY LOAM SOIL.

1. Yield.

The plant crop was harvested over the period from April 1962, to May 1963.

(a) Fruit weight per plot.

The weight of fruit per plot is given in Table 1.

TABLE 1. Average weight (lb) of fruit per plot (plant crop)

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	145.89	161.36	127.40	144.88
200	217.78	216.42	213.61	215.94
400	205.01	244.93	199.99	216.64
600	230.36	242.15	198.82	223.78
800	231.55	134.36	160.17	175.36
1000	239.41	208.92	194.53	214.29
Mean	224.82	209.36	193.42	198.48

L.S.D. ($P = 0.05$) means of N levels = 53.424 lb C.V. 14.8%
L.S.D. ($P = 0.01$) means of N levels = 75.991 lb
L.S.D. ($P = 0.05$) means of N frequency = 18.728 lb C.V. 12.6%
L.S.D. ($P = 0.01$) means of N frequency = 75.310 lb

With the exception of the 800 Kg ammonium sulphate treatment all other treatments gave an increase in fruit weight over the control at the 0.05 level. The 600 Kg treatment, however, gave an increase at the 0.01 level. The quadratic effect was negative and significant with 600 Kg giving the highest peak.

A frequency of 6 applications of ammonium sulphate gave a lower yield, significant at the 0.05 level compared with 4 applications and a reduction, significant at the 0.01 level, compared with 2 applications. The linear effect of increasing frequency of application was negative and highly significant amounting to $-15.70 \pm 4.257\%$ for each 2 additional dressings.

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In table 2 is given the conversion of the yield from Table 1 into tons per acre.

TABLE 2. Average weight (tons) of fruit per acre (plant crop).

$(NH_4)_2$ SO_4 (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	19.60	21.70	17.10	19.50
200	29.30	29.10	28.70	29.00
400	27.60	32.90	26.90	29.10
600	31.00	32.50	27.70	30.40
800	31.10	18.00	21.50	23.50
1000	32.20	28.10	26.20	26.80
Mean	28.50	27.00	24.70	26.70

Table 2 shows that the increase in yield with 600 Kg, compared with the control, could represent 10.9 tons of fruit per acre. The quadratic effect in the lowering of yield caused by 800 Kg and 1000 Kg was equal to 6.9 tons and 1.60 tons per acre respectively.

The reduction in yield by a frequency of 6 compared with 2 applications represents 3.80 tons per acre.

(b) Number of fruit.

The number o fruits per plot harvested for the plant crop is given in Table 3.

TABLE 3. Average number of fruits per plot (plant crop)

$(NH_4)_2SO_4$ (per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	51.67	55.67	45.67	51.00
200	54.00	54.67	50.33	53.00
400	49.67	55.00	44.00	49.56
600	53.00	52.33	46.33	50.56
800	53.00	30.00	35.00	39.33
1000	51.67	48.33	42.67	47.56
Mean	52.27	48.07	43.67	48.50

L.S.D. (P = 0.05) means of N levels = 10.91 fruits C.V. 12.9%
L.S.D. (P = 0.01) means of N levels = 15.52 fruits.
L.S.D. (P = 0.05) means of N frequency = 5.39 fruits C.V. 14.8%
L.S.D. (P = 0.01) means of N frequency = 7.29 fruits.

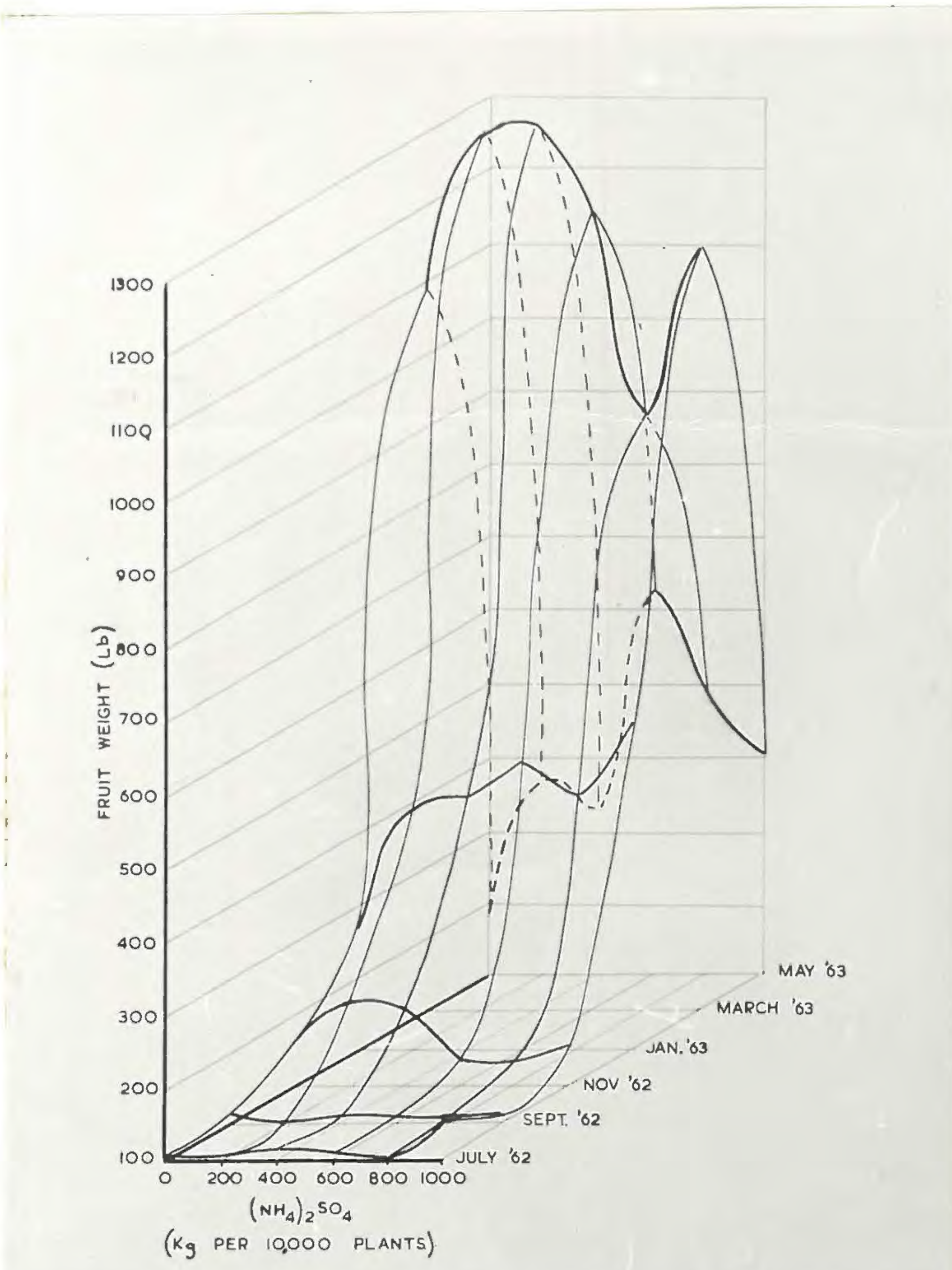

Figure 1. Fruit weight per plot for the plant crop.

The 800 Kg treatment produced less fruits, at the 0.05 level compared with the control and also the 200 and 600 Kg treatments.

A frequency of 6 applications gave a reduction in yield at the 0.01 level compared with 2 applications. There was no significant difference between 6 and 4 applications. The linear effect of increasing frequency of application was negative and highly significant with -.4.30 ± 1.19% for each 2 additional dressings.

(c) Average weight per fruit.

The average weight per fruit for the plant crop is given in Table 4.

TABLE 4. Average weight (lb) per fruit (plant crop).

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	2.83	2.88	2.78	2.828
200	4.05	3.96	4.32	4.110
400	4.03	4.39	4.46	4.293
600	4.34	4.63	4.60	4.526
800	4.37	4.50	4.58	4.484
1000	4.62	4.32	4.56	4.500
Mean	4.28	4.36	4.50	4.124

L.S.D. ($P = 0.05$) means of N levels = 0.49 lb
L.S.D. ($P = 0.01$) means of N levels = 0.69 lb
L.S.D. ($P = 0.05$) means of N frequency = 0.13 lb
L.S.D. ($P = 0.01$) means of N frequency = 0.18 lb

All the levels of N gave an increase of the average weight per fruit at the 0.01 level compared with the control. There was no significant difference between any of the N levels.

A frequency of 6 applications gave an increase in average weight per fruit at the 0.01 and 0.05 levels compared with 2 and 4 applications respectively.

(d) Time of harvesting.

The effect of increasing levels of N on the weight of fruit per plot throughout the harvesting period is presented in Figure 1.

From Figure 1 it appears that up to March 1963 there was very little difference in the weight of fruit harvested each month from the control and the N treatments. The biggest difference exists between the lower levels of N and 800 Kg where the latter produced a lower weight than the former. The tendency is a lower weight with higher N. At the end of May, 1963, there was a very large drop in the control compared with the others. The higher levels of N gave the highest weight. This

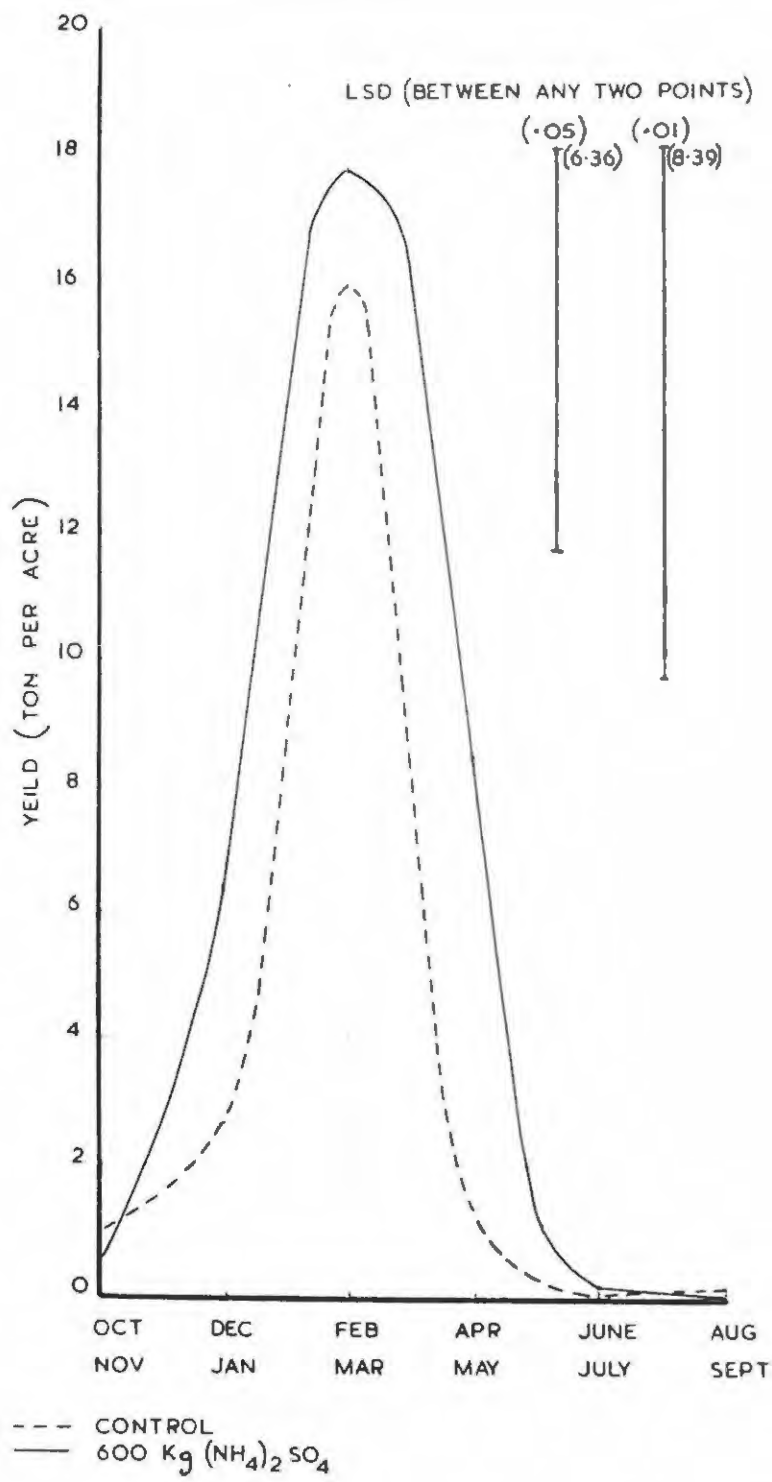

Figure 2. Mean fruit yield (tons per acre) for the plant crop. Significance is shown if the vertical distance at any one date is longer than that shown at the 0.05 or 0.01 levels.

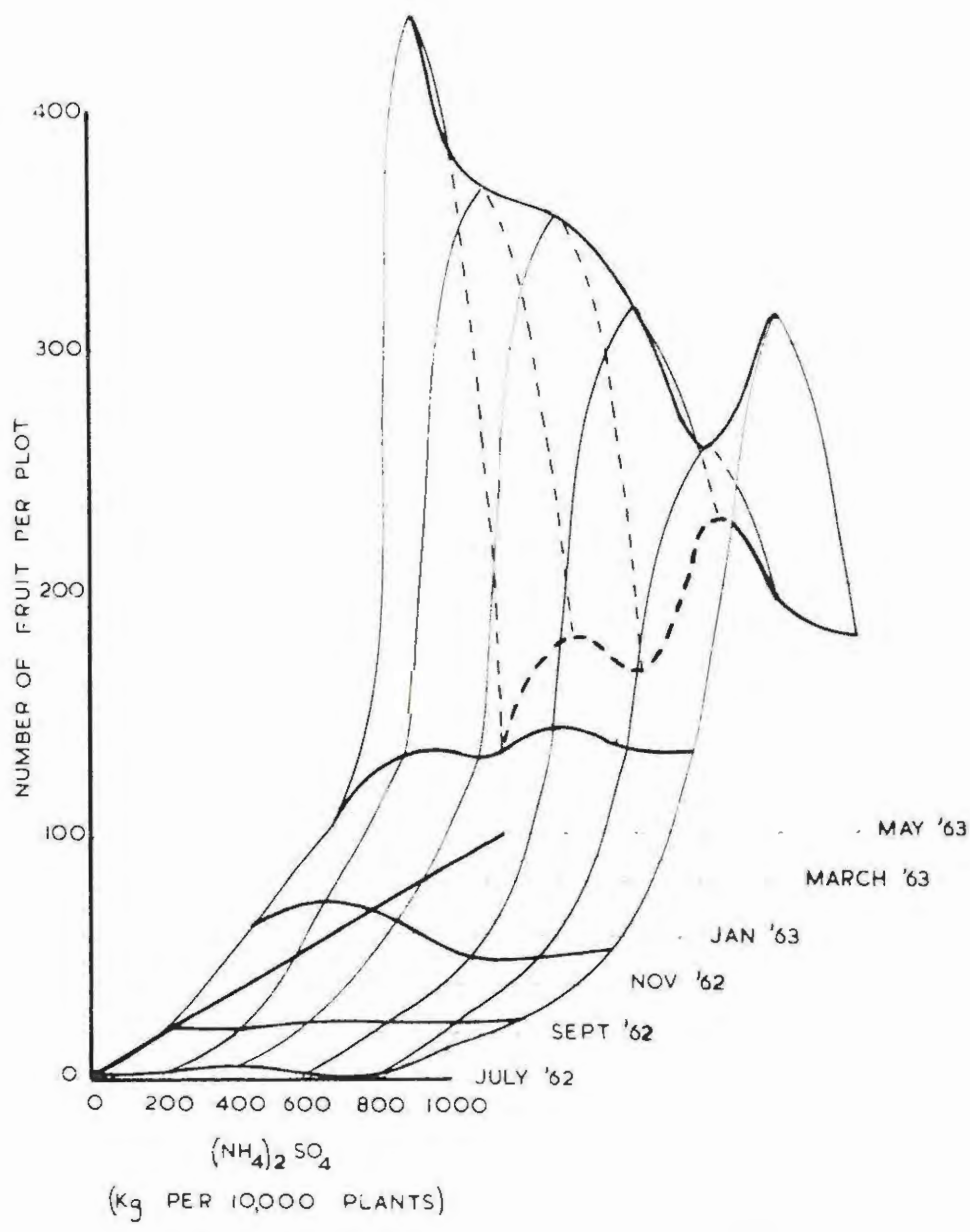

Figure 3. Number of fruit per plot for the plant crop.

indicates that higher levels of N might delay the yield.

The monthly weight of fruit for the control and the 600 Kg treatments is given in Figure 2.

Figure 2 shows a significant higher weight of fruit during April-May, 1963 in the 600 Kg treatment compared with the control.

The influence of increasing levels of N on the number of fruit per plot throughout the harvesting period is shown in Figure 3.

At the end of March the tendency was for a higher number of fruit in the control and decreasing with increasing levels of N. This position was reversed during April up to the end of May, 1963. From this it could be concluded that the higher levels of N showed a tendency to retard the crop.

2. Production of suckers.

The suckers were counted at the end of the plant crop on 13th May, 1963 and the results are given in Table 5.

TABLE 5. Average number of suckers per plot.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	52.33	54.67	74.00	60.33
200	83.67	72.00	66.67	74.11
400	87.67	87.67	89.00	88.11
600	93.67	115.67	98.67	102.67
800	95.00	78.67	69.67	81.11
1000	96.00	97.67	93.67	95.78
Mean	91.20	90.34	83.54	83.685

L.S.D. $(P = 0.05)$ means of N levels = 20.78 suckers C.V. 13.65%
L.S.D. $(P = 0.01)$ means of N levels = 29.56 suckers.
L.S.D. $(P = 0.05)$ means of N frequency = 11.26 suckers C.V. 17.92%
L.S.D. $(P = 0.01)$ means of N frequency = 15.22 suckers.

3. Leaf analyses.

(a) Nitrogen

The nitrogen content of the leaves 9 months after planting, i.e., immediately after the first winter from planting, is given in Table 6.

/ Table 6 .... 19.

TABLE 6. Nitrogen content (%) of the leaves 9 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	1.12	0.81	0.81	0.916
200	1.14	0.91	1.09	1.014
400	1.01	1.54	1.14	1.206
600	1.17	1.26	1.32	1.252
800	1.19	1.69	1.26	1.381
1000	1.43	1.64	1.55	1.640
Mean	1.194	1.370	1.331	1.235

L.S.D. ($P = 0.05$) means of N levels = 0.241% N C.V. 10.7%
L.S.D. ($P = 0.01$) means of N levels = 0.342% N.
L.S.D. ($P = 0.05$) means of N frequency = 0.197% N C.V. 21.2%
L.S.D. ($P = 0.01$) means of N frequency = 0.266% N.

The highest level of N gave an increase in leaf-N compared with all the N levels from 0 to 600 Kg significant at 0.01. There was no significant difference between 600 Kg and 800 Kg. The linear response of leaf-N to increasing levels of N was positive and highly significant, with an increase of 0.1362 ± 0.0183% N for each additional 200 Kg ammonium sulphate applied.

The nitrogen content of the leaves 13 months after planting, i.e. during midsummer prior to flower differentiation, is given in Table 7.

TABLE 7. Nitrogen content (%) of the leaves 13 months after planting.

(NH4)2SO4 (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	1.77	1.63	1.95	1.791
200	1.96	1.85	2.09	1.968
400	1.87	1.99	2.02	1.963
600	1.95	2.12	2.11	2.062
800	1.99	2.23	2.12	2.116
1000	2.22	1.93	2.27	2.07
Mean	1.958	2.026	2.124	1.995

L.S.D. ($P = 0.05$) means of N levels = 0.213% N. C.V. 5.86%
L.S.D. ($P = 0.01$) means of N levels = 0.303% N.
L.S.D. ($P = 0.05$) means of N frequency = 0.275% N. C.V. 18.36%
L.S.D. ($P = 0.01$) means of N frequency = 0.372% N.

The leaf-N for the control was lower than the three highest levels of N and significant at 0.05 level. There were no significant differences between any of the other treatments. The linear response of leaf-N to increasing levels of N was highly significant, with an increase of 0.0557 ± 0.0161% for each additional 200 Kg ammonium sulphate applied.

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The nitrogen content of the leaves 20 months after planting is given in Table 8. This is immediately after the second winter after planting, during the period of flower differentiation.

TABLE 8. Nitrogen content (%) of the leaves 20 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	1.15	1.12	1.05	1.106
200	1.32	1.36	1.62	1.436
400	1.56	1.61	1.73	1.633
600	1.67	1.57	1.77	1.672
800	1.69	1.78	1.82	1.762
1000	1.72	1.77	2.03	1.842
Mean	1.591	1.620	1.795	1.575

L.S.D. (P = 0.05) means of N levels = 0.193% N. C.V. 6.72%
L.S.D. (P = 0.01) means of N levels = 0.274% N.
L.S.D. (P = 0.05) means of N frequency = 0.103% N. C.V. 8.67%
L.S.D. (P = 0.01) means of N frequency = 0.139% N.

The control gave a lower leaf-N compared with all the levels of N significant at 0.01. The lowest level of N was lower than all the higher levels of N at 0.05 level. The linear response of leaf-N to increasing levels of N was positive and highly significant, with an increase of 0.1342 ± 0.0146% for each additional 200 Kg of ammonium sulphate applied. The quadratic response was negative and highly significant.

The frequency of application of N had no significant effect on the leaf-N between individual treatments. The linear response, however, with increasing frequency, was positive and highly significant, with an increase of 0.102 ± 0.250% for each additional 2 dressings.

The average effect of N levels on the leaf-N over the three sampling dates is given in Table 9.

TABLE 9. Average effect of N levels on leaf-N (%) for the 3 sampling dates.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Time of sampling (months from planting)			
	9	13	20	Mean
0	0.92	1.79	1.11	1.27
200	1.01	1.97	1.44	1.47
400	1.21	1.96	1.63	1.60
600	1.25	2.06	1.67	1.66
800	1.38	2.12	1.76	1.75
1000	1.64	2.07	1.84	1.85
Mean	1.23	2.00	1.58	1.60

L.S.D. (P = 0.05) means of sampling dates = 0.056% N
L.S.D. (P = 0.01) means of sampling dates = 0.074% N

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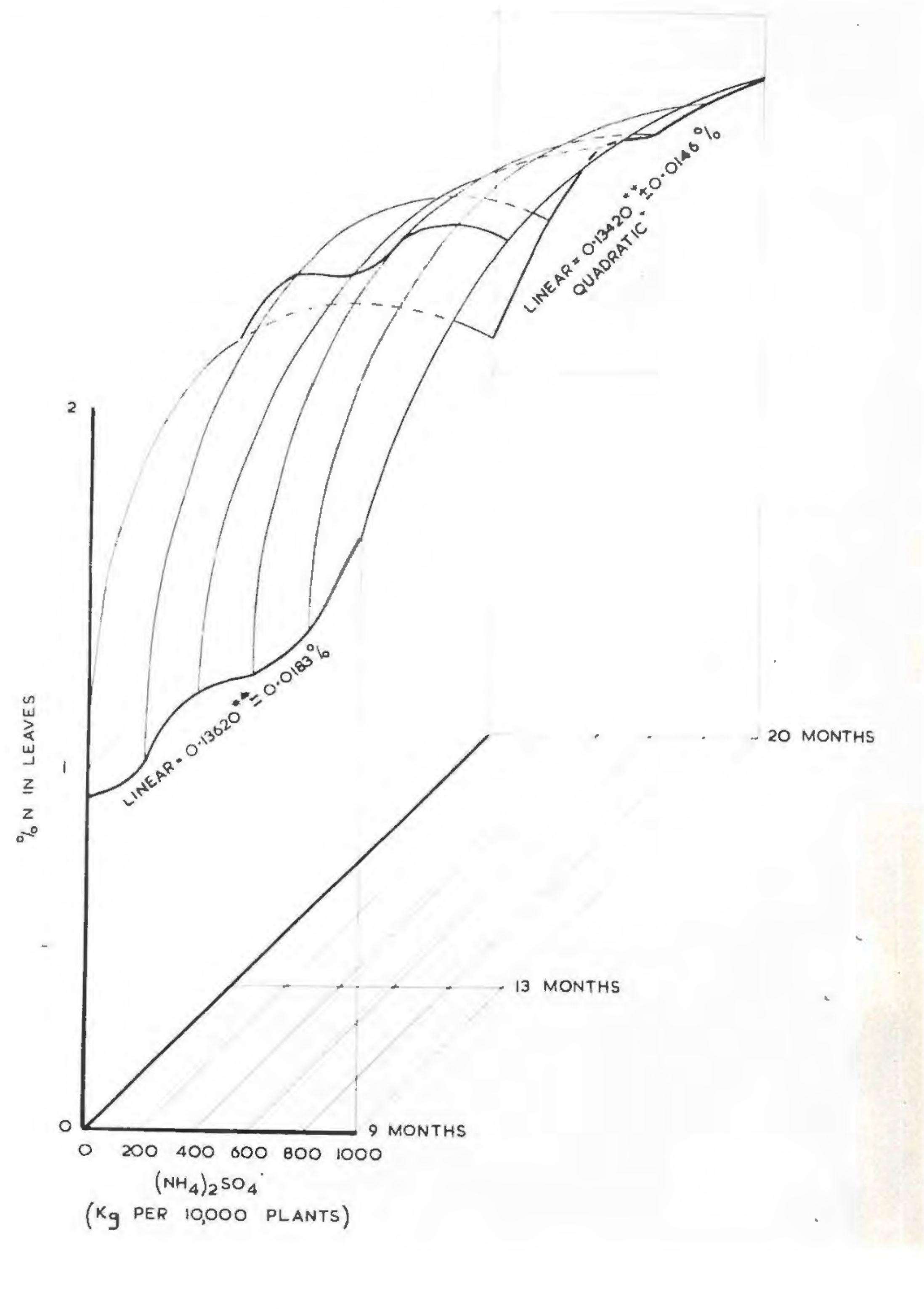

Figure 4. Overall effect of increasing levels of ammonium sulphate on the leaf-N.

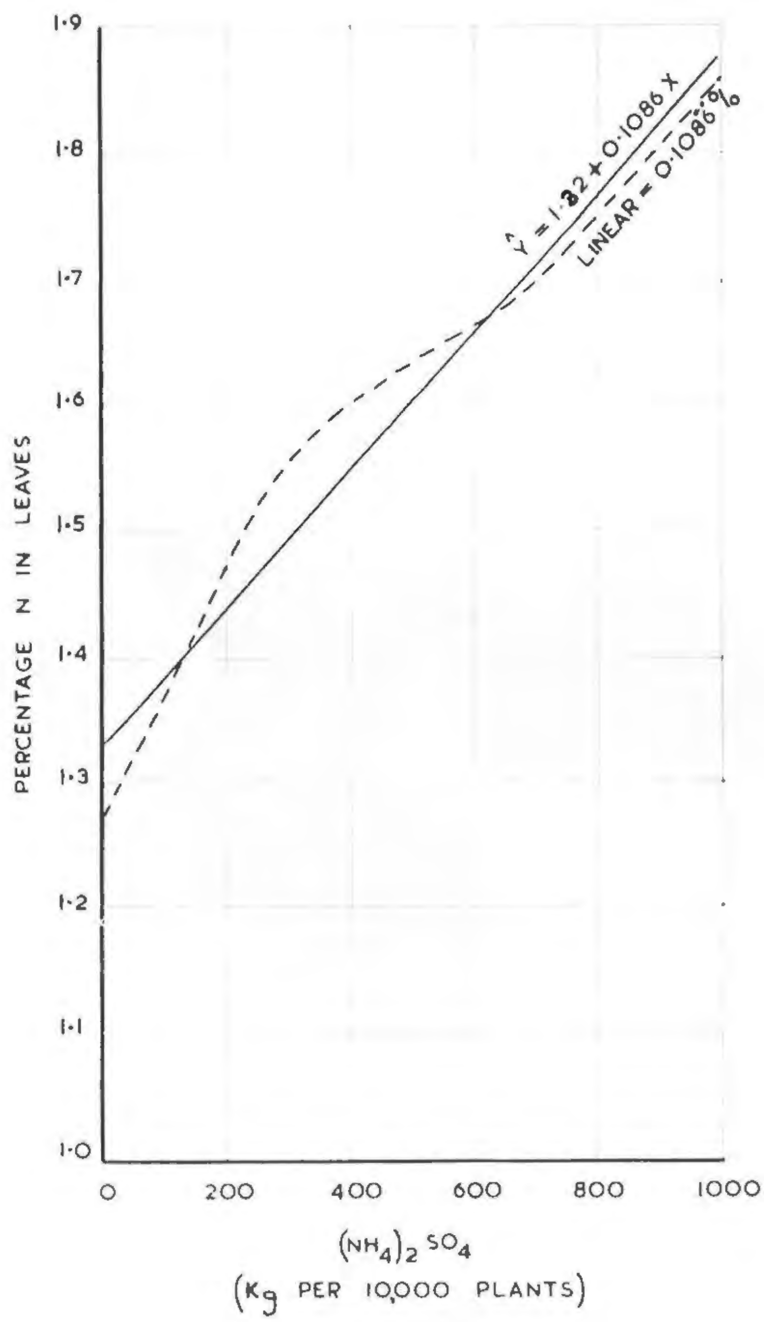

Figure 5. Average response of leaf-N to increasing levels of ammonium sulphate over the entire period. The linear response significant at 0.1086% N for every 200 Kg increment of ammonium sulphate.

At 13 months from planting, that is in midsummer, the leaves contained more N than at 9 and 20 months after planting. significant at 0.01. The latter two dates are immediately following the winter after planting and after winter at flower differentiation respectively.

The linear response to increasing levels of N over the mean of the three samples, Table 9, is highly significant giving a steady increase in leaf-N, of 0.1086 ± 0.008296% for each additional 200 Kg of ammonium sulphate applied.

Figure 4 shows the overall response of increasing levels of N on the leaf-N as taken over the entire period from Table 9. The significant linear response is given as an increase of leaf-N for every 200 Kg increment of ammonium sulphate.

Figure 5 represents the average response of N content in the leaves to the levels of N applied, over the entire period.

In Figure 5 the highly significant positive linear response of 0.1086% leaf-N for every 200 Kg increment of N application is evident.

The average response to the frequency of N application on leaf-N over the entire period is given in Table 10.

TABLE 10. Average effect of frequency of N application on leaf-N for the 3 sampling dates.

Frequency of application	Time of sampling (months from planting)			
	9	13	20	Mean
2	1.19	1.96	1.59	1.58
4	1.37	2.03	1.62	1.67
6	1.33	2.12	1.80	1.75
Mean	1.30	2.04	1.67	1.67

L.S.D. (P = 0.05) means of frequency of application = 0.10% N
L.S.D. (P = 0.01) means of frequency of application = 0.17% N

A frequency of 6 applications gave an increase in leaf-N over 2 applications at 0.01 but only significant at 0.05 over 4 applications.

The linear effect of increasing frequency of application is positive and highly significant with an increase of 0.085 ± 0.03% for each additional 2 dressings over the entire period.

(b) Potassium.

The potassium content of the leaves 9 months after planting, is given in Table 11,

/Table 11 .... 22.

TABLE 11. Potassium content (%) of the leaves 9 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	1.27	1.37	1.07	1.233
200	0.97	1.13	1.43	1.178
400	1.10	1.13	1.10	1.111
600	1.03	1.33	1.37	1.244
800	1.23	1.40	1.30	1.311
1000	1.37	1.50	1.50	1.456
Mean	1.140	1.300	1.340	1.256

L.S.D. ($P = 0.05$) means of N levels = 0.223% K. C.V. 9.8%
L.S.D. ($P = 0.01$) means of N levels = 0.317% K.
L.S.D. ($P = 0.05$) means of N frequency = 0.196% K C.V. 20.8%
L.S.D. ($P = 0.01$) means of N frequency = 0.264% K.

The highest level of N gave a higher leaf-K, significant at 0.05, compared with the three lowest levels of N. The 400 Kg level was lower than the highest level of N, significant at 0.01. The linear response of leaf-K to increasing levels of N was positive and significant, with an average increase of $0.04706 \pm 0.0169\%$ for each increment of 200 Kg ammonium sulphate. This was not consistant over all levels of N as the quadratic response was positive and significant.

The linear response of leaf-K to increasing frequency of application of N was positive and significant with an average increase of $0.1 \pm 0.0476\%$ for each additional 2 dressings.

The application of nitrogen had no significant effect on the leaf-K 13 months after planting.

The potassium content of the leaves 20 months after planting is given in Table 12.

TABLE 12. Potassium content (%) of the leaves 20 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	2.20	1.93	1.80	1.978
200	1.75	1.52	1.63	1.633
400	1.35	1.48	1.42	1.417
600	1.52	1.23	1.43	1.394
800	1.45	1.72	1.35	1.506
1000	1.60	1.65	1.33	1.528
Mean	1.533	1.520	1.433	1.576

L.S.D. ($P = 0.05$) means of N levels = 0.323% K. C.V. 11.26%
L.S.D. ($P = 0.01$) means of N levels = 0.459% K.
L.S.D. ($P = 0.05$) means of N frequency = 0.263% K. C.V. 22.21%
L.S.D. ($P = 0.01$) means of N frequency = 0.355% K.

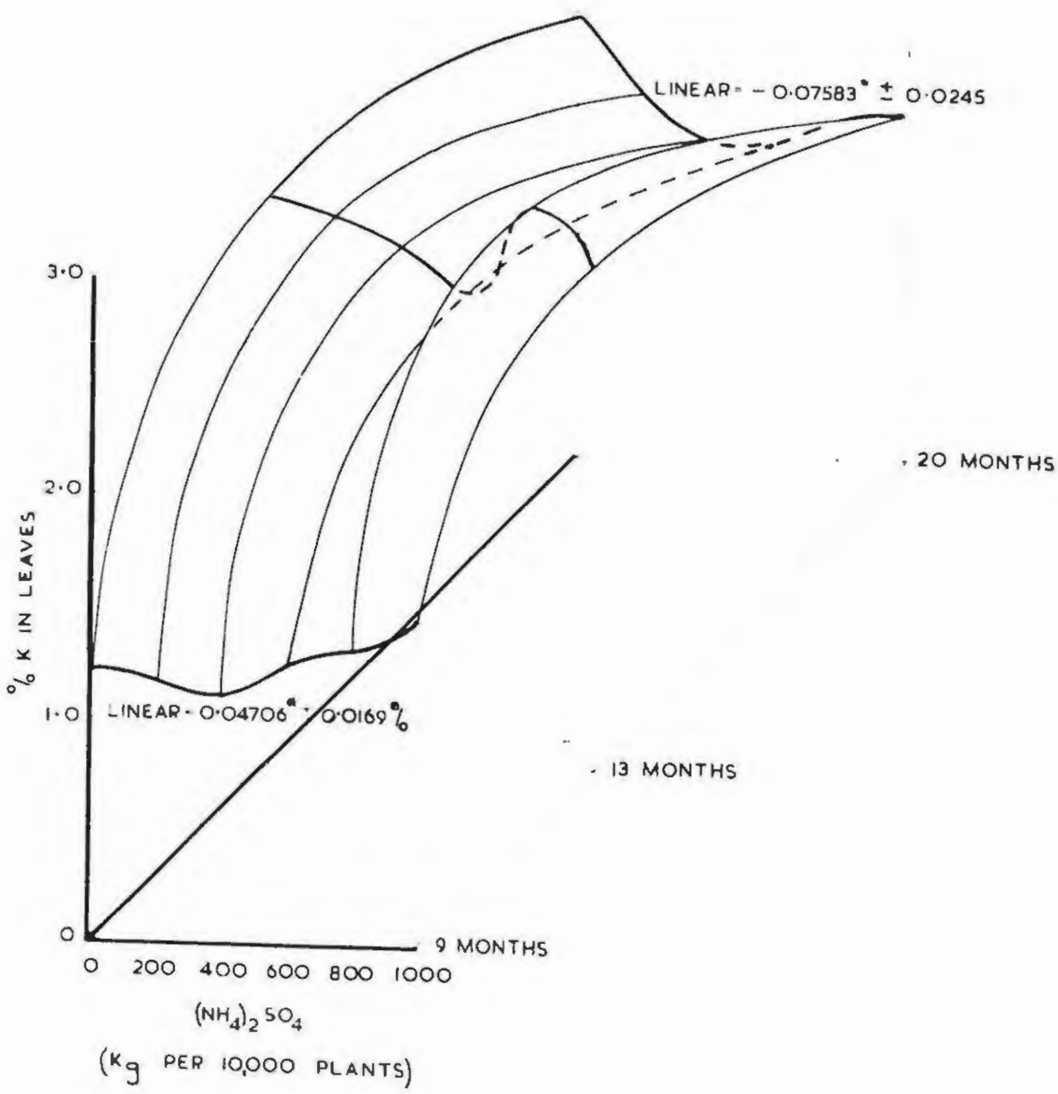

Figure 6. Overall effect of increasing levels of ammonium sulphate on the leaf-K.

All the levels of N gave a lower leaf-K compared with the control, significant at 0.05. The 400 and 800 Kg levels were lower than the control, and significant at 0.01. The linear response of leaf-K to increasing levels of N was negative and significant with an average decrease of 0.07583 ± 0.0245% for each additional 200 Kg ammonium sulphate applied. This was not constant over all levels of N as the quadratic response was positive and significant.

The average effect of N levels on the leaf-K for the 3 sampling dates is given in Table 13.

TABLE 13. Average effect of N levels on leaf-K (%) for the 3 sampling dates.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Time of sampling (months from planting)			
	9	13	20	Mean
0	1.23	2.55	1.98	1.92
200	1.18	2.46	1.63	1.76
400	1.11	2.33	1.42	1.62
600	1.24	2.11	1.39	1.58
800	1.31	2.51	1.51	1.76
1000	1.46	2.25	1.53	1.74
Mean	1.26	2.37	1.56	1.73

L.S.D. (P = 0.05) means of sampling times = 0.14% K
L.S.D. (P = 0.01) means of sampling times = 0.18% K

Although there is no significant effect on leaf-K between the N levels the quadratic effect was positive and significant. The lowest K content was reached at the 600 Kg level.

At thirteen months after planting the leaf-K was higher than both other periods and significant at 0.01. Twenty months after planting the leaves had a significantly higher K content than at nine months.

Figure 6 shows the overall effect of levels of N on the leaf-K over the entire period of sampling. The significant quadratic effect of levels of N on the leaf-K is particularly obvious.

(c) Calcium

The calcium content of the leaves 9 months after planting i.e. immediately after the first winter, is given in Table 14.

/ Table 14 .... 24.

TABLE 14. Calcium content (%) of the leaves 9 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.123	0.157	0.067	0.116
200	0.080	0.117	0.117	0.104
400	0.120	0.110	0.140	0.123
600	0.100	0.097	0.097	0.098
800	0.083	0.077	0.080	0.080
1000	0.077	0.063	0.060	0.067
Mean	0.092	0.093	0.099	0.098

L.S.D. (P = 0.05) means of N levels = 0.041% Ca. C.V. 22.94%
L.S.D. (P = 0.01) means of N levels = 0.088% Ca.
L.S.D. (P = 0.05) means of N frequency = 0.029% Ca. C.V. 39.53%
L.S.D. (P = 0.01) means of N frequency = 0.039% Ca.

The leaf-Ca of the highest N level was lower than that of the control and the two lowest N levels, significant at 0.05.

The linear effect of increasing N levels of the leaf-Ca was negative and significant with an average decrease of 0.00977 ± 0.0031% for each additional 200 Kg ammonium sulphate applied.

Frequency of application had no significant effect on the leaf-Ca.

The calcium content of the leaves 13 months after planting i.e. midsummer before flowering, is given in Table 15.

TABLE 15. Calcium content (%) of the leaves 13 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.570	0.493	0.560	0.541
200	0.600	0.617	0.577	0.598
400	0.583	0.527	0.663	0.591
600	0.640	0.607	0.560	0.602
800	0.713	0.560	0.553	0.609
1000	0.713	0.467	0.407	0.540
Mean	0.649	0.556	0.552	0.580

L.S.D. (P = 0.05) means of N levels = 0.104% Ca. C.V. 16.3%
L.S.D. (P = 0.01) means of N levels = 0.149% Ca.
L.S.D. (P = 0.05) means of N frequency = 0.071% Ca. C.V. 9.9%
L.S.D. (P = 0.01) means of N frequency = 0.096% Ca.

A frequency of 2 applications gave an increase in leaf-Ca, significant at 0.01 compared with 6 but only significant at 0.05 compared with 4 applications. The linear effect of frequency of application was negative and significant with an average

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decrease of 0.0485 ± 0.0172% for each additional 2 dressings. Levels of N gave no significant difference in Ca content.

The calcium content of the leaves 20 months after planting i.e. immediately after the second winter during flower differentiation, is given in Table 16.

TABLE 16. Calcium content (%) of leaves 20 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.227	0.630	0.273	0.243
200	0.297	0.363	0.260	0.309
400	0.247	0.367	0.260	0.291
600	0.413	0.303	0.397	0.371
800	0.457	0.360	0.347	0.388
1000	0.400	0.333	0.253	0.329
Mean	0.363	0.375	0.253	0.322

L.S.D. (P = 0.05) means of N levels = 0.119% Ca. C.V. 20.3%
L.S.D. (P = 0.01) means of N levels = 0.169% Ca.
L.S.D. (P = 0.05) means of N frequency = 0.064% Ca. C.V. 26.6%
L.S.D. (P = 0.01) means of N frequency = 0.087% Ca.

The leaf-Ca content of the control was lower than the 600 and 800 Kg treatments, and significant at 0.05. The linear effect of levels of N on leaf-Ca was positive and significant, with an average increase of 0.02134 ± 0.009% for each additional 200 Kg ammonium sulphate applied.

A comparison of the average effect of levels of N on the leaf-Ca for the three sampling dates is given in Table 17.

TABLE 17. Average effect of N levels on leaf-Ca (%) for the 3 sampling dates.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Time of sampling (months from planting)			
	9	13	20	Mean
0	0.11	0.54	0.24	0.30
200	0.10	0.60	0.31	0.34
400	0.12	0.59	0.29	0.34
600	0.10	0.60	0.37	0.36
800	0.08	0.61	0.39	0.36
1000	0.07	0.54	0.33	0.31
Mean	0.10	0.58	0.32	0.33

L.S.D. (P = 0.01) between means of sampling times = 0.04% Ca

Although the average effect of N levels had no significant effect on the leaf-Ca a negative quadratic effect was significant. Lower Ca contents were obtained for the control and the highest N level.

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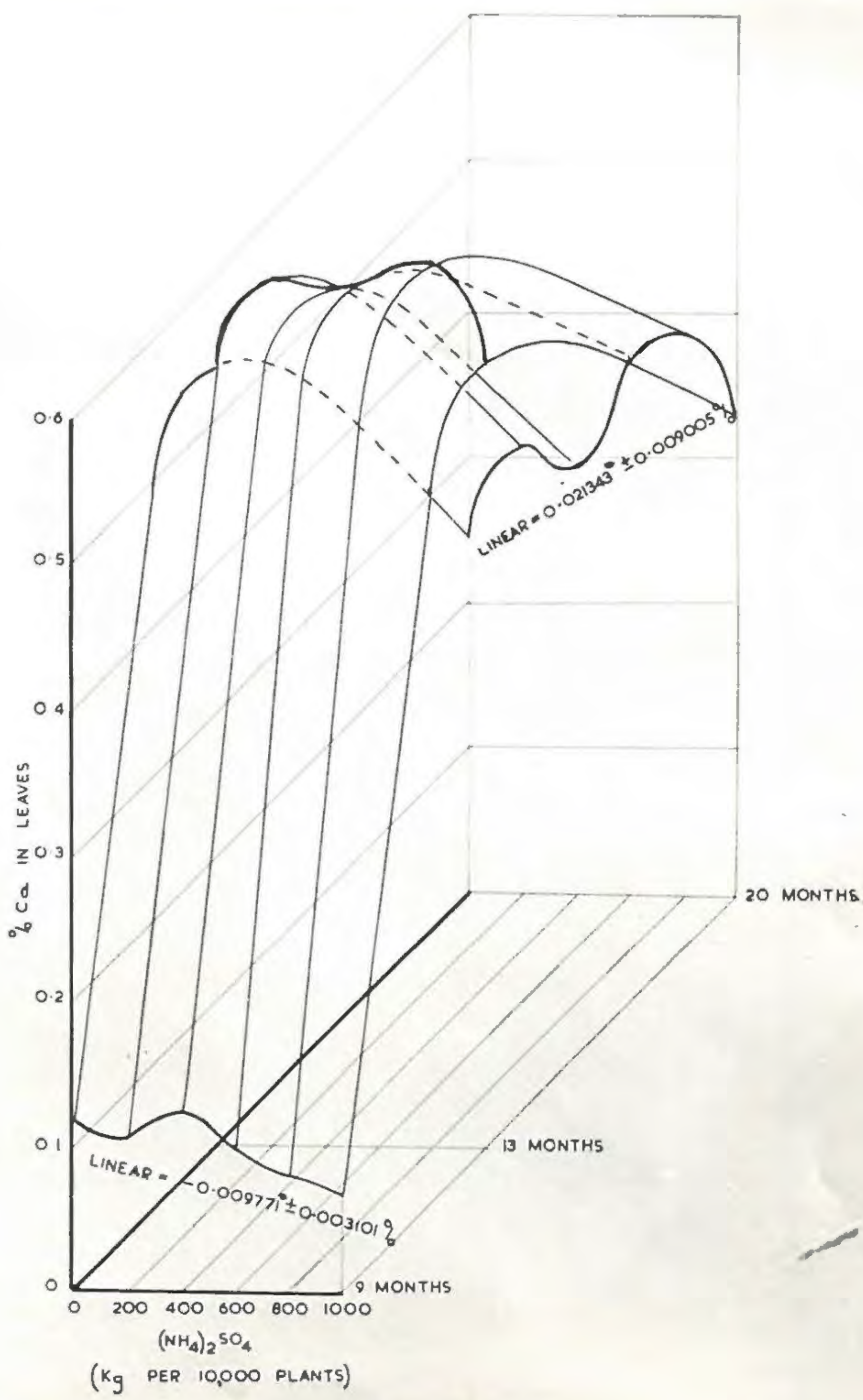

Figure 7. Overall effect of increasing levels of ammonium sulphate on the leaf-Ca.

The increase in leaf-Ca was significant at 0.01 for the 13 months period compared with 9 and 20 months.

Figure 7 shows the overall effect of levels of N on the leaf-Ca over the entire period. The change from a significantly negative effect with increasing N at 9 months to a significantly positive effect at 20 months is clear.

The average effect of the frequency of N applications on the three sampling dates is given in Table 18.

TABLE 18. Average effect of frequency of N application on leaf-Ca (%) for the 3 sampling dates.

Frequency of application	Time of sampling (months from planting)			
	9	13	20	Mean
2	0.092	0.649	0.363	0.368
4	0.093	0.556	0.375	0.341
6	0.099	0.552	0.303	0.318
Mean	0.098	0.580	0.322	0.342

Increasing frequency of N applications gave a significant negative linear effect on the leaf-Ca, with an average decrease of 0.025 $\pm$ 0.00797% for each additional 2 dressings.

(d) Magnesium

The magnesium content of the leaves 9 months after planting is given in Table 19.

TABLE 19. Magnesium content (%) of leaves 9 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.143	0.160	0.113	0.139
200	0.097	0.120	0.093	0.114
400	0.087	0.113	0.120	0.107
600	0.100	0.103	0.123	0.109
800	0.110	0.107	0.103	0.107
1000	0.097	0.083	0.083	0.088
Mean	0.105	0.114	0.106	0.111

L.S.D. (P = 0.05) means of N levels = 0.019% Mg. C.V. 9.2%
L.S.D. (P = 0.01) means of N levels = 0.026% Mg.
L.S.D. (P = 0.05) means of N frequency = 0.020% Mg. C.V. 23.7%
L.S.D. (P = 0.01) means of N frequency = 0.027% Mg.

The highest level of N gave a decrease in leaf-Mg compared with the control and the lowest N level and significant at 0.01. The second highest N level was lower in leaf-Mg than the control, significant at 0.01. All the other N levels were lower than the control and significant at 0.05.

The linear effect of increasing N levels on the leaf-Mg was negative and highly significant, with an average decrease of 0.00783 ± 0.00141% for each additional 200 Kg of ammonium sulphate.

Frequency of application had no significant effect on the Mg content of the leaves, 9 months after planting.

The magnesium content of the leaves 15 months after planting is given in Table 20.

TABLE 20. Magnesium content (%) of leaves 15 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.97	0.94	0.78	0.90
200	1.07	0.68	0.92	0.87
400	1.04	1.03	0.98	1.01
600	1.11	0.92	0.85	0.96
800	1.16	0.87	0.84	0.96
1000	1.11	0.88	0.75	0.92
Mean	1.10	0.88	0.87	0.94

L.S.D. (P = 0.05) means of N levels = 0.116% Mg. C.V. 6.68%
L.S.D. (P = 0.01) means of N levels = 0.165% Mg.
L.S.D. (P = 0.05) means of N frequency = 0.152% Mg. C.V. 21.29%
L.S.D. (P = 0.01) means of N frequency = 0.21% Mg.

A frequency of 4 and 6 applications of N gave a decrease in leaf-Mg compared with 2 applications, significant at 0.01. There was no significant difference between the former two treatments. The linear effect of increasing frequency of application on the leaf-Mg was negative and significant, with an average decrease of 0.115 ± 0.0538% due to each 2 additional applications.

Levels of N had no significant effect on leaf-Mg.

The magnesium content of the leaves at 20 months after planting is given in Table 21.

TABLE 21. Magnesium content (%) of leaves 20 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.48	0.52	0.56	0.52
200	0.56	0.58	0.53	0.56
400	0.63	0.60	0.61	0.61
600	0.57	0.61	0.63	0.60
800	0.67	0.59	0.59	0.62
1000	0.69	0.68	0.51	0.63
Mean	0.62	0.61	0.57	0.59

L.S.D. (P = 0.05) means of N levels = 0.09% Mg. C.V. 8.01%
L.S.D. (P = 0.01) means of N levels = 0.12% Mg.
L.S.D. (P = 0.05) means of N frequency = 0.[illegible]6% Mg. C.V. 12.55%
L.S.D. (P = 0.01) means of N frequency = 0.0[illegible]% Mg.

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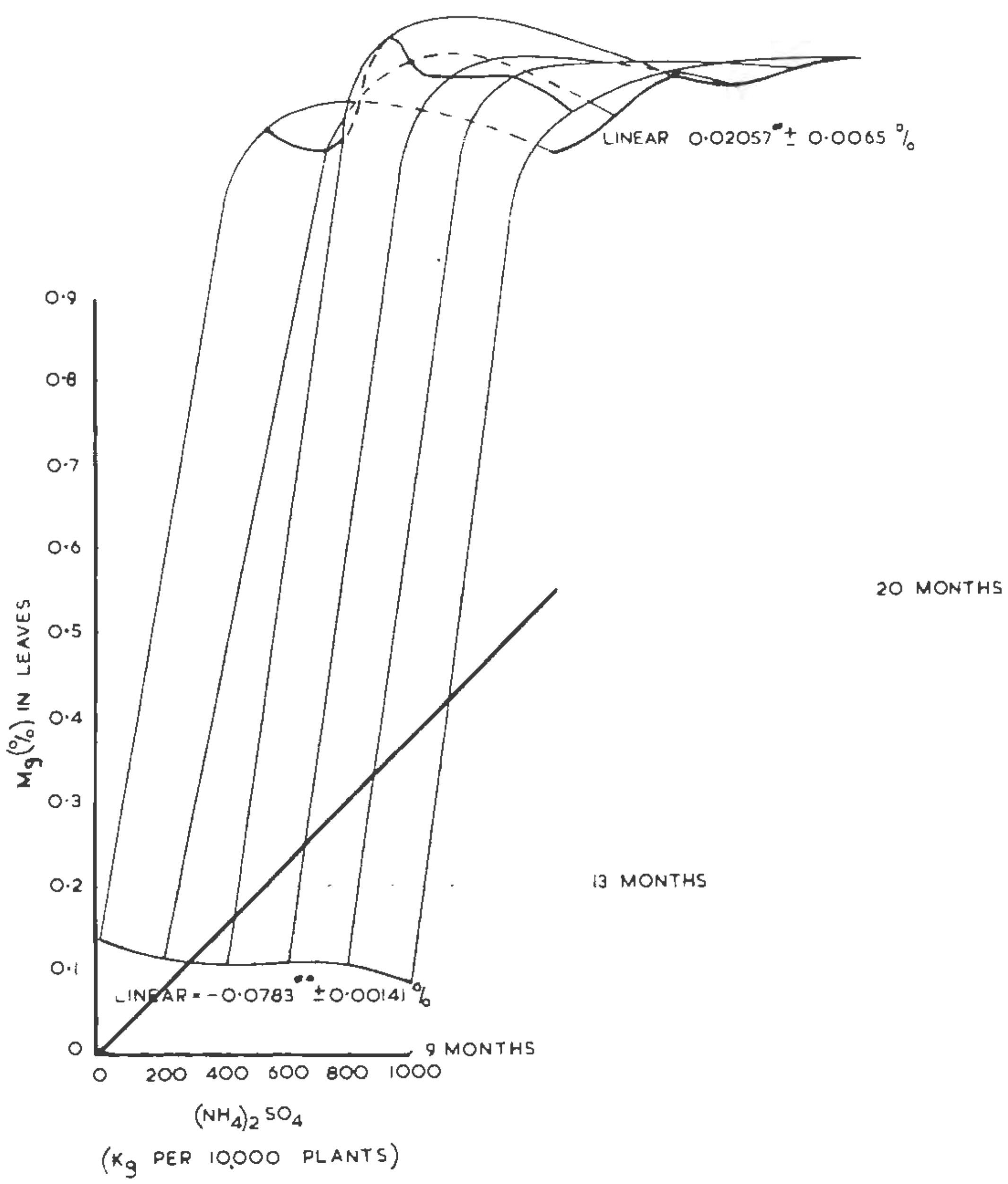

Figure 8. Overall effect of increasing levels of ammonium sulphate on the leaf-Mg.

The 400, 800 and 1,000 Kg levels of N gave an increase in leaf-Mg, significant at 0.05, compared with the control. There was no significant difference between any of the N levels. The linear effect of increasing levels of N on leaf-Mg was positive and significant, with an average increase of 0.0206 $\pm$ 0.0065% due to each increase of 200 Kg ammonium sulphate.

The means of leaf-Mg for the three sampling dates are given in Table 22.

TABLE 22. Means of leaf-Mg (%) for the 3 sampling times

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.53	0.54	0.49	0.52
200	0.55	0.46	0.53	0.51
400	0.58	0.59	0.56	0.58
600	0.59	0.55	0.53	0.56
800	0.65	0.52	0.51	0.56
1000	0.63	0.55	0.45	0.54
Mean	0.60	0.53	0.52	0.55

The frequency of application shows a highly significant negative linear effect on leaf-Mg. This decrease amounts to 0.04 $\pm$ 0.0104% for each additional two applications. This linear decrease is not significant over all the levels of N because the interaction between levels and frequency is significant.

The overall effect of increasing levels of N on the leaf-Mg over the entire period is given in Figure 8. The change from the negative highly significant linear effect of N at 9 months to a positive significant effect at 20 months is shown.

(e) <u>Sodium</u>

Figure 9 shows the overall effect of N levels on the leaf-Na.

At 9 months after planting neither N-levels nor frequency of N application had any significant effect of leaf-Na.

13 months after planting there was a significant negative linear effect with increasing levels of N on the leaf-Na. An average decrease of 0.0023 $\pm$ 0.00097% with each additional 200 Kg ammonium sulphate. There were no other significant effects of either the individual N levels or frequency on the leaf-Na.

At 20 months after planting only the negative quadratic effect of increasing levels of N on the leaf-Na was significant.

The average effect of increasing N levels on the means of the leaf-Na for the three sampling dates is given in Table 23.

TABLE 23. Means of leaf-Na (%) for the 3 sampling times.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Time of sampling (months from planting)			
	9	13	20	Mean
0	0.029	0.054	0.066	0.050
200	0.021	0.049	0.064	0.045
400	0.026	0.047	0.056	0.043
600	0.027	0.047	0.053	0.042
800	0.028	0.042	0.058	0.043
1000	0.024	0.042	0.069	0.045
Mean	0.026	0.047	0.061	0.045

L.S.D. ($P = 0.05$) means of N levels = 0.007% Na.
L.S.D. ($P = 0.01$) means of N levels = 0.01% Na.
L.S.D. ($P = 0.05$) means of sampling dates = 0.005% Na.
L.S.D. ($P = 0.01$) means of sampling dates = 0.006% Na.

The 400, 600 and 800 Kg levels of N gave a significant decrease in leaf-Na compared with the control. There was a significant positive quadratic effect of N levels on leaf-Na in the mean over the entire period.

At 20 months after planting there was more Na in the leaves than at 13 months, significant at 0.01. At the latter time the leaf-Na was higher than 9 months after planting, significant at 0.01.

(f) <u>Chlorophyll</u>

The chlorophyll content of the leaves 20 months after planting i.e. at flower differentiation, is given in Table 24.

TABLE 24. Chlorophyll (ppm) in leaves 20 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	169	125	154	149
200	222	136	227	195
400	161	192	189	181
600	201	247	174	207
800	217	219	200	212
1000	207	210	206	208
Mean	202	201	199	192

L.S.D. ($P = 0.05$) means of N levels = 53.48 ppm. C.V. 15.31%
L.S.D. ($P = 0.01$) means of N levels = 76.07 ppm.
L.S.D. ($P = 0.05$) means of N frequency = 30.37 ppm. C.V. 21.07%
L.S.D. ($P = 0.01$) means of N frequency = 41.04 ppm.

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The leaves of the three highest levels of N had a higher **chlorophyll** content compared with the control, significant at 0.05. There was no significant difference between any of the other treatments. Increasing levels of N had a positive significant linear effect on the chlorophyll content of the leaves, with an average increase of 10.6286 $\pm$ 4.05737% due to each additional 200 Kg ammonium treatments.

4·11 DISCUSSION AND CONCLUSIONS

1. Levels of ammonium sulphate.

In the plant crop, all the levels, with the exception of the 800 Kg ammonium sulphate, gave an increase, significant at 0.05, in the average weight of fruit per plot compared with the control. The quadratic effect with increasing levels of N however, was significant. The peak in increased weight of fruit was reached at the 600 Kg level, which represented an equivalent increase of 10.9 tons of fruit per acre compared with the control. The quadratic response was caused by a drop in yield of 6.9 tons of fruit per acre from the 600 Kg to the 800 Kg level. This drop in fruit was caused by a significant reduction in the number of fruit per plot at the latter level. On the whole the increase in weight of fruit per plot can be ascribed to a significant increase in the average weight per fruit in the nitrogen plots, compared with the control.

From the results it is apparent that the weight of fruit per plot, produced in the plant crop, is closely correlated with the nitrogen content of the leaves. This correlation is, however, more important during the eleven months period immediately preceding flower differentiation. Nine months after planting the highest level of N gave an increase in leaf-N, significant at 0.01, compared with the three lower levels of N. This, however, does not appear to have any correlation with the yield. This difference at nine months disappeared at thirteen months. ~~That is during the period immediately after the first~~

This represents the period from the end of the first winter to the following midsummer. During this period, therefore, the lower levels of ammonium sulphate were adequate to increase the leaf-N to the required level where significance disappeared.

deciding on the quantity of ammonium sulphate required, to give this desired effect, it will be necessary to mention that, at twenty months after planting the leaf-N in the 200 Kg level was lower than all the other N levels, and significant at 0.01. Although this treatment had no significant effect on the plant crop it may effect the first ratoon crop adversely. This will be ~~noticed~~ mentioned later in the discussion of the production of first ratoon suckers. It can be concluded therefore, that the quantity to be applied during the 9 to 13 months period in order to raise the leaf-N to the required value should be that applied in the 400 Kg and

In other words a total of 21.2 gm ammonium sulphate per plant obtained by the 400 Kg level which raised the leaf-N to 1.965% N, and not the 10.6 gm per plant as applied with the 200 Kg level.

represents the time from midsummer until flower differentiation, after the winter. The leaf-N was reduced from thirteen to twenty months, and significant at 0.01. According to Sideris and Young (1951) the total nitrogen in the non-chlorophyllous basal sections of the leaves, used for chemical analysis, is greater in the pre-flowering than post-flowering stages of plant growth. The leaf-N in the 200 Kg level was changed from not significant to significantly lower at 0.05 compared with the higher levels of N. As stated this may have a significant effect on the first ratoon crop and it is therefore advisable that the leaf-N should be 1.653% N, that is, the value for the 400 Kg level, at flower differentiation. The actual quantity of ammonium sulphate applied in the 400 Kg treatment during this period was 16.3 gm per plant.

The results obtained with increasing levels of N on the sucker production, after the plant crop, is important. The increase in sucker production, significant at 0.05, with 600 Kg ammonium sulphate compared with 200 Kg may result in an increase in the first ratoon crop because of the higher number of fruits that will be harvested. Therefore, although the 200 Kg level did not reduce the plant crop significantly, it will be advisable to use the 400 Kg level as a minimum quantity. The latter gave no significant difference in sucker production when compared with the 600 Kg treatment.

March is normally regarded as the peak harvesting month for cayenne pineapples. It is apparent from the results that up to March, 1963, the control produced a higher number of fruits compared with the N levels. It was only at the end of May, however, that the 600 Kg level produced a significantly higher number of fruits compared with the control. From this evidence it is clear that the higher levels of ammonium sulphate can be responsible for a delay in harvesting. From the results in

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project (A)T-O.L. 14 Dc, 1962/63 report, Pineapple Research Station, it was clear that a delay in the plant crop could be avoided if both ammonium sulphate and potassium sulphate were applied at optimum levels. The delay in harvesting of this experiment can, therefore, be attributed to the significant decrease in the leaf-K, at the time of flower differentiation, with increasing levels of N.

An additional factor in the delay of the crop may be excessive accumulation of leaf-N at flower differentiation at the higher levels. The 600 Kg, 800 Kg and 1000 Kg levels had 1.67%, 1.76% and 1.84% leaf-N, respectively, at this time compared with the desirable 1.633% N established above. According to Sideris, Young and Chun (1947) "excessive supplies of inorganic nitrogen either as NH_4^+ or NO_3^- may cause accumulations of soluble organic-N fractions produced by enzymatic synthesis from ammonia with carboxylic acids and similar to those presumably released from protein breakdown." According to Nightingale (1942) it is important, for optimum yields, to avoid excessive application of N when the leaf-content of N is already at an optimum.

The results obtained with the chlorophyll content of the leaves is in accordance with those of Tam and Magistad (1935). ~~That is,~~ The linear response of leaf-chlorophyll to increasing levels of N was positive and significant over the eleven months immediately preceding flower differentiation. Provided therefore, that iron deficiency is not a limiting factor, the chlorophyll content of the leaves can be used as a determining factor of available nitrogen. In this experiment there was no significant change in the total chlorophyll of the leaves from thirteen to twenty months after planting. If the determining quantities of leaf-N, as discussed above, ~~is taken into quantities of leaf-N, as discussed above,~~ is taken into consideration then it appears that the chlorophyll should be maintained at approximately 180 ppm during the eleven months preceding flower differentiation.

The response of Mg and Ca in the leaves to increasing levels of ammonium sulphate is very similar. The leaf content of both gave a negative linear reaction to increasing levels of N nine months after planting. In both instances, this effect disappeared after thirteen months growth. At flower differentiation, however, this linear response changed to a positive and significant increase of Mg and Ca. The results obtained

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with the K content of the leaves were directly opposite to those for Mg and Ca throughout the entire period. This indicates a strong interaction between these elements and may be due to the predominance of Mg and Ca in this particular soil. According to Sideris and Young (1950) high Ca concentrations interfered less with the absorption of K than high K concentrations with Ca. If this is taken into account it appears that the high Mg must be responsible for the depression of leaf-K. Except for the possible delay in fruiting caused by the low K there does not seem to be any further correlation with the yield. Apart from possible interactions of Na with Ca and/or Mg there did not appear to be any well defined reason for the apparent overall significant reduction of leaf-Na with increasing levels of N.

2. Frequency of application of ammonium sulphate.

Increasing frequency of application of ammonium sulphate resulted in reduction in the weight of fruit per plot. Two applications gave a higher yield (3.8 tons per acre) significant at 0.01, compared with six applications and also significantly higher (1.5 tons per acre) at 0.05, than four applications. The fact that the total number of fruit per plot was significantly lower with six applications, compared with two applications, proves that the crop was delayed with the higher levels. Here again the cause must have been the excessive accumulation of leaf-N. According to Nightingale (1942) the time of application of N is of great importance to avoid excessive accumulation of N when the leaf-N is already at an

The 400 kg level of ammonium sulphate, with a 1.963% leaf-N, was found to give the best yield, (irrespective of the frequency of application). If this latter leaf-N is compared with the 2.12% leaf-N, obtained with a frequency of six applications (irrespective of the level of ammonium sulphate applied), it is clear that the 2.12% N was excessive, at thirteen months after planting.

1.96% and 2.05% N respectively. The frequencies of 2, 4 and 6 applications had respectively 1, 2 and 3 applications of N, during this period (9 to 13 months). The total quantity of ammonium sulphate in each instance was 25.4 gm per plant. This weight is therefore in excess of that established under levels of N viz. 21.2 gm per plant. If the latter quantity is used therefore in two applications, it may be possible to obtain the required 1.963% leaf-N at thirteen months after planting. At flower differentiation, twenty months after planting, there was no significant difference between any of the frequency of application treatments. The frequency of 6 applications gave 1.795% N (irrispective of level of ammonium sulphate applied) which was higher than the 1.653%N established as desirable with the levels of ammonium sulphate (irrespective of the frequency of application).

may be applied in either one or two applications during the period of thirteen to twenty months.

The effect of frequency of application on the Mg and Ca content of the leaves is of interest. Thirteen months after planting. i.e. January in midsummer, the linear response of leaf-Mg and leaf-Ca to increasing frequency of N was negative and significant. The general response of Mg and Ca therefore followed the same linear pattern as the weight of fruit per plot. This was also the case with the levels of N. Whether increasing amounts of Mg and Ca may benefit the yields when directly or indirectly in association with nitrogen is not clear at this stage.

4.2: (A)T. - Bh. 3C:

THE EFFECT OF DIFFERENT LEVELS AND INTERVALS OF APPLICATION OF AMMONIUM SULPHATE ON THE GROWTH, CHEMICAL COMPOSITION AND YIELD OF CAYENNE PINEAPPLE PLANTS UNDER FIELD CONDITIONS:
EAST LONDON, ~~RED LOAM SOIL~~ REDDISH-BROWN, LOAM VIRGIN SOIL.

1. Yield.

The plant crop was harvested over the period from June 1962, to May 1963.

(a) Fruit weight per plot.

The average weight of fruit per plot is given in Table 1.

TABLE 1. Average weight (lb) of fruit per plot (plant crop)

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	97.49	103.07	91.86	98.03
200	147.49	144.90	151.71	148.00
400	153.22	149.98	167.87	157.02
600	159.79	154.79	164.65	159.74
800	157.16	164.40	168.14	163.23
1000	156.83	171.83	171.65	166.77
Mean	154.90	157.18	164.80	148.805

L.S.D. (P = 0.05) means of N levels = 10.6439 lb C.V. 8.75%
L.S.D. (P = 0.01) means of N levels = 14.1680 lb
L.S.D. (P = 0.05) means of N frequency = 6.4065 lb C.V. 11.92%
L.S.D. (P = 0.01) means of N frequency = 8.4634 lb

All levels of N gave an increase in fruit weight, per plot, significant at 0.01 compared with the control. 600 Kg and higher levels gave an increase over 200 Kg, significant at 0.05. The linear response of increasing levels of N on the fruit weight was positive and significant at 0.01. This response is not consistant for all levels as the quadratic effect was negative and significant at 0.01. The greatest response came from the application of the first 200 Kg, thereafter the response fell off in size until 800 Kg was reached. From the latter to 1000 Kg there was a slight but significant increase again.

A frequency of 6 applications of ammonium sulphate gave a higher yield, significant at 0.05 compared with four applications as well as an increase over 2 applications, significant at 0.01.

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The linear effect of frequency of application was significant at 0.05.

The conversion of the yield from Table 1 into tons per acre is given in Table 2.

TABLE 2. Average weight (tons) of fruit per acre (Plant crop).

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	22.64	23.94	21.34	22.64
200	24.26	33.65	35.24	31.00
400	35.59	34.83	38.99	36.47
600	37.11	35.95	38.24	37.10
800	36.50	38.18	39.05	37.91
1000	36.43	39.91	39.87	38.74
Mean	32.09	34.41	35.46	33.99

Table 2 shows that the increase in yield with 1000 Kg, compared with the control represented 16.1 tons per acre, significant at 0.01. The 600 Kg level gave an increase of 14.46 and 6.10 tons per acre compared with the control and the 200 Kg level. A frequency of six applications compared with 2 gave an increase of 3.27 tons per acre, significant at 0.01 level.

(b) Number of fruit:

None of the treatments had any significant effect on the number of fruit per plot. The linear response of number of fruit on increasing levels of N was positive and significant at 0.05. The quadratic effect, however, was significant at 0.01 with the largest difference between the control and the lowest level of N.

(c) Average weight per fruit.

The average weight per fruit for the plant crop is given in Table 3.

TABLE 3. Average weight (lb) per fruit (plant crop).

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	2.34	2.46	2.44	2.41
200	3.22	3.27	3.31	3.27
400	3.39	3.27	3.80	3.52
600	3.51	3.38	3.91	3.68
800	3.54	3.62	3.78	3.68
1000	3.50	3.71	3.96	3.79
Mean	3.43	3.91	3.75	3.39

L.S.D. (P = 0.05) means of N levels = 0.1754 lb C.V. 6.32%
L.S.D. (P = 0.01) means of N levels = 0.2334 lb
L.S.D. (P = 0.05) means of N frequency = 0.0996 lb C.V. 8.13%
L.S.D. (P = 0.01) means of N frequency = 0.1316 lb

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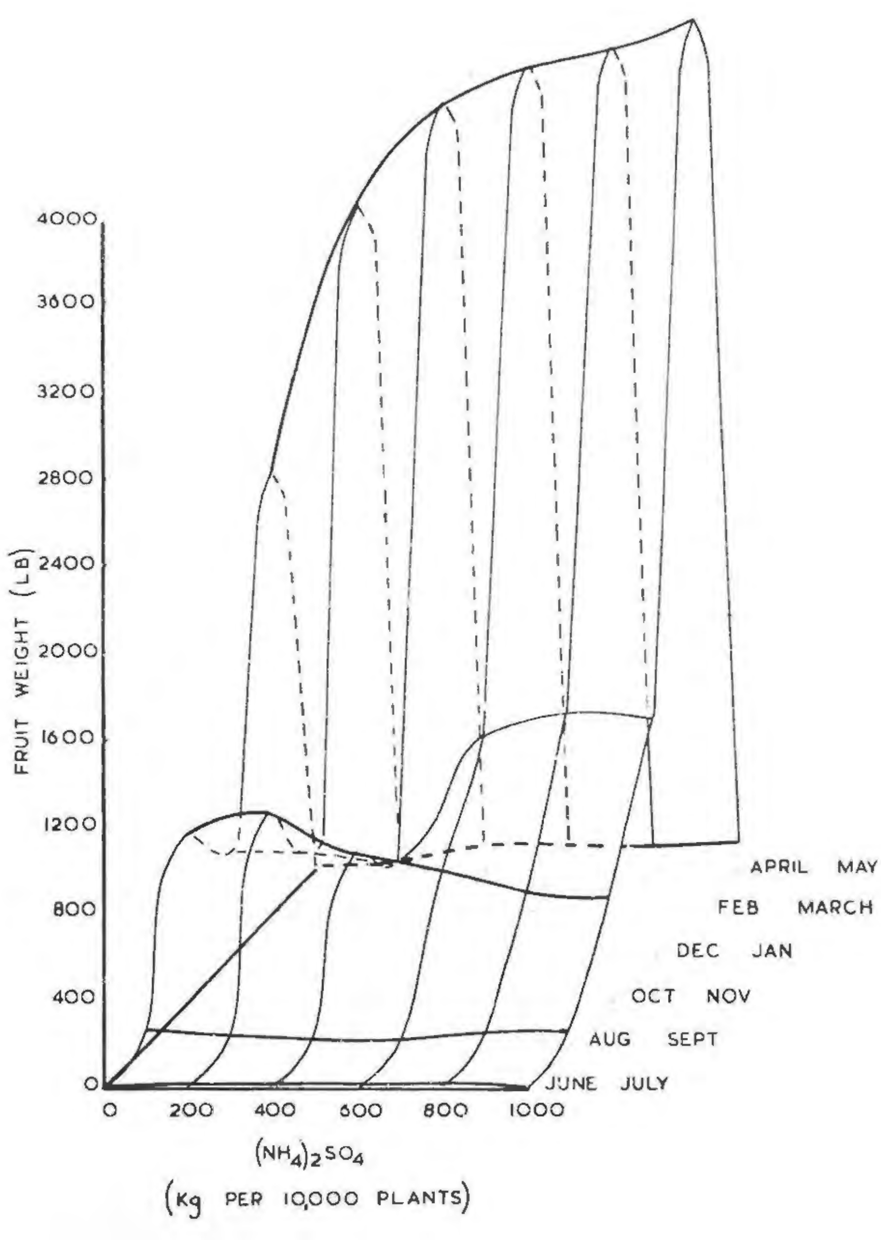

Figure 1. Fruit weight per plot for the plant crop.

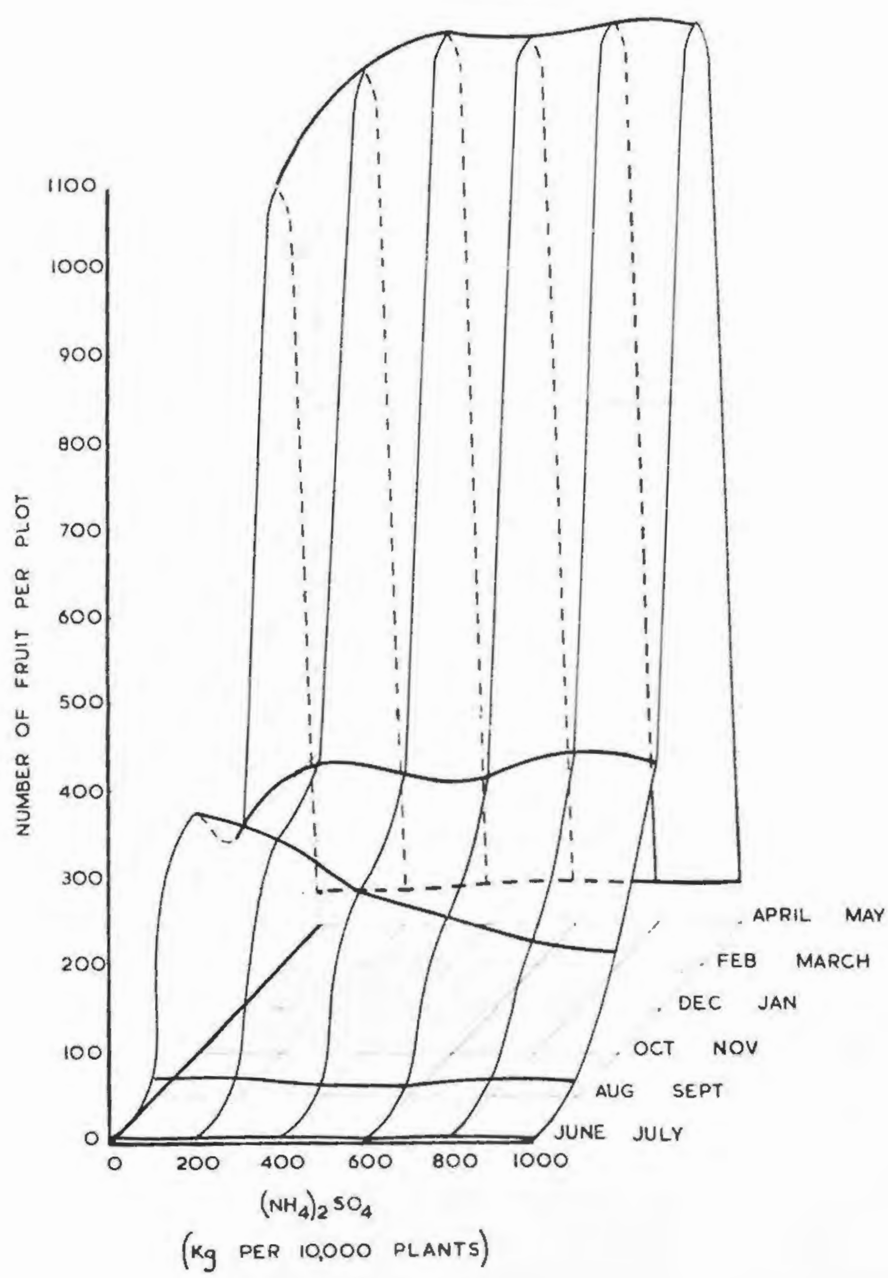

Figure 2. Number of fruit per plot for the plant crop.

All the levels of N from 400 Kg and higher gave an increase of the average weight per fruit, significant at 0.01, compared with 200 Kg and the control. The 1000 Kg treatment gave a higher average weight per fruit compared with 400 Kg, significant at 0.05.

A frequency of 4 and 6 applications gave an increase in average weight per fruit compared with 2, significant at 0.01. 4 Applications were, however, only significantly higher at 0.05, compared with 6 applications.

The linear response of average weight per fruit to increasing levels of N was significant at 0.01. This linear increase was not constant over all levels as the quadratic response was also significant at 0.01. The increase is greatest for the first addition of N and falls off fairly steadily with increasing levels of N.

The cubic effect of levels of N was highly significant. This was caused by the positive response of N on the average weight per fruit at the 1000 Kg level.

(d) Time of harvesting.

The effect of increasing levels of N on the fruit weight per plot throughout the harvesting period is presented in Fig. 1. None of the N levels produced a noticeably higher yield in the early crop. At the end of the spring crop, (October) there is an indication that the lower levels of N, and the control, gave a higher weight than 600 Kg and over. This position was exactly reversed at the end of December. From this time onwards the higher levels maintained the lead over the control. The lower levels of N, however, increased rapidly and overshadowed the control. Even at the end of the summer crop, April, the control dropped to the same low level compared with all the N treatments.

(e) Translucency.

The average degree of translucency per fruit is given in Table 4.

/ Table 4 .... 38.

TABLE 4. Average degree of translucency per fruit. (plant crop)

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.12	0.07	0.11	0.10
200	0.35	0.60	0.59	0.51
400	0.63	0.76	1.16	0.85
600	0.53	0.69	1.13	0.78
800	0.68	1.14	0.93	0.92
1000	0.96	1.21	1.13	1.10
Mean	0.63	0.88	0.99	0.71

L.S.D. ($P = 0.05$) means of N levels = 0.17. C.V. 50.01%
L.S.D. ($P = 0.01$) means of N levels = 0.22
L.S.D. ($P = 0.05$) means of N frequency = 0.09. C.V. 35.34%
L.S.D. ($P = 0.01$) means of N frequency = 0.12

The degree of translucency for the control was lower than all the N levels, significant at 0.01. The lowest N level was lower than all higher levels, and significant at 0.01. The highest N level was higher than the 400 and 600 Kg treatments and significant at 0.01, but only significantly higher at 0.05 compared with 800 Kg. The linear response of translucency to increasing levels of N was positive and significant at 0.01 with an average increase of 0.1756 $\pm$ 0.01416% for each increment of 200 Kg ammonium sulphate. This increase was not constant for all the levels as the quadratic response was also significant at 0.01.

A frequency of 2 applications of N gave a reduction in translucency compared with 4 and 6 applications, significant at 0.01. The 6 applications gave a higher degree of translucency than 4 applications, and significant at 0.05. The linear response of translucency to increasing frequency of application was positive and significant at 0.01, with an average increase of 0.180 $\pm$ 0.04186% for each additional two dressings.

(f) Number of suckers.

Table 5 gives the average number of suckers per plot, after the plant crop.

/ Table 5 .... 39.

TABLE 5. Average number of suckers per plot, after plant crop.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	49.8	48.8	48.4	49.0
200	55.6	53.9	57.0	55.5
400	59.2	55.2	60.1	58.2
600	58.8	58.3	58.8	58.6
800	58.3	59.8	65.4	61.2
1000	61.8	62.4	62.6	62.3
Mean	57.3	56.4	58.7	57.5

L.S.D. $(P = 0.05)$ means of N levels = 1.86. C.V. 6.33%
L.S.D. $(P = 0.01)$ means of N levels = 2.6
L.S.D. $(P = 0.05)$ means of N frequency = 1.29. C.V. 8.11%
L.S.D. $(P = 0.01)$ means of N frequency = 1.87

All the N levels gave a higher sucker production than the control, significant at 0.01. The 400 Kg level gave a higher production than 200 Kg, and significant at 0.01. The 800 and 1000 Kg levels were higher than all the other N levels, and also significant at 0.01.

The frequency of 6 applications gave a higher sucker production than 4, significant at 0.01, but only significantly higher at 0.05 compared with 2 applications.

(g) Number of slips.

Table 6 shows the average number of slips per plot, after the plant crop.

TABLE 6. Average number of slips per plot after the plant crop.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	1.58	2.42	1.92	1.97
200	17.00	19.08	20.75	18.94
400	18.83	24.17	28.58	23.86
600	19.83	29.83	26.33	25.33
800	24.08	26.92	25.83	25.61
1000	26.08	30.33	37.92	31.44
Mean	17.90	22.13	23.56	21.2

L.S.D. $(P = 0.05)$ means of N levels = 1.0860 C.V. 60.86%
L.S.D. $(P = 0.01)$ means of N levels = 1.5476
L.S.D. $(P = 0.05)$ means of N frequency = 0.2438. C.V. 44.89%
L.S.D. $(P = 0.01)$ means of N frequency = 0.3456.

All the N levels gave an increase in the number of slips, significant at 0.01, compared with the control.

/ The .... 40.

The 200 Kg level was lower than all the other N levels, and significant at 0.01. The 1000 Kg level was higher than all the other levels, and significant at 0 01. The 800 Kg and 600 Kg treatments were higher than the 400 Kg, and significant at 0.05.

A frequency of 4 applications gave an increase in slips, significant at 0.01 compared with 2 applications. 6 applications, in turn was higher than the former treatment, and significant at 0.01.

2. Leaf analysis.

(a) D-leaf weight and length.

The average weight per D-leaf 20 months after planting is given in Table 7.

TABLE 7. Average weight (gm) per D-leaf, 20 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	50.2	49.5	47.7	49.130
200	62.83	67.55	67.15	65.840
400	68.32	70.23	70.62	69.725
600	67.94	74.61	73.89	72.161
800	70.36	71.52	70.42	70.768
1000	73.23	71.49	74.14	72.954
Mean	68.54	71.08	71.24	66.763

L.S.D. (P = 0.05) means of N levels = 4.567 gm C.V. 8.36%
L.S.D. (P = 0.01) means of N levels = 6.079 gm
L.S.D. (P = 0.05) means of N frequency = 2.17 gm C.V. 8.89%
L.S.D. (P = 0.01) means of N frequency = 2.87 gm

The D-leaf weight of the control was lower than all the N levels, and significant at 0.01. The lowest level of N was lower than the 600 and 1000 Kg levels, significant at 0.01 but only significantly lower at 0.05 compared with the 800 Kg level. The linear response of D-leaf weight to increasing levels of N was positive and significant at 0.01. The quadratic response was negative and highly significant. The cubic response was highly significant from a depression at the 800 Kg level and a positive rise at the 1000 Kg level.

A frequency of 2 applications gave a lower D-leaf weight, significant at 0.05, compared with 4 and 6 applications. There was no significant difference between the latter two treatments. The linear response of D-leaf weight to increasing frequency of N application is positive and significant.

/ Table .... 41.

Table 8 gives the D-leaf length per plant at 6 months after planting.

TABLE 8. D-leaf length (inches) 6 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	19.8	20.2	19.6	19.9
200	21.2	20.1	21.7	21.0
400	20.4	20.3	21.0	20.6
600	20.9	20.9	21.5	21.1
800	20.3	20.4	21.8	21.6
1000	21.0	20.8	21.6	21.2
Mean	20.6	20.5	21.1	20.7

L.S.D. (P = 0.05) means of N levels = 0.6 inches
L.S.D. (P = 0.01) means of N levels = 0.9 inches
L.S.D. (P = 0.05) means of N frequency = 0.3 inches
L.S.D. (P = 0.01) means of N frequency = 0.4 inches

The D-leaves of the control were shorter than the 400 Kg treatment, significant at 0.05, but significantly shorter at 0.01 compared with all the other N levels.

A frequency of 6 applications of N gave longer D-leaves compared with 4 and 2 applications and significant at 0.01.

(b) Chlorophyll.

The chlorophyll content of the D-leaves 10 months after planting is given in Table 9.

TABLE 9. Chlorophyll content (ppm) of the leaves 10 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	111.7	114.5	99.8	108.7
200	105.3	86.3	103.1	98.2
400	126.7	118.7	128.1	124.5
600	113.5	101.8	115.0	110.1
800	131.2	125.4	123.7	126.8
1000	111.5	129.3	118.9	119.9
Mean	117.6	112.3	117.8	114.69

L.S.D. (P = 0.05) means of N levels = 20.428 ppm C.V. 21.78%
L.S.D. (P = 0.01) means of N levels = 27.192 ppm
L.S.D. (P = 0.05) means of N frequency = 14.535 ppm C.V. 35.10%
L.S.D. (P = 0.01) means of N frequency = 19.201 ppm

The levels 400, 800 and 1000 Kg gave higher chlorophyll concentrations, compared with the lowest level of N, significant at 0.05.

Frequency of application had no significant effect on the chlorophyll content of the leaves.

/ Table .... 42.

Table 10 shows the chlorophyll concentration in the D-leaves 15 months after planting.

TABLE 10. Chlorophyll content (ppm) in the leaves 15 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	151.4	159.3	147.1	152.6
200	167.3	183.7	171.1	174.0
400	173.4	188.8	184.0	182.1
600	180.3	75.3	147.4	167.9
800	177.6	193.9	187.8	186.4
1000	182.3	165.8	179.8	176.0
Mean	176.2	181.5	174.0	173.13

L.S.D. (P = 0.05) means of N levels = 22.752 ppm C.V. 16.07%
L.S.D. (P = 0.01) means of N levels = 30.285 ppm
L.S.D. (P = 0.05) means of N frequency = 18.832 ppm C.V. 30.12%
L.S.D. (P = 0.01) means of N frequency = 24.878 ppm

The levels 400, 800 and 1000 Kg $(NH_4)_2SO_4$ gave a higher chlorophyll concentration than the control, significant at 0.05.

The linear response of chlorophyll to increasing levels of N was positive and significant with an average increase of 3.9913 $\pm$ 1.9197% for each additional 200 Kg ammonium sulphate applied.

Frequency of application had no significant effect on the chlorophyll content.

Table 11 shows the chlorophyll concentration in the D-leaves 20 months after planting.

TABLE 11. Chlorophyll content (ppm) in the leaves 20 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	109.8	98.8	104.2	104.28
200	140.2	130.5	138.8	138.64
400	152.3	148.8	146.8	149.31
600	154.4	137.8	146.3	146.18
800	155.7	138.9	146.0	146.86
1000	156.1	148.6	135.7	146.78
Mean	151.74	140.92	142.72	138.85

L.S.D. (P = 0.05) means of N levels = 16.267 ppm C.V. 14.32%
L.S.D. (P = 0.01) means of N levels = 21.652 ppm
L.S.D. (P = 0.05) means of N frequency = 10.098 ppm C.V. 20.14%
L.S.D. (P = 0.01) means of N frequency = 13.340 ppm

All the nitrogen levels gave an increase in chlorophyll concentration over the control, significant at 0.01. The linear response of chlorophyll to increasing levels of N was positive and highly significant, with an average increase of 6.858 ± 1.373% for each additional 200 Kg ammonium sulphate. This increase was not constant over all levels as the quadratic response was negative and significant at 0.01.

Frequency of application had no significant effect on the chlorophyll content.

(c) Nitrogen.

The nitrogen content of the leaves 10 months after planting is given in Table 12.

TABLE 12. N content (%) in the leaves 10 month after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	1.21	1.23	1.25	1.23
200	1.36	1.32	1.35	1.34
400	1.39	1.35	1.36	1.37
600	1.44	1.36	1.44	1.41
800	1.51	1.47	1.56	1.51
1000	1.62	1.56	1.65	1.61
Mean	1.46	1.41	1.47	1.412

L.S.D. (P = 0.05) means of N levels = 0.063% N C.V. 5.41%
L.S.D. (P = 0.01) means of N levels = 0.083% N
L.S.D. (P = 0.05) means of N frequency = 0.055% N C.V. 10.81%
L.S.D. (P = 0.01) means of N frequency = 0.073%

All the N levels gave a higher leaf-N than the control, and significant at 0.01. The two highest N levels were higher than the three lowest levels, significant at 0.01. The highest N level was higher than the 800 Kg level, significant at 0.01. The linear response of leaf-N to increasing levels of N was positive and significant at 0.01, with an average increase of 0.07017 ± 0.00528% for each additional 200 Kg ammonium sulphate applied.

A frequency of 6 applications was higher than 4, and significant at 0.05. The quadratic response of leaf-N to increasing frequency of N applications was positive and significant at 0.05.

The nitrogen content of the leaves 15 months after planting is given in Table 13.

/Table 13 .... 44.

TABLE 13. N content (%) in the leaves 15 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	1.58	1.60	1.47	1.550
200	1.73	1.94	1.81	1.826
400	1.83	2.02	2.12	1.986
600	1.78	2.09	2.04	1.967
800	1.82	2.04	2.00	1.953
1000	1.75	2.05	1.97	1.924
Mean	1.78	2.03	1.99	1.868

L.S.D. $(P = 0.05)$ means of N levels = 0.101% N. C.V. 6.63%
L.S.D. $(P = 0.01)$ means of N levels = 0.135% N.
L.S.D. $(P = 0.05)$ means of N frequency = 0.079% N. C.V. 11.66%
L.S.D. $(P = 0.01)$ means of N frequency = 0.104% N.

All the N levels gave a higher leaf-N than the control, significant at 0.01. The lowest level of N was lower than all the other N levels, and significant at 0.01. The linear response of leaf-N to increasing levels of N was positive and significant, at 0.01 with an average increase of 0.0637 $\pm$ 0.0086% for each increment of 200 Kg ammonium sulphate applied. This increase was not constant, however, as the quadratic response was negative and significant at 0.01. The cubic effect was significant.

A frequency of 4 and 6 applications of N gave a higher leaf-N than 2 applications, significant at 0.01. There was no significant difference between 4 and 6 applications. The linear response of leaf-N to increasing frequency of N applications was positive and significant at 0.01, with an average increase of 0.105 $\pm$ 0.0182% for each additional 2 dressings. This was not constant as the quadratic response was also significant at 0.01.

The nitrogen content of the leaves 20 months after planting is given in Table 14.

TABLE 14. N content (%) in the leaves 20 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	1.05	1.10	1.20	1.120
200	1.10	1.18	1.19	1.154
400	1.07	1.19	1.20	1.153
600	1.25	1.27	1.31	1.269
800	1.22	1.26	1.30	1.256
1000	1.19	1.48	1.31	1.328
Mean	1.16	1.28	1.26	1.213

L.S.D. $(P = 0.05)$ means of N levels = 0.098% N C.V. 9.16%
L.S.D. $(P = 0.01)$ means of N levels = 0.121% N
L.S.D. $(P = 0.05)$ means of N frequency = 0.069% N C.V. 15.74%
L.S.D. $(P = 0.01)$ means of N frequency = 0.091% N

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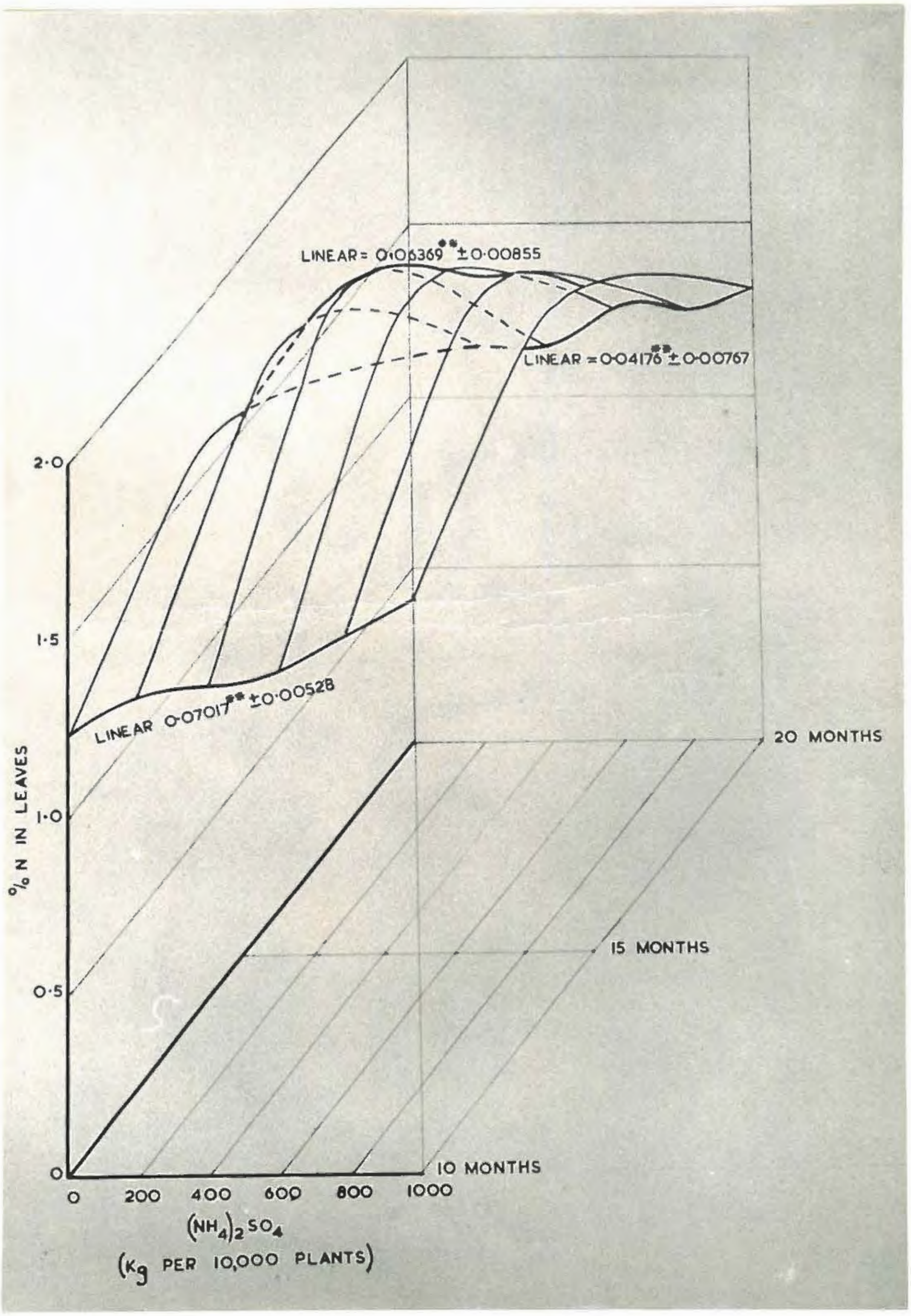

Figure 3. Overall effect of increasing levels of ammonium sulphate on the leaf-N.

The control gave a lower leaf-N compared with all the N levels, and significant at 0.01. The two lowest levels of N were lower than the highest N level, significant at 0.01, but only significantly lower at 0.05 compared with the 600 Kg and 800 Kg levels. The linear response of leaf-N to increasing levels of N was positive and significant at 0.01, with an average increase of 0.0418 $\pm$ 0.0077% for each increment of 200 Kg ammonium sulphate.

A frequency of 2 applications of N gave a lower leaf-N compared with 4 and 6 applications, significant at 0.01. There was no significant difference between the latter two treatments. The linear response of leaf-N to increasing frequency of application of N was positive and significant at 0.01 with an average increase of 0.05 $\pm$ 0.016% for each additional 2 dressings of ammonium sulphate. This was not constant as the quadratic effect was negative and significant.

The average response of leaf-N to increasing levels of N over the three sampling dates is given in Table 15.

TABLE 15. Average response of leaf-N (%) to increasing N levels over the entire sampling period.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Sampling times (months) from planting			
	10	15	20	Mean
0	1.23	1.55	1.12	1.29
200	1.34	1.83	1.15	1.44
400	1.37	1.99	1.15	1.50
600	1.41	1.97	1.27	1.55
800	1.51	1.95	1.26	1.57
1000	1.61	1.92	1.33	1.62
Mean	1.412	1.868	1.213	1.50

L.S.D. $(P = 0.05)$ means of N levels = 0.04% N
L.S.D. $(P = 0.01)$ means of N levels = 0.06% N

The control gave a lower leaf-N than all N levels, significant at 0.01. The 2 lowest levels of N were lower than the two highest N levels, significant at 0.01, and significantly lower at 0.05 compared with the 600 Kg level. The highest N level was higher than the 800 Kg level, significant at 0.05. Figure 3 shows the average linear response, over the entire period, of leaf-N to increasing levels of N which was positive and significant at 0.01. The quadratic response was negative and significant, at 0.01. The cubic effect was significant with a sudden rise of leaf-N in the 1,000 Kg level.

/ At .... 46.

At the 15 months period the leaf-N was highly significantly higher than at the 10 and 20 month periods.

The average response of leaf-N to increasing frequency of N application over the three sampling dates is given in Table 16.

TABLE 16. Average response of leaf-N (%) to increasing frequency of N applications over the entire sampling period.

Frequency of application	Sampling times (months) from planting			
	10	15	20	Mean
2	1.46	1.[illegible]8	1.16	1.46
4	1.41	2.03	1.28	1.57
6	1.47	1.99	1.26	1.58
Mean	1.412	1.868	1.213	1.53

L.S.D. (P = 0.05) means of N frequency = 0.04% N
L.S.D. (P = 0.01) means of N frequency = 0.05% N

A frequency of two applications of N gave a lower leaf-N than 4 and 6 applications over the entire period, and significant at 0.01. There was no significant difference between the latter two frequencies.

The mean linear response to frequency of application over the entire period was positive and significant at 0.01. The mean quadratic response over the entire period was negative and significant at 0.01.

(d) Potassium.

The potassium content of the leaves 10 months after planting is given in Table 17.

TABLE 17. K content (%) in the leaves 10 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	2.63	2.54	2.36	2.511
200	2.28	2.48	2.15	2.325
400	2.38	2.21	2.41	2.332
600	2.27	2.19	2.29	2.250
800	2.28	2.41	2.09	2.260
1000	2.19	2.21	2.13	2.179
Mean	2.280	2.300	2.216	2.309

L.S.D. (P = 0.05) means of N levels = 0.277% K C.V. 14.66%
L.S.D. (P = 0.01) means of N levels = 0.369% K
L.S.D. (P = 0.05) means of N frequency = 0.184% K C.V. 22.00%
L.S.D. (P = 0.01) means of N frequency = 0.243% K

The highest level of N gave a lower leaf-K compared with the control and significant at 0.05. The linear response of leaf-K to increasing levels of N was negative and significant at 0.05, with an average decrease of 0.0554 ± 0.0234% for each additional 200 Kg ammonium sulphate.

There was no significant difference in leaf-K 15 months after planting with increasing levels of N. The quadratic effect of increasing frequency of application of N on the leaf-K was negative and significant at 0.01.

The potassium content of the leaves 20 months after planting is given in Table 18.

TABLE 18. K content (%) in the leaves 20 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	1.45	1.62	1.67	1.567
200	1.39	1.43	1.36	1.393
400	1.18	1.34	1.34	1.286
600	1.28	1.30	1.34	1.281
800	1.25	1.23	1.35	1.275
1000	1.11	1.30	1.15	1.190
Mean	1.24	1.32	1.31	1.332

L.S.D. (P = 0.05) means of N levels = 0.134% K C.V. 12.3%
L.S.D. (P = 0.01) means of N levels = 0.178% K
L.S.D. (P = 0.05) means of N frequency = 0.08% K C.V. 16.7%
L.S.D. (P = 0.01) means of N frequency = 0.11% K

The leaf-K for the highest level of N was lower than the control and the lowest N level, significant at 0.01. The control was higher than the 400, 600 and 800 Kg levels, significant at 0.01, but only significantly higher at 0.05, compared with the 200 Kg level. The linear response of leaf-K to increasing levels of N is negative and significant at 0.01, with an average decrease of 0.064 ± 0.0113% for each additional 200 Kg ammonium sulphate.

A frequency of 2 applications of N gave a decrease in leaf-K compared with 4 applications, significant at 0.05.

The average response of leaf-K to increasing levels of N over the entire period of sampling is given in Table 19.

/ Table 19 .... 48.

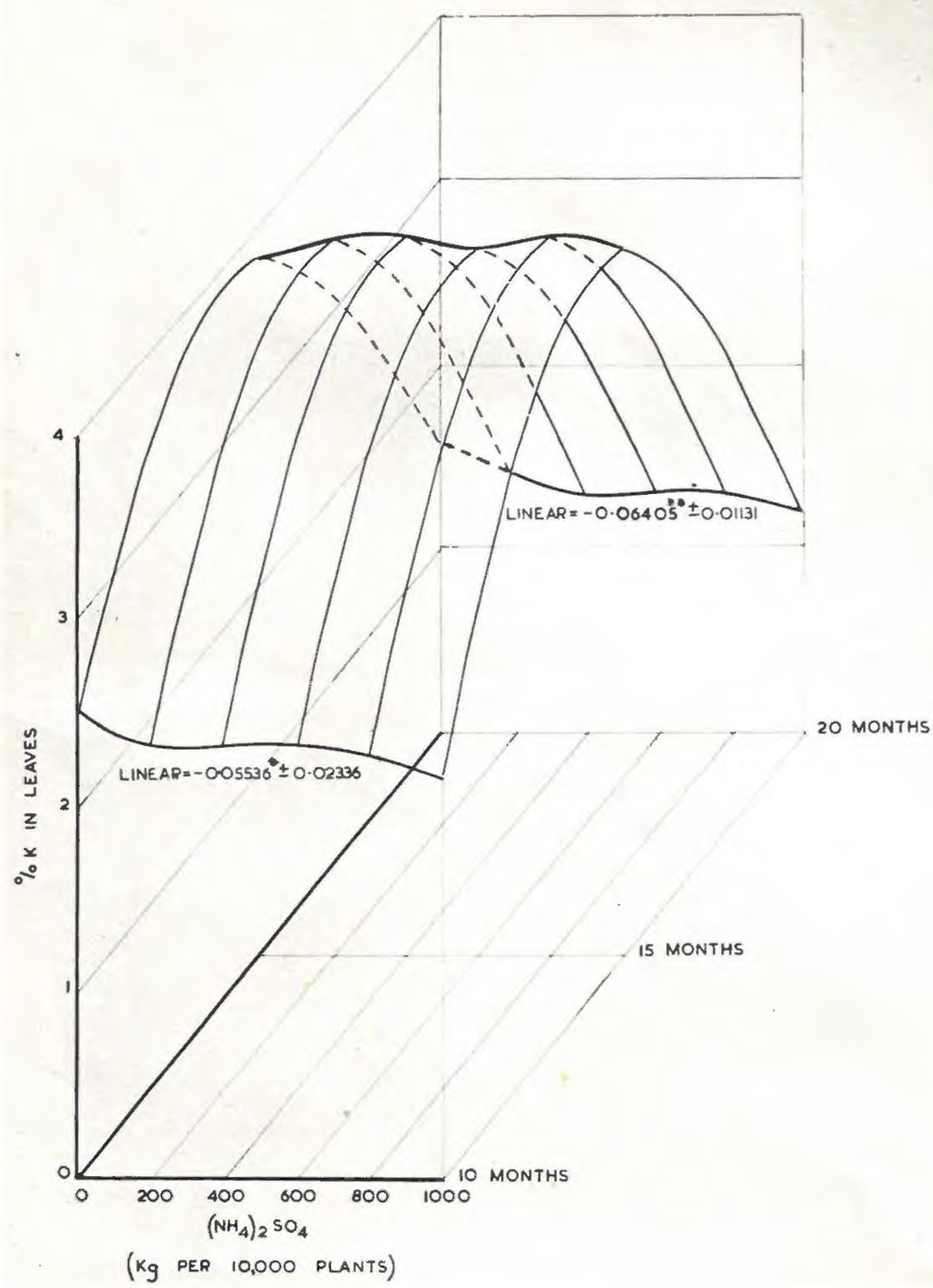

Figure 4. Overall effect of increasing levels of ammonium sulphate on the leaf-K.

TABLE 19. Average response of leaf-K (%) to increasing levels of N over the entire sampling period.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Sampling time (months) from planting			
	10	15	20	Mean
0	2.51	3.76	1.57	2.61
200	2.33	3.85	1.39	2.52
400	2.33	3.89	1.29	2.50
600	2.25	3.81	1.28	2.45
800	2.26	3.90	1.28	2.48
1000	2.18	3.82	1.19	2.40
Mean	2.309	3.838	1.332	2.49

L.S.D. (P = 0.05) means of N levels = 0.17% K
L.S.D. (P = 0.01) means of N levels = 0.023% K
L.S.D. (P = 0.05) means of sampling times = 0.09% K
L.S.D. (P = 0.01) means of sampling times = 0.12% K

The control had a higher mean leaf-K content than the highest level of N, significant at 0.05. The linear effect of increasing levels of N on the leaf-K was negative and significant at 0.05 with an average decrease of 0.0366 ± 0.0143% for each additional 200 Kg of ammonium sulphate. This linear effect over the period is shown in figure 4.

The leaf-K was higher at 15 months than at 10 and 20 months after planting, and significant at 0.01. There was no significant difference between the latter two times of sampling.

The average response of leaf-K to increasing frequency of N application over the entire period is given in Table 20.

TABLE 20. Average response of leaf-K (%) to increasing frequency of N applications over the entire sampling period.

Frequency of application	Sampling time (months) from planting			
	10	15	20	Mean
2	2.28	3.79	1.24	2.44
4	2.30	4.01	1.32	2.55
6	2.22	3.76	1.31	2.42
Mean	2.31	2.84	1.33	2.47

L.S.D. (P = 0.05) means of N frequency = 0.09% K.
L.S.D. (P = 0.01) means of N frequency = 0.12% K.

A frequency of 4 applications of N gave a higher leaf-K than 6 applications, significant at 0.01, but only significantly higher at 0.05 compared with 2 applications. The mean quadratic response of leaf-K to increasing levels of N was negative and significant at 0.01.

/ (e) .... 49.

(e) Magnesium.

The magnesium content of the leaves 10 months after planting is given in Table 21.

TABLE 21. Mg content (%) of the leaves 10 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.54	0.59	0.54	0.557
200	0.50	0.61	0.65	0.585
400	0.61	0.59	0.61	0.604
600	0.61	0.63	0.62	0.620
800	0.67	0.64	0.58	0.629
1000	0.63	0.64	0.65	0.640
Mean	0.59	0.62	0.61	0.6059

L.S.D. (P = 0.05) means of N levels = 0.057% Mg C.V. 11.57%
L.S.D. (P = 0.01) means of N levels = 0.076% Mg
L.S.D. (P = 0.05) means of N frequency = 0.039% Mg C.V. 17.85%
L.S.D. (P = 0.01) means of N frequency = 0.052% Mg

The control gave a lower leaf-Mg compared with the highest N level, significant at 0.01 but only significantly lower at 0.05 compared with the 600 and 800 Kg levels. The linear response of leaf-Mg to increasing levels of N was positive and significant at 0.01 with an average increase of 0.01598 ± 0.00484% for each additional 200 Kg ammonium sulphate.

There were no significant differences between the means of the frequency of application.

The magnesium content of the leaves 15 months after planting is given in Table 22.

TABLE 22. Mg content (%) of the leaves 15 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.68	0.64	0.62	0.647
200	0.72	0.81	0.71	0.744
400	0.82	0.87	0.83	0.846
600	0.81	0.87	0.75	0.811
800	0.83	0.88	0.76	0.821
1000	0.85	0.83	0.84	0.841
Mean	0.808	0.852	0.778	0.785

L.S.D. (P = 0.05) means of N levels = 0.055% Mg C.V. 8.59%
L.S.D. (P = 0.01) means of N levels = 0.073% Mg
L.S.D. (P = 0.05) means of N frequency = 0.047% Mg C.V. 16.63%
L.S.D. (P = 0.01) means of N frequency = 0.062% Mg

/ All .... 50.

All the N levels gave a higher leaf-Mg than the control, significant at 0.01. The lowest level of N was lower than the 2 highest N levels and the 400 Kg level significant at 0.01, and also significantly lower at 0.05 compared with the 600 Kg level. The linear response of leaf-Mg to increasing levels of N was positive and significant at 0.01 with an average increase of 0.0333 ± 0.0047% for each increment of 200 Kg ammonium sulphate. The cubic effect was also significant because of a sudden rise in leaf-Mg at the 1000 Kg level.

A frequency of 4 applications of N gave an increase in leaf-Mg significant at 0.05 compared with 6 applications. The quadratic response of increasing frequency of applications was significant at 0.01.

The magnesium content of the leaves 20 months after planting is given in Table 23.

TABLE 23. Mg content (%) of the leaves 20 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.37	0.36	0.37	0.367
200	0 39	0.41	0.40	0.398
400	0.40	0.40	0.42	0.407
600	0.43	0.44	0.42	0.407
800	0.43	0.40	0.44	0.424
1000	0.42	0.44	0.43	0.437
Mean	0.41	0.42	0.42	0.410

L.S.D. (P = 0.05) means of N levels = 0.03% Mg C.V. 8.91%
L.S.D. (P = 0.01) means of N levels = 0.04% Mg
L.S.D. (P = 0.05) means of N frequency = 0.02% Mg C.V. 14.81%
L.S.D. (P = 0.01) means of N frequency = 0.03% Mg

The control gave a lower leaf-Mg, significant at 0.05, compared with the 200 Kg level but was significantly lower at **0.01** compared with all the other N levels. The lowest level of N was significantly lower at 0.05 compared with the 600 and 1000 Kg levels. The linear response of leaf-Mg to increasing levels of N was positive and significant at 0.01 with an average increase of 0.01286 ± 0.012865% for each increment of 200 Kg ammonium sulphate.

There were no significant differences in the leaf-Mg to increasing levels of N over the entire period of sampling is given in Table 24.

/Table 24 .... 51.

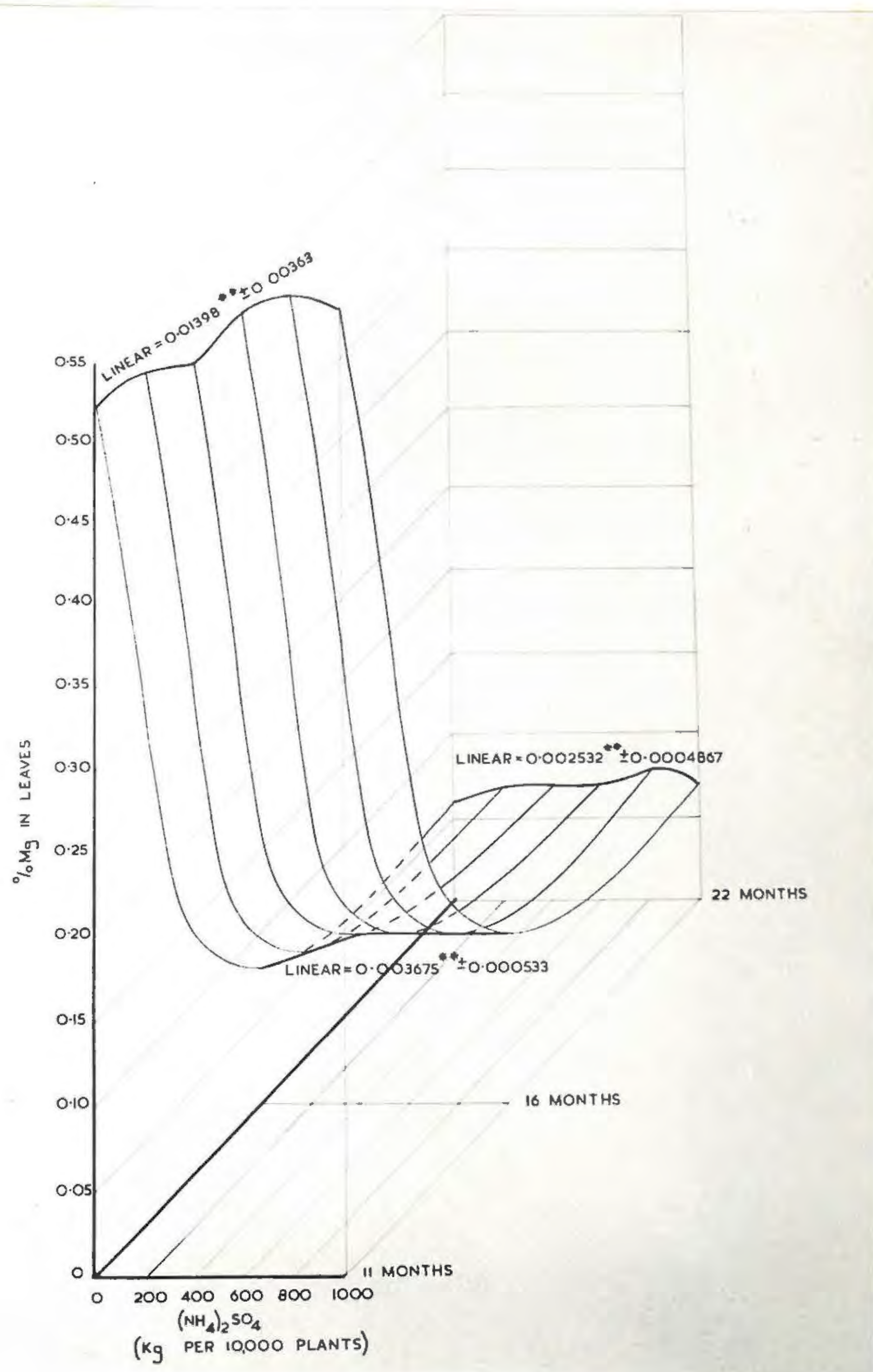

Figure 5. Overall effect of increasing levels of ammonium sulphate on the leaf-Mg.

TABLE 24. Average response of leaf-Mg (%) to increasing levels of N over the entire sampling period.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Sampling time (months) from planting			
	10	15	20	Mean
0	0.56	0.65	0.37	0.52
200	0.59	0.74	0.40	0.58
400	0.60	0.85	0.41	0.62
600	0.62	0.81	0.41	0.62
800	0.63	0.82	0.42	0.62
1000	0.64	0.84	0.44	0.64
Mean	0.606	0.785	0.410	0.60

L.S.D. (P = 0.05) means of N levels = 0.03% Mg
L.S.D. (P = 0.01) means of N levels = 0.04% Mg
L.S.D. (P = 0.05) means of sampling times = 0.02% Mg
L.S.D. (P = 0.01) means of sampling times = 0.03% Mg

The mean leaf-Mg over the entire period was significantly lower at 0.01 for the control than all the N levels. The lowest level of N was lower than all the other N levels and significant at 0.01. The mean linear response of leaf-Mg to increasing levels of N, over the entire period, was positive and significant at 0.01. The linear response over this period is shown in figure 5. The quadratic effect was negative and significant at 0.01.

The leaf-Mg was higher at 15 months after planting than at both 10 and 20 months, and significant at 0.01. At 10 months it was higher than at 20 months, significant at 0.01.

The average response of leaf-Mg to increasing frequency of application of N over the entire period of sampling is given in Table 25.

TABLE 25. Average response of leaf-Mg (%) to increasing frequency of N applications over the entire sampling period.

Frequency of application.	Sampling time (months) from planting			
	10	15	20	Mean
2	0.59	0.81	0.41	0.61
4	0.62	0.85	0.42	0.63
6	0.61	0.78	0.42	0.61
Mean	0.61	0.79	0.41	0.62

L.S.D. (P = 0.05) means of N frequency = 0.02% Mg
L.S.D. (P = 0.01) means of N frequency = 0.03% Mg

/ A .... 52.

A frequency of 4 applications of N gave a higher leaf-Mg, significant at 0.05, compared with 2 and 6 applications. There was no significant difference between the latter 2 treatments. The quadratic response of leaf-Mg to increasing frequency of application of N was negative and significant at 0.05.

(f) Calcium.

The calcium content of the leaves 10 months after planting is given in Table 26.

TABLE 26. Ca content (%) of the leaves 10 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.27	0.29	0.29	0.283
200	0.29	0.30	0.35	0.312
400	0.35	0.29	0.31	0.319
600	0.37	0.32	0.31	0.335
800	0.37	0.35	0.25	0.338
1000	0.37	0.36	0.36	0.364
Mean	0.35	0.32	0.32	0.325

L.S.D. (P = 0.05) means of N levels = 0.037% Ca C.V. 13.98%
L.S.D. (P = 0.01) means of N levels = 0.050% Ca
L.S.D. (P = 0.05) means of N frequency = 0.030% Ca C.V. 25.85%
L.S.D. (P = 0.01) means of N frequency = 0.040% Ca

The three highest levels of N gave an increase in leaf-Ca, significant at 0.01 compared with the control. The highest level of N was significantly higher at 0.01 compared with the 200 Kg level and significantly higher at 0.05 compared with 400 Kg.

The linear response of leaf-Ca to increasing levels of N was positive and significant at 0.01, with an average increase of 0.01429 $\pm$ 0.00314% for each increment of 200 Kg ammonium sulphate.

A frequency of 2 applications of N gave a significantly higher leaf-Ca compared with 4 and 6 applications. There was no significant difference between the latter 2 treatments.

The calcium content of the leaves 15 months after planting is given in Table 27.

/Table 27 .... 53.

TABLE 27. Ca content (%) of the leaves 15 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.69	0.57	0.60	0.619
200	0.89	0.81	0.73	0.808
400	0.95	0.82	0.96	0.909
600	0.92	1.10	0.87	0.962
800	0.90	0.94	0.77	0.869
1000	0.95	0.91	0.88	0.914
Mean	0.922	0.916	0.84	0.847

L.S.D. (P = 0.05) means of N levels = 0.107% Ca C.V. 15.41%
L.S.D. (P = 0.01) means of N levels = 0.142% Ca
L.S.D. (P = 0.05) means of N frequency = 0.082% Ca C.V. 26.93%
L.S.D. (P = 0.01) means of N frequency = 0.109% Ca

The control gave a lower leaf-Ca than all the N levels, significant at 0.01. The lowest level of N was significantly lower at 0.01 compared with the 600 Kg level. The linear response of leaf-Ca to increasing levels of N was positive and significant at 0.01, wit an average increase of 0.04892 ± 0.00901% for each additional 200 Kg ammonium sulphate. This increase was however, not consistant for all levels as the quadratic response was negative and significant at 0.01.

The calcium content of the leaves 20 months after planting is given in Table 28.

TABLE 28. Ca content (%) of the leaves 20 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.18	0.18	0.20	0.184
200	0.18	0.18	0.18	0.181
400	0.23	0.19	0.22	0.213
600	0.23	0.19	0.20	0.207
800	0.24	0.22	0.23	0.231
1000	0.22	0.24	0.21	0.223
Mean	0.22	0.20	0.21	0.206

L.S.D. (P = 0.05) means of N levels = 0.027% Ca C.V. 15.77%
L.S.D. (P = 0.01) means of N levels = 0.035% Ca
L.S.D. (P = 0.05) means of N frequency = 0.021% Ca C.V. 28.48%
L.S.D. (P = 0.01) means of N frequency = 0.028% Ca

The 800 and 1000 Kg levels gave a higher leaf-Ca than the control and 200 Kg level, significant at 0.01. The latter two treatments were significantly lower at 0.05 compared with the 400 Kg level. The linear response of leaf-Ca to increasing levels of N was positive and highly significant at 0.05 with an average increase of 0.00969 ± 0.00225% for each an increment of 200 Kg ammonium sulphate.

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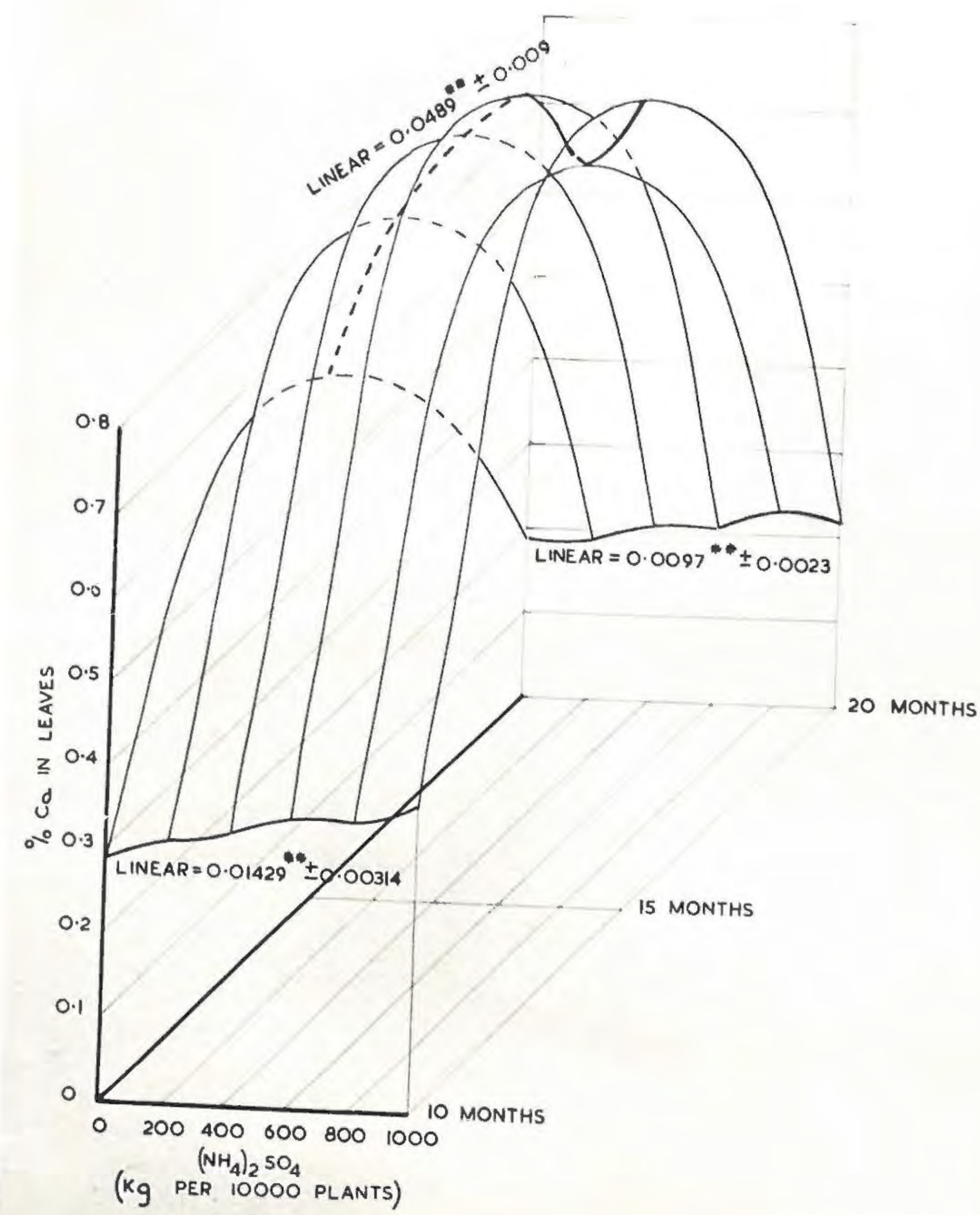

Figure 6. Overall effect of increasing levels of ammonium sulphate on the leaf-Ca.

There were no significant differences between increasing frequency of N applications.

The average response of leaf-Ca to increasing levels of N over the entire period of sampling is given in Table 29.

TABLE 29. Average response of leaf-Ca (%) to increasing levels of N over the entire sampling period.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Sampling time (months) from planting.			
	10	15	20	Mean
0	0.28	0.62	0.18	0.36
200	0.31	0.81	0.18	0.43
400	0.32	0.91	0.21	0.48
600	0.34	0.96	0.21	0.50
800	0.34	0.87	0.23	0.48
1000	0.36	0.91	0.22	0.50
Mean	0.33	0.85	0.21	0.46

L.S.D. (P = 0.05) means of N levels = 0.14% Ca
L.S.D. (P = 0.01) means of N levels = 0.18% Ca
L.S.D. (P = 0.05) means of sampling times = 0.09% Ca
L.S.D. (P = 0.01) means of sampling times = 0.12% Ca

The control gave a significantly lower leaf-Ca, at 0.05, compared with the 600 Kg and 1000 Kg levels. The mean linear response of leaf-Ca over the entire period was positive and significant, at 0.01. This overall response is shown in figure 6. The linear response due to increasing levels of N varies with the time. Starting at an increase of 0.014% Ca at 10 months, increasing to 0.049% Ca at 15 months and dropping to 0.010% Ca at 20 months for every 200 Kg increase. The mean quadratic response over the entire period was negative and significant at 0.01.

The leaf-Ca was higher 15 months after planting compared with 10 and 20 months, significant at 0.01. At 20 months the leaf-Ca was lower than at 10 months and significant at 0.01.

(g) Sodium

Increasing levels of nitrogen and increasing frequency of N application had no significant influence on the leaf-Na.

4.21 DISCUSSION AND CONCLUSIONS

1. Levels of ammonium sulphate.

All levels of ammonium sulphate produced an increase in weight of fruit per plot, significant at 0.01 compared with the control. The 600 Kg and higher levels of ammonium sulphate were also significantly higher than the 200 Kg level, but at 0.05.

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Although these results gave a positive linear increase in fruit weight per plot with increasing levels of N, significant at 0.01, the quadratic response was negative and significant at 0.01. The highest peak in this response was reached at the 600 Kg level, which gave an equivalent increase of 14.46 tons of fruit per acre compared with the control. Although the 1,000 Kg level produced an equivalent of 16.1 tons per acre more than the control, it was not significantly higher than the 600 Kg level, and therefore not any more economical. There was no significant difference in the number of fruit per plot. The increase in weight of fruit per plot, must therefore, be due to similar increases in the average weight per fruit with increasing levels of N.

The response of fruit weight per plot, with increasing levels of N, is very similar to the results obtained with the nitrogen content of the leaves. This correlation is particularly important during the ten months preceding flower differentiation. Ten months after planting, that is immediately after the first winter, the linear response of leaf-N to increasing levels of ammonium sulphate was positive and significant at 0.01. The two highest levels of N gave a significantly higher leaf-N at 0.01 compared with the 600 Kg and 400 Kg levels, but gave no significant increase in yield. These responses do not seem to have any connection with the eventual yield, and it may therefore be concluded, that the leaf-N up to ten months after planting will not be critical. All that will be necessary is sufficient ammonium sulphate to stimulate plant growth. The main response being in the D-leaf growth at six months after planting. In the treatment with a frequency of six applications the plants have already received two applications during that period whereas the plants in the frequency of four and two applications only received one application. Where the plants have received two applications during the first six months the D-leaf growth was increased significantly compared with only one. This indicated, therefore, that two smaller quantities of even 3.3 gm ammonium sulphate gave equal and better growth than larger quantities. Sideris and Young (1950) found that nitrate absorption was very low during the first three months period after planting. From the second three month period, however, nitrate absorption increased considerably. This indicates that the one application of ammonium sulphate which was applied during the third month after planting, in the frequency of two and four treatments were ineffective because of the inability of the plants to utilize the nitrogen. In the frequency of six applications treatment the second application was made during the second three month period which will account for the significant increase in growth. During the period ten to fifteen months after planting, i.e. from October to March, through the spring and summer months, it appears to be important to have an optimum leaf-N. Fifteen months after planting, the control and the lowest level of N gave a significant reduction in leaf-N compared with the higher N levels. This was in closer correlation with the weight of fruit per plot as in both instances there were also no significant differences between the four highest levels of N. The 400 Kg ammonium sulphate level which was the lowest level to give a significant increase gave 1.986% leaf-N. It appears, therefore, that this optimum leaf-N content will be adequate for an optimum yield. A total quantity of 23.4 gm ammonium sulphate per plant was applied in the 400 Kg level to give 1.986% leaf-N.

From the end of summer, fifteen months after planting, no further ammonium sulphate was applied per plant. The leaf-N dropped during this period, significant at 0.01. At the end of winter, during flower differentiation, therefore, the two lowest levels of N were significantly lower in leaf-N than the higher levels of N. It appears now that although the optimum required leaf-N at fifteen months, 1.986%, was in accordance with the results of project (A) T.-Bh. 3, 1.963%, it dropped at flower differentiation to 1.153% leaf-N as compared with 1.633% leaf-N in the latter project. This lower leaf-N may not have effected the plant crop but it could have been responsible for the differences between the two highest and lower levels of N in the sucker production after the plant crop, significant at 0.01. Adequate sucker production is most important for the number of fruit, and therefore the total yield, in the first ratoon crop. These suckers start to develop mostly from after flower differentiation. It appears, therefore, that it would have been advisable to give one or two applications of ammonium sulphate during the fifteen to twenty months period. The leaves were already at the optimum of 1.980% leaf-N at fifteen months, therefore, the only period ammonium sulphate can be applied to advantage will be between fifteen and twenty months. The quantity necessary will probably be that required to increase the leaf-N from 1.153% to 1.633%. The necessity for an application of ammonium sulphate during this period is emphasized by the fact that from the time of the last application, fifteen months after planting, these plants will not have any further nitrogen until after the plant crop, twenty seven months after planting. According to Nightingale (1942) it is not advisable to fertilise pineapple plants after flower differentiation, as it would have no further beneficial effect on the yield. Therefore, to shorten this period of twelve months without nitrogenous fertiliser, some applications may be made during the fifteen to twenty month period.

The increase in slips at the 1000 Kg level, significant at 0.01 compared with all the lower N levels is further indication that the leaf-N at twenty months may have been higher. Slip production for planting material is important provided there will not be an excess which may interfere with sucker production and growth for the first ratoon crop. In this instance, however, the average slip production was only approximately 0.5 slips per plant which may be considered as low. Slips are formed on the peduncle after fruit formation and additional ammonium sulphate fertilisation just prior to this, during the fifteen to twenty month period, may be to advantage.

The linear response of the degree of translucency of the fruit to increasing levels of ammonium sulphate was positive and significant at 0.01. A degree of translucency of up to approximately 1 is normally tolerated by canneries. Even the degree of 1.10 with the highest level of N in this project need not seriously affect the canning quality. The quadratic response was also significant, therefore, the quality may not be of any serious consequences.

A response in the plant growth can be seen in the positive linear response of D-leaf weight to increasing levels of N, significant at 0.01. The quadratic response, however, was negative and significant at 0.01 indicating that the response drops off at higher levels. It is therefore doubtful whether plant growth could be improved during the plant crop period. Any benefit from additional ammonium sulphate applications may only be on the first ratoon crop. The results of the average weight per D-leaf appears to be closely correlated with the average weight per fruit. Py and Lossois (1962) also established a correlation between D-leaf weight and average weight per fruit. This relationship was also established in the first cycle of project (A)T. - Bh. 4 on the Bathurst Research Station. These results will be of particular interest in crop estimates.

The positive and significant linear response of the leaf-chlorophyll to increasing levels of N at 10, 15 and 20 months after planting is in accordance with the results obtained with leaf-N. Also the higher leaf-chlorophyll at fifteen months compared with 10 and 20 months after planting was similar. The chlorophyll analysis of leaves in the experiment can, however, not be used with great accuracy in determining the leaf-N status. Where leaf-N gave clearly significant lower values for the two lowest levels of N compared with the higher levels, it was not the case with leaf-chlorophyll. The reason for this deviation was the chlorosis produced by iron deficiency in the plants. The loss in chlorophyll as a result of iron deficiency was therefore confused with that caused through nitrogen deficiency, and the chlorophyll of the higher N levels was lowered accordingly.

Increasing levels of ammonium sulphate resulted in a negative and significant linear effect on the leaf-K ten to twenty months after planting. Fifteen months after planting there was no significant influence by N on the leaf-K but the latter was on the average highly significantly higher than at ten and twenty months. This indicates a suppressing effect of increasing levels of N on the leaf-K during the winter months when there is no active growth. During the summer months, ten to fifteen months, the plants could apparently ab adequate potassium through the roots to supply the plants' needs. It may be, however, that the depressing effect of N levels is only indirect as a result of the interaction of K with Ca and Mg. The latter two nutrients gave the exact opposite results in leaf content with increasing levels of N compared with leaf-K.

Magistad (1934), showed that the soil must contain from 160 to 220 ppm exchangeable potash if the requirement of the plant is to be fully satisfied. Annexure B indicates, therefore, that the potash content of the soil in this project should have been adequate for plant growth. The response of leaf-K to the nitrogen treatment can, therefore, be considered as a guide to what can be expected under normal conditions in the field.

2. Frequency of application of ammonium sulphate.

A frequency of six applications of ammonium sulphate increased the weight of fruit per plot significantly, compared with four applications (1.05 tons per acre) and two applications (3.37 tons per acre). The reason for this may be the significantly increased growth with six applications which was already obtained six months after planting. It was shown that two small applications produced significantly longer D-leaves than one large application during the first six months of growth. The quantity for the two small applications may vary between 3.3 gm to 10 gm per plant per application. This increased growth was maintained until flower differentiation i.e. twenty months after planting. Six applications gave a significantly heavier D-leaf compared with two applications but with no significant difference between four and six applications. These results are identical with the average weight per fruit. This again established the possibility of using the average D-leaf weight as a basis for crop forecasting.

The leaf-N, ten months after planting, did not seem to have any correlation with the plant growth, as represented by the D-leaf growth, and the fruit weight per plot. The necessity of adequate nitrogen application to build up the leaf-N to an optimum between ten and fifteen months was important. During this period the frequencies of two, four and six applications received respectively 25.0 gm, 40.8 gm and 26.7 gm ammonium sulphate per plant. The treatment with six applications gave the highest weight of fruit per plot and had at fifteen months an average of 1.99% leaf-N. This nitrogen content is in correlation with the required 1.986% leaf-N established for the levels of N at the same period. In the case of two applications only 1.78% leaf-N was recovered. It is clear, therefore, that as a result of the infrequent applications in large quantities a large amount of the nitrogen was lost to the plants. In this instance it may have been due to the prolonged drought during spring, 1961. This drought coincided with the second application, which was also the last in the treatment, ten months after planting.

There was no significant difference in the leaf-N

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between frequencies of four and six applications (2.03% N and 1.99% N respectively), fifteen months after planting. These results are approximately the same as the required optimum obtained under levels of N, viz. 1.986% leaf-N. Although a frequency of four applications gave a significantly lower weight of fruit per plot compared with six applications, the results with average weight per fruit were just the opposite. It can be assumed, therefore, that it must have been the number of fruit, although not significant, that caused this variation in fruit weight per plot. Under these circumstances the optimum leaf-N required for an optimum yield could, therefore, be accepted to be approximately 1.99% N, representing the treatment which gave the highest yield. During the period ten to fifteen months, a total quantity of 26.7 gm ammonium sulphate per plant, was applied in the treatment for a frequency of six applications and could be regarded as the maximum requirement. The quantity established under levels of N was 25.4 gm ammonium sulphate per plant for this period which is actually closer to the total quantity in the frequency of two applications, viz. 25.0 gm. It appears, however, that the most important factor was to split this total quantity in three separate applications over this period. The main reason was to avoid the effects of the drought and possible loss of nitrogen through volatalisation when applied in one large quantity.

There were no further applications of ammonium sulphate from fifteen months after planting to flower differentiation. There was a decrease in leaf-N, significant at 0.01 for all three frequencies over the period, to below the value established in (A)T.-Bh. 3 viz. 1.6% leaf-N compared with an average of 1.213%. All other results, in the latter project, up to fifteen months after planting were in close correlation with this project. It can therefore be safely assumed, that better results would have been obtained if ammonium sulphate was applied during the period of fifteen months to flower differentiation. The sucker production with a frequency of six applications was significantly higher at 0.05, than the other two frequencies with no quadratic significance. Therefore also in this instance, a higher sucker production may have been obtained which can effect the first ratoon crop directly. The same reasons apply to the number of slips per plot which may be increased by an additional application during that period.

The degree of translucency in the fruits was increased significantly by increased frequency of application. It appears, therefore, that not only the increasing rates of ammonium sulphate but also the increasing frequency must be observed in the degree of translucency. In other words, it will be important to harvest fruits from plants which will be important to harvest fruits from plants which received high nitrogen at frequent intervals when they are still green as by so doing the degree of translucency will be reduced.

The chlorophyll in the leaves was not affected by frequency of application throughout the plant crop period. This may be due to the interference of iron deficiency chlorosis in the leaves. This emphasized the fact that leaf-chlorophyll content can not be used as an index for nitrogen fertilisation when small differences are measured. It will be more accurate to use the leaf-N as a measure.

The response of leaf-K and leaf-Mg to increasing frequency of application of ammonium sulphate was very similar. In the average response of both elements over the entire plant crop period, four applications gave a significantly higher leaf-K and leaf-Mg compared with the two and six applications. The only correlation of these results was with the average weight per fruit, which was the same. Whether K and Mg were directly or indirectly responsible through N frequency for the increased weight per fruit can only be judged by the preliminary results obtained by Martin-Prével (1961). That is, a beneficial effect on average fruit weight with addition of K and Mg.

The results with leaf-Ca and leaf-Na did not seem to be affected by the frequency of application of ammonium sulphate.

4.3: (A)T-Bh. 3B:

THE EFFECT OF DIFFERENT LEVELS AND INTERVALS OF APPLICATION OF AMMONIUM SULPHATE ON THE GROWTH, CHEMICAL COMPOSITION AND YIELD OF QUEEN PINEAPPLE PLANTS UNDER FIELD CONDITIONS: EAST LONDON

REDDISH-BROWN, CLAY VIRGIN SOIL.

1. Yield.

The first harvesting year was from 1/7/62 to 30/6/63 which will be dealt with in this report.

(a) Fruit weight per plot.

The average weight of fruit harvested per plot is given in Table 1.

TABLE 1. Average weight (lb) of fruit per plot.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	17.35	25.85	25.85	23.02
200	37.97	33.25	36.24	35.82
400	38.33	28.72	32.26	33.10
600	40.97	31.47	30.43	34.29
800	48.49	25.57	32.11	35.39
1000	39.04	27.43	32.00	32.82
Mean	40.96	29.29	32.61	32.41

L.S.D. (P = 0.05) means of N levels = 3.268 lb C.V. 30.34%
L.S.D. (P = 0.01) means of N levels = 4.652 lb
L.S.D. (P = 0.05) means of N frequency = 2.314 lb C.V. 29.29%
L.S.D. (P = 0.01) means of N frequency = 3.292 lb

The control gave a decrease in fruit weight per plot compared with all the N levels, and significant at 0.01.

The linear response of fruit weight per plot to increasing levels of N was positive and significant. The quadratic response was negative and significant.

A frequency of 2 applications of N gave a higher weight of fruit per plot, significant at 0.01, compared with 4 and 6 applications. A frequency of 6 applications was significantly higher at 0.01, than 4 applications.

The linear response of fruit weight per plot to increasing frequency of application of N was negative and significant at 0.01.

The conversion of fruit weight per plot to the equivalent tons per acre is given in Table 2.

/Table 2 .... 63.

TABLE 2. Average weight (tons) of fruit per acre.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	3.02	4.50	4.50	4.00
200	6.61	5.79	6.31	6.24
400	6.66	5.00	5.62	5.77
600	7.14	5.48	5.30	5.97
800	8.45	4.45	5.59	6.16
1000	6.80	4.78	5.57	5.72
Mean	6.45	5.00	5.48	5.64

The decrease in yield for the control compared with the mean of all the N levels amounted to 1.99 tons per acre. which was significant at 0.01.

A frequency of 2 applications gave an increase in yield of 1.45 and 0.97 tons per acre compared with 4 and 6 applications respectively and significant at 0.01.

(b) <u>Number of fruit per plot.</u>

The average number of fruit harvested per plot is given in Table 3.

TABLE 3. Average number of fruit per plot.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	12.53	19.83	20.42	17.61
200	25.[illegible]	22.83	24.58	24.44
400	25.00	17.58	19.17	20.58
600	26.83	18.67	19.00	21.50
800	29.00	15.33	20.00	21.44
1000	24.67	15.92	19.17	19.92
Mean	24.00	18.36	20.39	20.92

L.S.D. ($P = 0.05$) means of N levels = 0.85
L.S.D. ($P = 0.01$) means of N levels = 1.14
L.S.D. ($P = 0.05$) means of N frequency = 0.18
L.S.D. ($P = 0.01$) means of N frequency = 0.89

The control gave a lower number of fruit per plot, significant at 0.01 compared with all N levels. The highest level of N was significantly lower, at 0.01 compared with the 200, 600 and 800 Kg levels. The lowest level of N was higher than all the other N levels, significant at 0.01.

A frequency of 2 applications gave an increase in the number of fruit, significant at 0.01, compared with 4 and 6 applications. The 6 applications treatment was higher than 4 applications, and significant at 0.01. The linear response of numbers of fruit per plot to increasing frequency of N applications was negative and significant at 0.01. This was not consistant as the quadratic response was positive and significant at 0.01.

(c) Average weight per fruit.

The average weight per fruit is given in Table 4.

TABLE 4. Average weight (lb) per fruit.

	Frequency of application			
	2	4	6	Mean
0	1.25	1.31	1.28	1.28
200	1.48	1.46	1.47	1.47
400	1.55	1.66	1.62	1.61
600	1.56	1.69	1.58	1.61
800	1.65	1.66	1.63	1.65
1000	1.62	1.78	1.69	1.70
Mean	1.57	1.65	1.60	1.55

L.S.D. (P = 0.05) means of N levels = 0.07 lb C.V. 9.24%
L.S.D. (P = 0.01) means of N levels = 0.09 lb
L.S.D. (P = 0.05) means of N frequency = 0.05 lb C.V. 8.55%
L.S.D. (P = 0.01) means of N frequency = 0.06 lb

The control and lowest level of N gave a lower average weight per fruit than all the other N levels, significant at 0.01. The highest level of N gave an increase in average weight per fruit compared with the 400 and 600 Kg levels, significant at 0.01. There was no significant difference between any of the other N levels. The linear and quadratic effects of increasing N levels were positive and significant at 0.01.

A frequency of 4 applications gave an increase in average weight per fruit, significant at 0.01, compared with 2 applications but only significant at 0.01 over 6 applications. The quadratic effect was positive and significant at 0.01.

(d) Average degree of translucency.

The average degree of translucency per fruit is given in Table 5.

/ Table 5 .... 65.

TABLE 5. Average degree of translucency per fruit.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.28	0.18	0.19	0.22
200	0.72	0.50	0.45	0.56
400	0.51	1.08	1.01	0.87
600	0.83	0.79	1.01	0.88
800	0.59	0.78	0.90	0.76
1000	0.86	0.91	1.04	0.94
Mean	0.70	0.81	0.88	0.70

L.S.D. (P = 0.05) means of N levels = 0.24 C.V. 73.33%
L.S.D. (P = 0.01) means of N levels = 0.32
L.S.D. (P = 0.05) means of N frequency = 0.16 C.V. 63.63%
L.S.D. (P = 0.01) means of N frequency = 0.21

All N levels gave a significant increase, at 0.01, in the degree of translucency compared with the control. The highest level of N and the 600 Kg gave a significant increase at 0.01 over the lowest level of N. There was no significant difference between the other N levels. The linear effects of N levels was significant at 0.01, with an average increase in translucency of 0.1199 ± 0.0205% for each 200 Kg increment in ammonium sulphate. This was not consistant as the quadratic effect was significant.

A frequency of 6 applications gave a significant increase in translucency at 0.05 compared with 2 applications. There was no significant difference between any of the other frequencies. The linear effect of increasing number of applications was positive and significant at 0.05, with an average increase of 0.09 ± 0.0372% for each 2 additional dressings.

2. Leaf Analysis.

Leaf analysis were done on three separate dates over the plant crop period, viz. at 11, 16 and 20 months from the date of planting.

(a), Nitrogen.

The nitrogen content of the leaves at 11 months after planting is given in Table 6.

/Table 6 .... 66.

TABLE 6. Nitrogen content (%) of the leaves 11 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	1.59	1.64	1.62	1.619
200	1.70	1.76	1.80	1.755
400	1.66	1.71	1.92	1.763
600	1.96	2.00	1.80	1.918
800	1.78	1.68	1.93	1.797
1000	1.93	2.11	1.95	1.995
Mean	1.81	1.85	1.88	1.808

L.S.D. (P = 0.05) means of N levels = 0.126% N C.V. 8.21%
L.S.D. (P = 0.01) means of N levels = 0.168% N
L.S.D. (P = 0.05) means of N frequency = 0.085% N C.V. 13.05%
L.S.D. (P = 0.01) means of N frequency = 0.113% N

The highest level of N gave a significant increase in leaf-N at 0.01 compared with all the treatments except 600 Kg which was not significant. The latter treatment was significantly higher at 0.05 compared with the two lowest levels of N. The control was significantly lower at 0.01 compared with the two lowest levels of N but only significantly lower at 0.05 compared with the two lowest levels. The linear effect of increasing levels of N on the leaf-N was positive and significant at 0.01 with an average increase of 0.0617 $\pm$ 0.0106% for each additional 200 Kg ammonium sulphate.

There was no significant difference in the frequency of applications.

The leaf-N at 16 months after planting is given in Table 7.

TABLE 7. Nitrogen content (%) of the leaves 16 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	1.54	1.69	1.60	1.610
200	1.85	1.85	1.91	1.841
400	1.91	2.08	2.06	2.017
600	2.10	2.10	2.20	2.133
800	2.00	2.12	1.97	2.031
1000	2.06	2.25	2.00	2.103
Mean	1.98	2.08	2.03	1.956

L.S.D. (P = 0.05) means of N levels = 0.148% N C.V. 9.27%
L.S.D. (P = 0.01) means of N levels = 0.198% N
L.S.D. (P = 0.05) means of N frequency = 0.103% N C.V. 14.54%
L.S.D. (P = 0.01) means of N frequency = 0.138% N

/ All ....67.

All nitrogen levels gave an increase in leaf-N, compared with the control and significant at 0.01. The lowest level of N was significantly lower, at 0.01 compared with the highest level and 600 Kg but only significantly lower at 0.05 compared with all the other N levels. The linear response of increasing levels of N on the leaf-N was positive and significant at 0.01 with an average increase of 0.0899 ± 0.025% for each additional 200 Kg ammonium sulphate. This was not consisted for all the levels as the quadratic response was also positive and significant at 0.01.

The leaf-N at 22 months after planting is given in Table 8.

TABLE 8. Nitrogen content (%) of the leaves 22 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	1.42	1.51	1.45	1.460
200	1.55	1.54	1.49	1.526
400	1.51	1.65	1.60	1.585
600	1.62	1.60	1.80	1.673
800	1.58	1.73	1.61	1.639
1000	1.58	1.71	1.82	1.703
Mean	1.57	1.65	1.66	1.598

L.S.D. (P = 0.05) means of N levels = 0.108% N C.V. 8.23%
L.S.D. (P = 0.01) means of N levels = 0.143% N
L.S.D. (P = 0.05) means of N frequency = 0.078% N C.V. 13.54%
L.S.D. (P = 0.01) means of N frequency = 0.103% N

The control had a lower leaf-N content, significant at 0.01 compared with the three highest levels of N but only significant at 0.05 compared with the 400 Kg. The lowest level of N was lower than the 600 Kg and 1000 Kg treatments and significant at 0.01, but only significantly lower at 0.05 compared with 800 Kg. The second lowest N level was significantly lower at 0.05 compared with the highest level. The linear effect of increasing levels of N on the leaf-N was positive and significant at 0.01 with an average increase of 0.04695 ± 0.0091% for each increment of 200 Kg ammonium sulphate.

A frequency of 2 applications gave a lower leaf-N than 4 and 6 applications, significant at 0.05. The linear effect of increasing frequency of N application on the leaf-N was positive and significant at 0.01 with an average increase of 0.04695 ± 0.0361% for every additional 2 dressings.

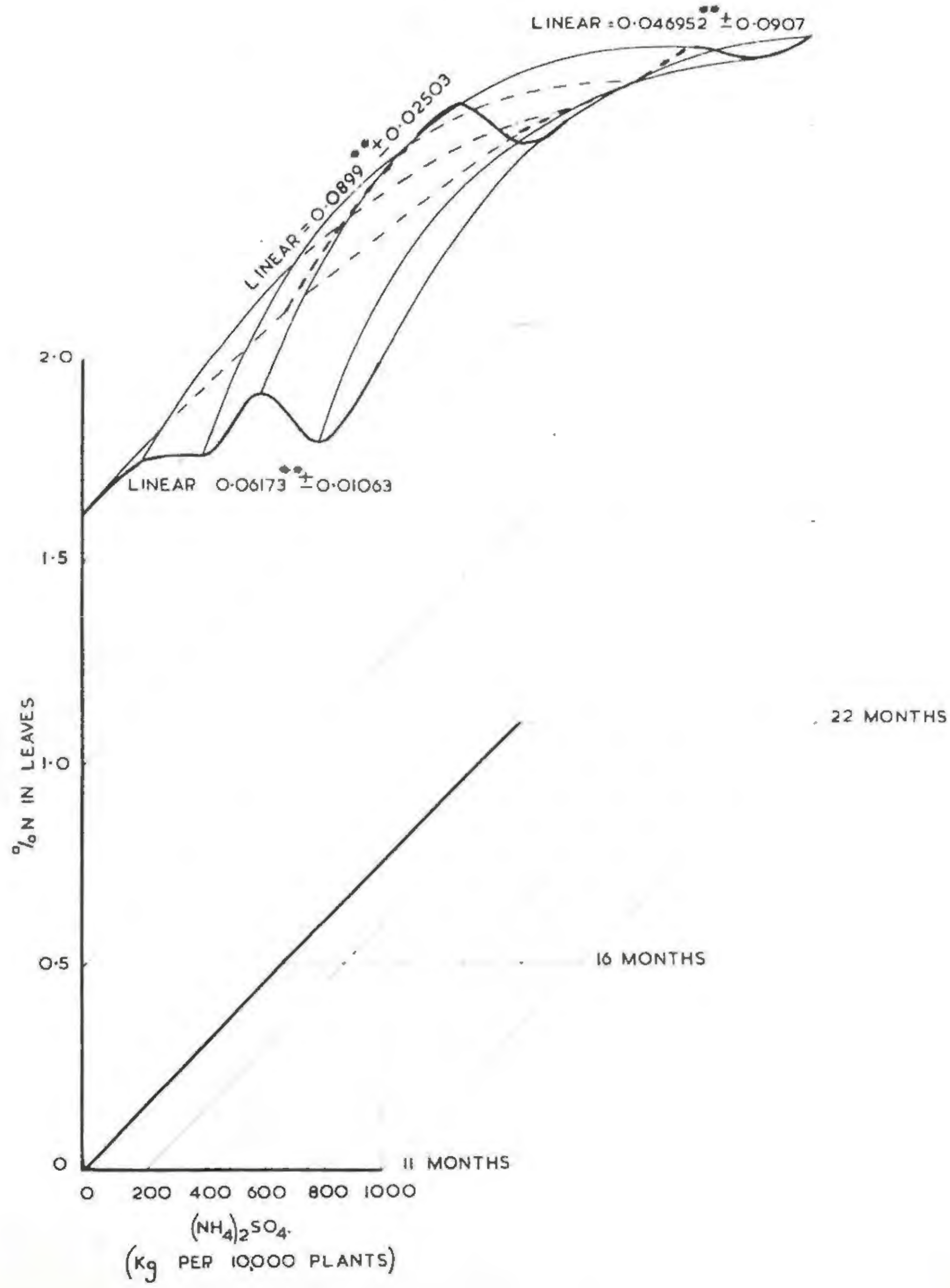

Figure 1. Overall effect of increasing levels of ammonium sulphate on the leaf-N.

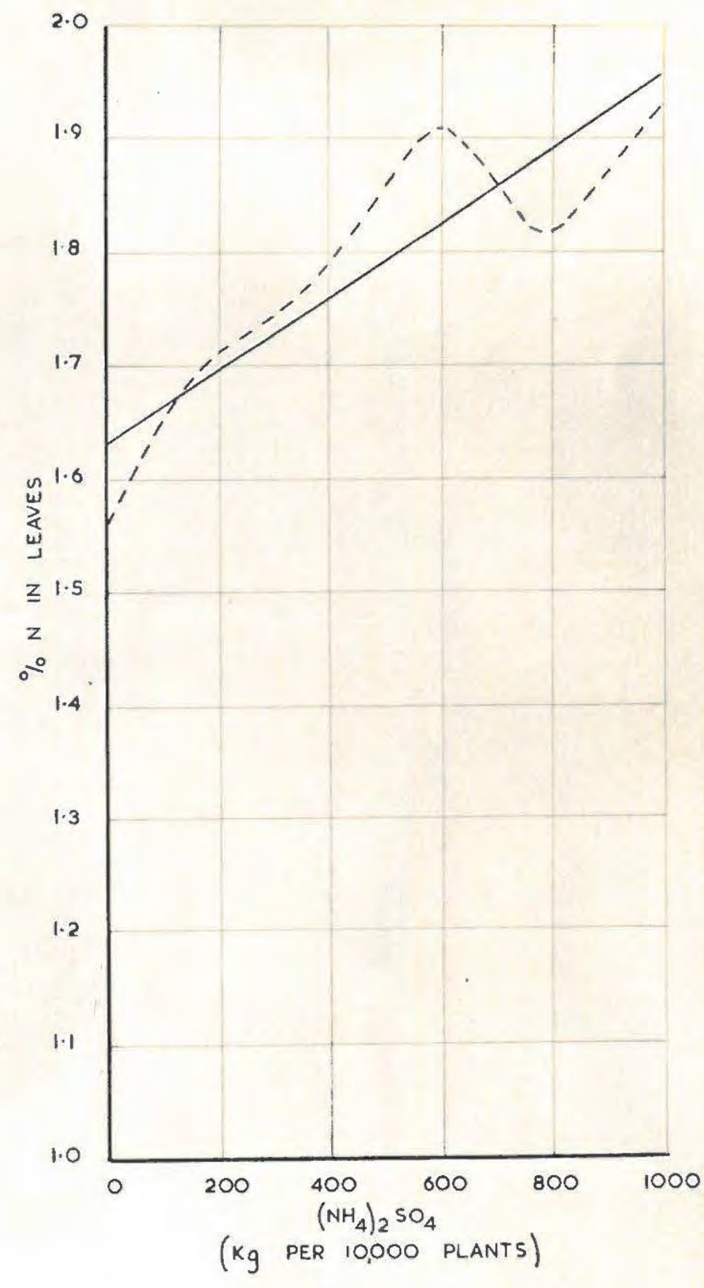

Figure 2. Mean response of leaf-N to increasing levels of ammonium sulphate for the 3 times of sampling. A positive linear increase of 0.662 ± 0.0065% was obtained for each additional 200 Kg ammonium sulphate applied. This was not consistant for the higher levels as the quadratic effect became significant.

The effect of increasing levels of N on the leaf-N over the period of sampling is given in Table 9.

TABLE 9. Effect of N levels on leaf-N (%) over the three sampling dates.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Time of sampling (months) from planting			
	11	16	22	Mean
0	1.619	1.610	1.460	1.563
200	1.755	1.841	1.526	1.707
400	1.763	2.017	1.585	1.788
600	1.918	2.133	1.673	1.907
800	1.797	2.031	1.639	1.822
1000	1.995	2.103	1.703	1.933
Mean	1.808	1.956	1.598	1.787

L.S.D. (P = 0.05) means of N levels = 0.076% N
L.S.D. (P = 0.01) means of N levels = 0.102% N
L.S.D. (P = 0.05) means of sampling times = 0.054% N
L.S.D. (P = 0.01) means of sampling times = 0.071% N

All N levels gave an increase in leaf-N compared with the control and significant at 0.01. The 600 Kg treatment gave an increase in the leaf-N, significant at 0.01, with the two lowest levels of N and significantly higher at 0.05 compared with 800 Kg. With the exception of 600 Kg the highest level of N gave a significant increase at 0.01 over all other N levels. The linear response of leaf-N to increasing levels of N was positive and significant with an average increase of 0.662 ± 0.0065% for each additional 200 Kg ammonium sulphate. This was not consistant for all levels as the quadratic response was significant. These effects are shown in figure 1 for the complete period and in figure 2 for the mean of the three sampling times.

The positive linear response was significantly higher at the 16 month period compared with that at 22 months.

At the 16 month period the mean leaf-N was higher than at 11 and 22 months and significant at 0.01. The sample at 22 months was lower than that at 11 months and significant at 0.01.

The response of leaf-N to increasing frequency of N application is given in Table 10.

/ Table 10 .... 69.

TABLE 10. Response of leaf-N to frequency of N application over 3 sampling dates.

Frequency of application	Time of sampling (months) from planting			
	11	16	22	Mean
2	1.81	1.98	1.57	1.780
4	1.85	2.08	1.65	1.860
6	1.88	2.03	1.66	1.856
Mean	1.808	1.956	1.598	1.832

L.S.D. (P = 0.05) means of N frequency = 0.048% N
L.S.D. (P = 0.01) means of N frequency = 0.063% N

A frequency of two applications gave a decrease in leaf-N compared with 4 and 6 applications, and significant at 0.01.

(b) Potassium.

The potassium content of the leaves 11 months after planting is given in Table 11.

TABLE 11. K content (%) of the leaves 11 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.62	2.98	3.06	2.887
200	3.05	3.08	2.89	3.007
400	3.07	2.94	2.97	2.994
600	3.07	2.95	2.67	2.896
800	2.81	2.87	2.78	2.822
1000	3.32	3.20	3.16	3.224
Mean	3.064	4.008	2.894	2.972

L.S.D. (P = 0.05) means of N levels = 0.319% K C.V. 13.12%
L.S.D. (P = 0.01) means of N levels = 0.424% K
L.S.D. (P = 0.05) means of N frequency = 0.216% K C.V. 20.08%
L.S.D. (P = 0.01) means of N frequency = 0.285% K

The control and the 800 Kg treatments gave a lower leaf-K compared with the highest level of N, significant at 0.05.

Frequency of application had no significant effect on the leaf-K.

The potassium content of the leaves 16 months after planting is given in Table 12.

/ Table 12 .... 70.

TABLE 12. K content (%) of the leaves 16 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	4.43	4.20	4.32	4.32
200	4.49	4.25	4.33	4.36
400	4.58	4.45	4.25	4.43
600	4.44	4.48	4.48	4.47
800	4.10	4.68	4.53	4.44
1000	4.57	4.61	4.70	4.63
Mean	4.44	4.49	4.46	4.44

L.S.D. (P = 0.05) means of N levels = 0.298% K C.V. 8.19%
L.S.D. (P = 0.01) means of N levels = 0.396% K
L.S.D. (P = 0.05) means of N frequency = 0.178% K C.V. 11.14%
L.S.D. (P = 0.01) means of N frequency = 0.236% K

The highest level of N had a higher leaf-K content than the control, significant at 0.05. The linear effect of increasing levels of N on the leaf-K was positive and significant at 0.01 with an average increase of 0.0521 ± 0.0251% for each additional 200 Kg ammonium sulphate applied.

Frequency of application had no significant effect on the leaf-K.

The potassium content of the leaves 22 months after planting is given in Table 13.

TABLE 13. K content (%) of the leaves 22 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	3.06	3.15	3.15	3.12
200	2.76	3.02	2.73	2.84
400	2.83	2.90	2.75	2.83
600	2.88	3.02	2.87	2.92
800	3.80	2.73	2.73	2.75
1000	3.03	2.93	3.11	3.02
Mean	2.86	2.92	2.84	2.91

L.S.D. (P = 0.05) means of N levels = 0.222% K C.V. 9.3%
L.S.D. (P = 0.01) means of N levels = 0.295% K
L.S.D. (P = 0.05) means of N frequency = 0.152% K C.V. 14.43%
L.S.D. (P = 0.01) means of N frequency = 0.201% K

The control had a higher K content in the leaves than the 800 Kg treatment significant at 0.01. The control was only significantly higher at 0.05 compared with 200 and 400 Kg treatments. The quadratic effect of increasing levels of N was positive and significant at 0.01.

/ Frequency .... 71.

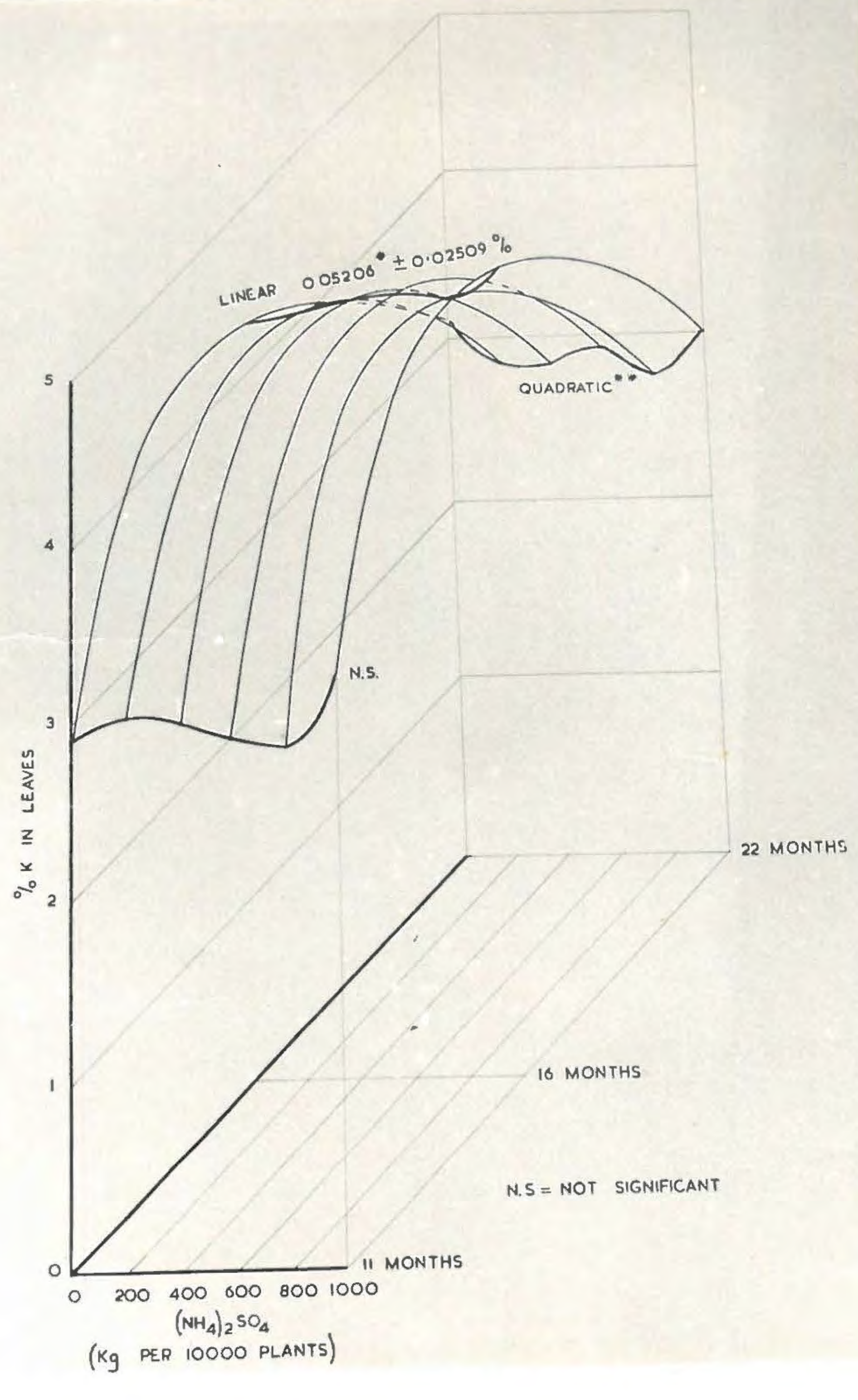

Figure 3. Overall effect of increasing levels of ammonium sulphate on leaf-K.

Frequency of application had no significant effect on the leaf-K.

The effect of increasing levels of N on the leaf-K over the period of sampling is given in Table 14.

TABLE 14. Effect of N levels on leaf-K (%) over the 3 sampling dates.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Time of sampling (months) from planting			
	11	16	22	Mean
0	2.89	4.32	3.12	3.440
200	3.01	4.36	2.84	3.400
400	2.99	4.43	2.83	3.416
600	2.90	4.47	2.92	3.428
800	2.82	4.44	2.75	3.336
1000	3.22	4.63	3.02	3.624
Mean	2.972	4.438	2.913	3.441

L.S.D. (P = 0.05) means of N levels = 0.207% K
L.S.D. (P = 0.01) means of N levels = 0.275% K
L.S.D. (P = 0.05) means of sampling dates = 0.143% K
L.S.D. (P = 0.01) means of sampling dates = 0.188% K

The leaf-K for the highest level of N was higher than the 800 Kg treatment, significant at 0.01.

At 16 months after planting the leaf-K was higher than at 11 and 22 months and significant at 0.01.

There was no significant difference between the latter two sampling dates.

Figure 3 shows the overall effect of increasing levels of N on the leaf-K. The significant linear increase in leaf-K at 16 months is shown as well as the quadratic effect at 22 months. The latter is caused by the significantly lower leaf-K in 800 Kg treatment throughout the whole period (Table 14).

(c) <u>Calcium</u>

The calcium content of the leaves 11 months after planting is given in Table 15.

TABLE 15. Ca content (%) of the leaves 11 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.43	0.45	0.40	0.428
200	0.45	0.45	0.44	0.447
400	0.42	0.49	0.46	0.455
600	0.46	0.45	0.51	0.471
800	0.49	0.47	0.54	0.499
1000	0.48	0.48	0.51	0.489
Mean	0.460	0.468	0.492	0.465

L.S.D. $(P = 0.05)$ means of N levels = 0.068% Ca C.V. 17.95%
L.S.D. $(P = 0.01)$ means of N levels = 0.091% Ca
L.S.D. $(P = 0.05)$ means of N frequency = 0.049% Ca C.V. 29.24%
L.S.D. $(P = 0.01)$ means of N frequency = 0.065% Ca

The control had a lower leaf-Ca, significant at 0.05, compared with the 800 Kg treatment. The linear effect of increasing levels of N on the leaf-Ca was positive and significant at 0.05, with an average increase of $0.01358 \pm 0.0057\%$ for every additional 200 Kg of ammonium sulphate added.

The calcium content of the leaves 16 months after planting is given in Table 16.

TABLE 16. Ca content (%) of the leaves 16 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.55	0.50	0.51	0.52
200	0.65	0.62	0.65	0.64
400	0.72	0.71	0.65	0.69
600	0.71	0.58	0.68	0.66
800	0.78	0.70	0.68	0.72
1000	0.78	0.76	0.71	0.75
Mean	0.728	0.674	0.674	0.663

L.S.D. $(P = 0.05)$ means of N levels = 0.055% Ca C.V. 10.17%
L.S.D. $(P = 0.01)$ means of N levels = 0.074% Ca
L.S.D. $(P = 0.05)$ means of N frequency = 0.044% Ca C.V. 18.51%
L.S.D. $(P = 0.01)$ means of N frequency = 0.059% Ca

The leaf-Ca of the control was lower than all the N levels significant at 0.01. The lowest level of N was lower than the two highest levels of N and significant at 0.01. The 600 Kg treatment was significantly lower at 0.01 compared with the highest N level but only significantly lower at 0.05 compared with the 800 Kg treatment. There was no significant difference between the 200, 400 and 600 Kg treatments. The linear response of leaf-Ca to increasing N levels was positive and significant at 0.01 with an average increase of 0.0389 $\pm$ 0.0047% for each additional 200 Kg ammonium sulphate. This increase was not constant for all levels as the quadratic effect was also significant at 0.01.

A frequency of 2 applications gave a higher leaf-Ca content significant at 0.05 compared with 4 and 6 applications. The linear effect of increasing frequency of application was negative and significant at 0.05 with an average increase of 0.027 $\pm$ 0.0205% for each additional 2 dressings.

The calcium content of the leaves 22 months after planting is given in Table 17.

TABLE 17. Ca content (%) of the leaves 22 months from planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.38	0.43	0.46	0.42
200	0.45	0.48	0.46	0.46
400	0.43	0.49	0.47	0.46
600	0.44	0.51	0.46	0.47
800	0.50	0.54	0.48	0.51
1000	0.47	0.52	0.50	0.50
Mean	0.458	0.508	0.474	0.47

L.S.D. (P = 0.05) means of N levels = 0.032% Ca C.V. 8.20%
L.S.D. (P = 0.01) means of N levels = 0.042% Ca
L.S.D. (P = 0.05) means of N frequency = 0.02% Ca C.V. 11.69%
L.S.D. (P = 0.01) means of N frequency = 0.026% Ca

The control had a lower leaf-Ca content, significant at 0.01 compared with all the N levels. The 800 Kg and 1000 Kg treatments were significantly higher at 0.01 and 0.05 compared with the three lowest N levels, respectively. The linear response of leaf-Ca to increasing levels of N was positive and significant at 0.01 with an average increase of 0.01502 $\pm$ 0.00266% for each increment of 200 Kg ammonium sulphate.

A frequency of 4 applications of N gave an increase in leaf-Ca, significant at 0.01 compared with 2 and 4 applications. There was no significant difference between the two latter treatments. The quadratic effect of increasing frequency of application was negative and significant at 0.01.

The response of leaf-Ca to increasing levels of N over the whole period of sampling is given in Table 18.

/ Table 18 .... 74.

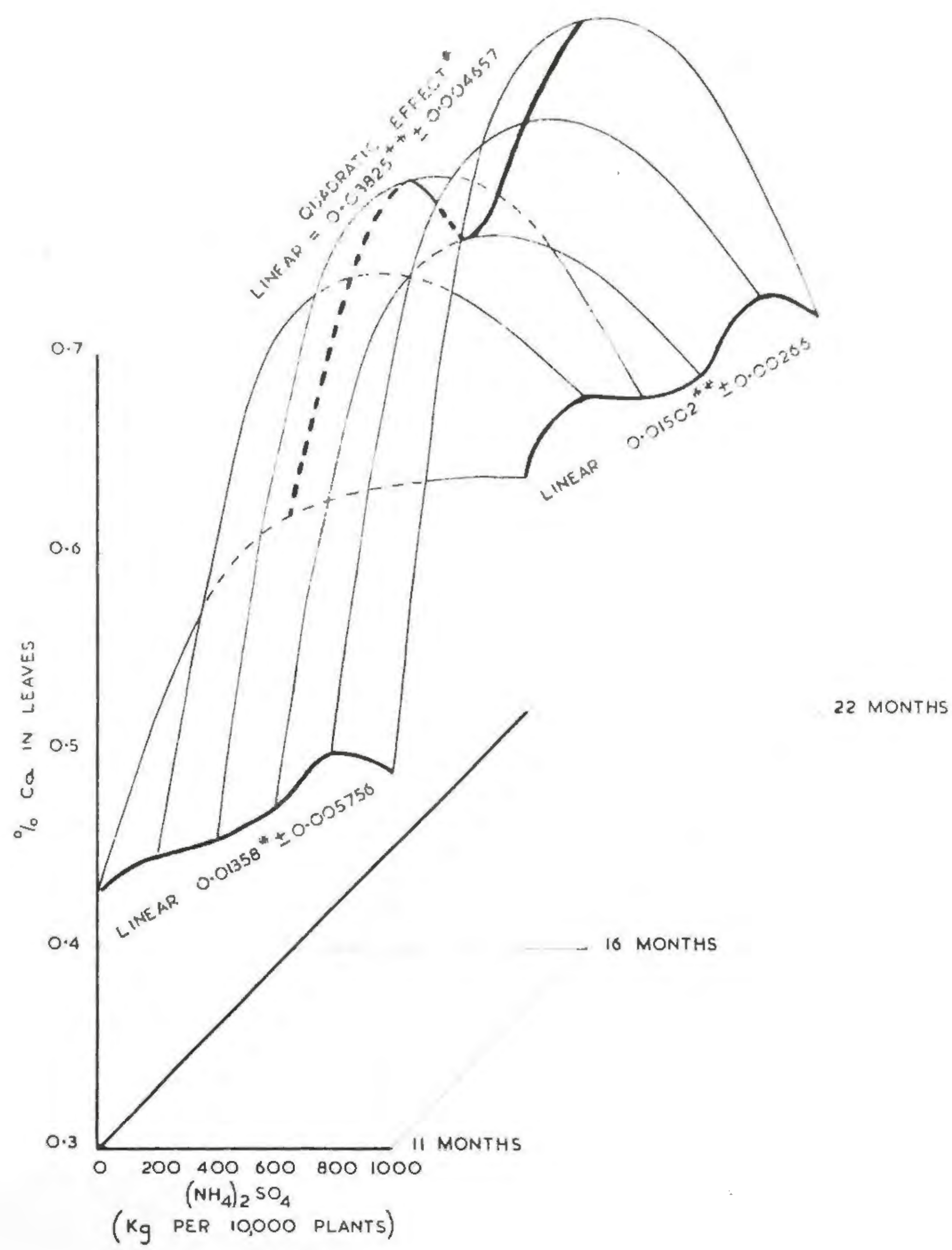

Figure 4. Overall effect of increasing levels of ammonium sulphate on the leaf-Ca.

TABLE 18. Effect of N levels on leaf-Ca (%) over the 3 sampling dates.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Time of sampling (months) from planting			
	11	16	22	Mean
0	0.43	0.52	0.42	0.457
200	0.45	0.64	0.46	0.517
400	0.46	0.69	0.46	0.537
600	0.47	0.66	0.47	0.531
800	0.50	0.72	0.51	0.575
1000	0.49	0.75	0.50	0.579
Mean	0.47	0.66	0.47	0.533

L.S.D. (P = 0.05) means of N levels = 0.034% Ca
L.S.D. (P = 0.01) means of N levels = 0.045% Ca
L.S.D. (P = 0.05) means of sampling dates = 0.024% Ca
L.S.D. (P = 0.01) means of sampling dates = 0.032% Ca

The control gave a decrease in leaf-Ca significant at 0.01 compared with all levels of N. The two highest levels of N gave an increase, significant at 0.01, compared with the lowest level of N. The 600 Kg treatment was significantly lower at 0.01 compared with the highest N level but only significantly lower at 0.05 compared with 800 Kg. There was a positive linear increase of leaf-Ca, significant at 0.01, with increasing levels of N amounting to 0.0222 $\pm$ 0.0029% Ca, for each additional 200 Kg ammonium sulphate.

The leaf-Ca was higher at 16 months after planting compared with 11 and 22 months, and significant at 0.01.

Figure 4 shows the overall effect of increasing levels of N on the leaf-Ca over the entire period. The significant linear effect over the whole period is shown. At 16 months after planting, however, the linear effect was significantly higher at 0.01 compared with the other two periods amounting to 0.01863% Ca.

Although there was no significant difference in leaf-Ca for frequency of application, the quadratic effect was negative and significant at 0.01. A frequency of 4 applications giving the highest Ca content in the leaves.

(d) Magnesium.

The magnesium content of the leaves 11 months after planting is given in Table 19.

/ Table 19 .... 75.

TABLE 19. Mg content (%) of the leaves 11 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.52	0.51	0.53	0.52
200	0.52	0.54	0.57	0.54
400	0.50	0.56	0.59	0.55
600	0.56	0.58	0.60	0.58
800	0.58	0.60	0.60	0.59
1000	0.58	0.56	0.61	0.58
Mean	0.548	0.568	0.594	0.561

L.S.D. (P = 0.05) means of N levels = 0.043% Mg C.V. 9.57%
L.S.D. (P = 0.01) means of N levels = 0.057% Mg
L.S.D. (P = 0.05) means of N frequency = 0.032% Mg C.V. 15.96%
L.S.D. (P = 0.01) means of N frequency = 0.043% Mg

The control gave a lower leaf-Mg significant at 0.01 compared with the three highest levels of N. The lowest level of N was significantly lower at 0.05 compared with the two highest levels of N. The linear response of leaf-Mg to increasing levels of N was positive and significant at 0.01 with an average increase of 0.01398 $\pm$ 0.00363% for each additional 200 Kg ammonium sulphate.

A frequency of 6 applications gave a higher leaf-Mg, significant at 0.01 compared with 2 applications. There was no significant difference between 4 and 6 applications. The linear response of leaf-Mg to increasing frequency of N application was positive and significant at 0.01 with an average increase of 0.023 $\pm$ 0.008% for each additional 2 dressings.

The magnesium content of the leaves 16 months after planting is given in Table 20.

TABLE 20. Mg content (%) of the leaves 16 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.08	0.09	0.08	0.083
200	0.09	0.09	0.09	0.090
400	0.10	0.10	0.10	0.100
600	1.10	0.10	0.10	0.100
800	0.11	0.10	0.10	0.100
1000	0.10	0.10	0.10	0.100
Mean	0.100	0.098	0.098	0.098

L.S.D. (P = 0.05) means of N levels = 0.006% Mg C.V. 8.11%
L.S.D. (P = 0.01) means of N levels = 0.008% Mg
L.S.D. (P = 0.05) means of N frequency = 0.005% Mg C.V. 8.71%
L.S.D. (P = 0.01) means of N frequency = 0.007% Mg

The control and lowest levels of N gave a lower leaf-Mg, significant at 0.01, compared with all the other N levels. The lowest N level was significantly higher at 0.05 compared with the control. The linear effects of increasing levels of N on the leaf-Mg was significant at 0.01, with an average increase of 0.00368 $\pm$ 0.00533% for each additional 200 Kg ammonium

/ sulphate .... 76.

sulphate. This was not constant for all levels as the quadratic response was negative and significant at 0.01.

Frequency of application had no significant effect on the leaf-Mg.

The magnesium content of the leaves 22 months after planting is given in Table 21.

TABLE 21. Mg content (%) of the leaves 22 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.06	0.06	0.06	0.06
200	0.07	0.07	0.07	0.07
400	0.07	0.07	0.07	0.07
600	0.07	0.07	0.07	0.07
800	0.08	0.08	0.08	0.08
1000	0.07	0.07	0.08	0.07
Mean	0.07	0.07	0.07	0.069

L.S.D. (P = 0.05) means of N levels = 0.006% Mg C.V. 9.28%
L.S.D. (P = 0.01) means of N levels = 0.008% Mg
L.S.D. (P = 0.05) means of N frequency = 0.003% Mg C.V. 12.23%
L.S.D. (P = 0.01) means of N frequency = 0.004% Mg

The control gave a lower leaf-Mg, significant at 0.01 compared with all N levels. The 800 Kg treatment was higher, significant at 0.01 compared with the three lowest levels of N but only significantly higher at 0.05 than the highest level of N. The linear response of leaf-Mg to increasing levels of N was positive and significant at 0.01, with an average increase of 0.0025 $\pm$ 0.0005 for each additional increase of 200 Kg ammonium sulphate.

The overall response of leaf-Mg to increasing levels of N over the entire period of sampling is given in Table 22.

TABLE 22. Effect of N levels on leaf-Mg (%) over the 3 sampling dates.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Time of sampling (months) from planting			
	11	16	22	Mean
0	0.52	0.08	0.06	0.221
200	0.54	0.09	0.07	0.235
400	0.55	0.10	0.07	0.239
600	0.58	0.10	0.07	0.250
800	0.59	0.10	0.08	0.256
1000	0.58	0.10	0.07	0.253
Mean	0.561	0.095	0.069	0.242

L.S.D. (P = 0.05) means of N levels = 0.015% Mg
L.S.D. (P = 0.01) means of N levels = 0.020% Mg
L.S.D. (P = 0.05) means of sampling times = 0.011% Mg
L.S.D. (P = 0.01) means of sampling times = 0.015% Mg

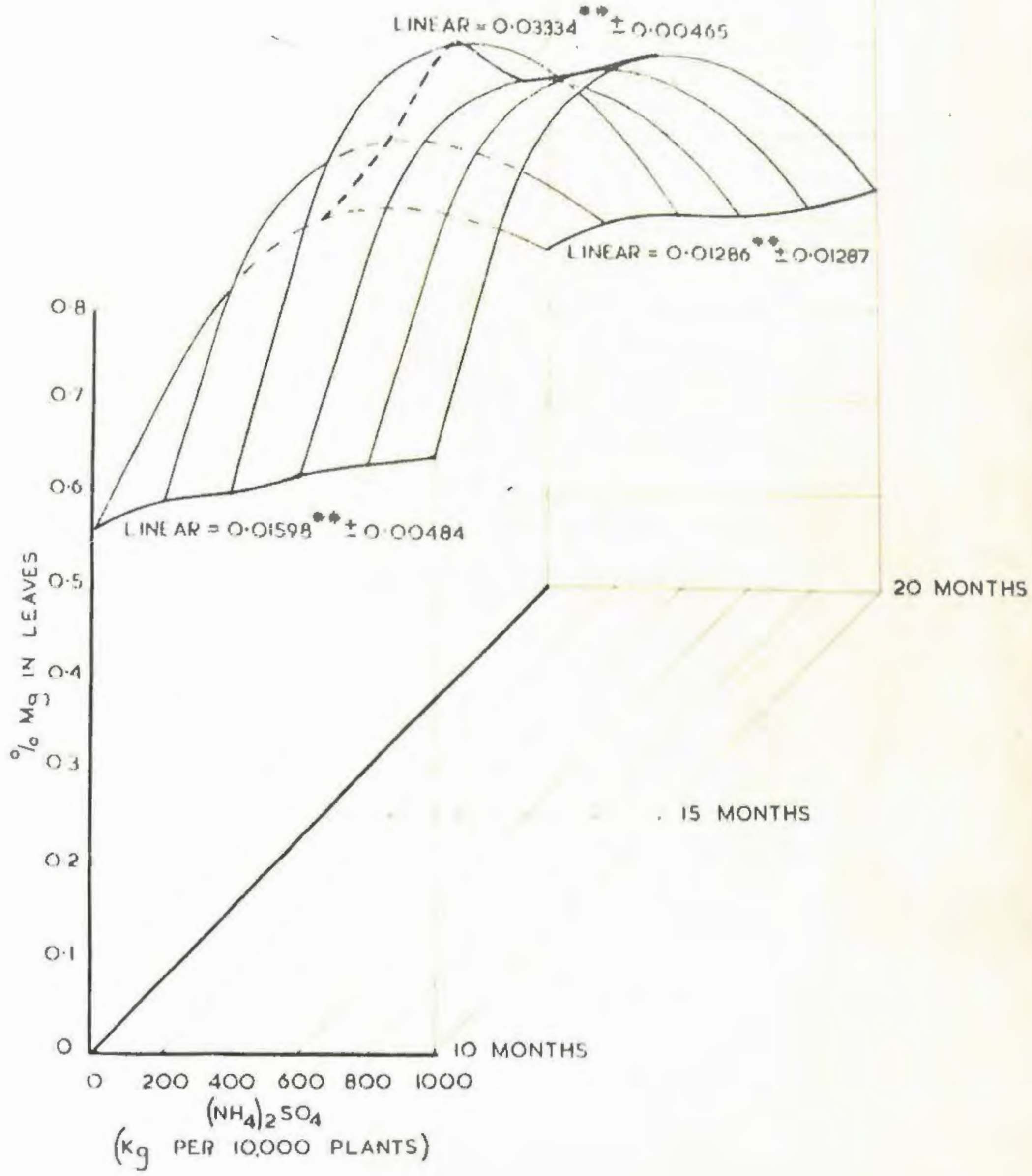

Figure 5. Overall effect of increasing levels of ammonium sulphate on the leaf-Mg.

The control gave a decrease in leaf-Mg, significant at 0.01 compared with the three highest levels of N but only significantly lower at 0.05, than the 400 Kg treatment. The lowest level of N was lower, significant at 0.01 compared with 800 Kg and significantly lower at 0.05, than 600 Kg and 1000 Kg. The mean linear effect of increasing levels of N on the leaf-Mg over the whole period was positive and significant at 0.01 with an average increase of 0.0067 ± 0.00125% for each additional 200 Kg ammonium sulphate. In Figure 5 the response of leaf-Mg to increasing levels of N, over the entire sampling period, is given. The positive linear response at 11 months after sampling was significantly higher than at 16 and 22 months.

The leaf-Mg 11 months after the planting was higher than the other two periods and significant at 0.01. The leaf-Mg at 16 months was higher than at 22 months, significant at 0.01.

The overall response of leaf-Mg to increasing frequency of N applications is given in Table 23.

TABLE 23. Effect of frequency of N application on leaf-Mg over the 3 sampling dates.

Frequency of application	Time of sampling (months) from planting			
	11	16	22	Mean
2	0.548	0.100	0.070	0.240
4	0.568	0.098	0.070	0.245
6	0.594	0.098	0.070	0.253
Mean	0.561	0.095	0.070	0.246

L.S.D. (P = 0.05) means of N frequency = 0.011% Mg
L.S.D. (P = 0.01) means of N frequency = 0.014% Mg

A frequency of 2 applications of N gave a lower leaf-Mg than 6 applications, significant at 0.05. The mean linear response of the leaf-Mg to increasing frequency of N applications is positive and significant at 0.01 with an average increase of 0.0065 ± 0.0028% for each additional 2 dressings. This linear response varies with the time of sampling and is significantly higher at 11 months than at 22 months.

(e) Sodium.

The effect of neither increasing levels nor increasing frequency of N applications had any significant effect on the leaf-Na over the entire period of sampling.

(f) Chlorophyll ...... 78.

(f) Chlorophyll.

The chlorophyll content of the leaves 22 months after planting is given in Table 24.

TABLE 24. Chlorophyll content (ppm) of the leaves 22 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	131.92	130.92	135.25	132.69
200	140.67	144.83	161.00	148.83
400	146.67	150.17	165.25	154.03
600	159.17	158.42	146.08	154.56
800	142.17	153.75	157.83	151.25
1000	150.08	164.33	157.41	157.83
Mean	147.75	154.30	157.60	149.796

L.S.D. (P = 0.05) means of N levels = 10.75 ppm C.V. 8.77%
L.S.D. (P = 0.01) means of N levels = 14.31 ppm
L.S.D. (P = 0.05) means of N frequency = 8.89 ppm C.V. 16.43%
L.S.D. (P = 0.01) means of N frequency = 11.74 ppm

All the levels of N gave an increase in chlorophyll, significant at 0.01 compared with the control. The linear response of chlorophyll to increasing levels of N was positive and significant at 0.01 with an average increase of 3.7540 $\pm$ 0.90681% for each additional 200 Kg ammonium sulphate. This was not constant over all levels as the quadratic effect was negative and significant at 0.05.

A frequency of 6 applications of N gave an increase in chlorophyll compared with 2 applications, significant at 0.05. The linear response with increasing frequency of application was positive and significant at 0.05 with an average increase of 4.925 $\pm$ 2.0511% for each additional two dressings.

3. D-leaf length.

The D-leaf length of the plants 22 months after planting is given in Table 25.

/Table 25 .... 79.

TABLE 25. D-leaf length (inches) 22 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	21.8	21.8	22.2	21.94
200	26.7	26.6	26.5	26.59
400	27.4	27.4	27.1	27.60
600	27.9	28.4	28.4	28.21
800	29.1	28.8	28.2	28.71
1000	29.1	28.8	29.4	29.10
Mean	28.0	28.0	27.9	27.03

L.S.D. ($P = 0.05$) means of N levels = 0.96 inches C.V. 4.34%
L.S.D. ($P = 0.01$) means of N levels = 1.28 inches
L.S.D. ($P = 0.05$) means of N frequency = 0.320 inches C.V. 3.27%
L.S.D. ($P = 0.01$) means of N frequency = 0.422 inches

The D-leaves were shorter in the control compared with all levels of N, and significant at 0.01. The lowest level of N was shorter than the three highest levels, significant at 0.01. The 400 Kg treatment was significantly shorter at 0.01 compared with the highest level but not significantly shorter than the 600 and 800 Kg treatments. There was no significant difference between the three highest levels of N. The linear response of D-leaf length to increasing levels of N was positive and significant at 0.01 with an average increase of 1.2214 ± 0.0810% for each additional 200 Kg ammonium sulphate. This was not constant for all levels as the quadratic effect was negative and significant at 0.01.

Frequency of application had no significant effect on the D-leaf length.

4. <u>D-leaf weight</u>.

The D-leaf weight of the plants 22 months after planting is given in Table 26.

TABLE 26. D-leaf weight (gram) 22 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	21.3	21.7	21.3	21.42
200	27.7	27.0	28.0	27.54
400	29.2	28.7	30.2	29.59
600	29.3	29.8	31.3	30.18
800	31.4	31.6	30.1	30.77
1000	32.7	31.7	31.3	31.89
Mean	30.1	29.8	30.2	28.57

L.S.D. ($P = 0.05$) means of N levels = 1.65 gm C.V. 7.05%
L.S.D. ($P = 0.01$) means of N levels = 2.19 gm
L.S.D. ($P = 0.05$) means of N frequency = 0.854 gm C.V. 8.27%
L.S.D. ($P = 0.01$) means of N frequency = 1.128 gm

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The D-leaf weight was lower for the control, significant at 0.01, compared with all the N levels. The lowest level of N was significantly lighter at 0.01, than the three highest levels of N and only significantly lower at 0.05 compared with the 400 Kg treatment. The latter was significantly lower 1000 Kg at 0.01 but only significatnly lower at 0.05 compared with 600 and 800 Kg. The 600 Kg treatment was significantly lower at 0.05 compared with 1000 Kg. There was no significant difference between the latter and the 800 Kg treatment. The linear response of D-leaf weight to increasing levels of N was positive and significant at 0.01 with an average increase of 1.7898 $\pm$ 0.1391% for each additional 200 Kg ammonium sulphate. This was not constant for all the levels as the quadratic response was negative and significant at 0.01.

Frequency of application had no significant effect on the D-leaf weight.

4·31 DISCUSSION AND CONCLUSIONS

1. Levels of ammonium sulphate.

All the levels of ammonium sulphate, compared with the control, produced a higher weight of fruit per plot, significant at 0.05. The average increase between all the levels was 1.99 tons per acre. This increase can be attributed to the significantly higher number of fruit per plot in the N levels. Although the response of fruit weight to increasing N levels was linearly positive and significant, the quadratic response, however, was negative and significant. From these results it is clear that the fruit weight per plot will not necessarily be increased economically by increasing the ammonium sulphate.

Excluding the control, the results with the number of fruits per plot, gave indications that increasing levels of ammonium sulphate may be responsible for a delay in harvesting. At the end of the first year the number of fruits were significantly higher in the lowest level of N than in all the higher N levels. Furthermore, the highest level of N was significantly lower than all the lower levels of N.

The average weight per fruit compared with the lowest levels was increased by the highest level of N and significant at 0.01. These results, however, appear to be coupled with the degree of translucency. The highest level also gave a significant increase in the degree of translucency.

/ This .... 81.

This as will be proved later may be as a result of the excessively high leaf-N at the higher levels of ammonium sulphate. A high degree of translucency may affect the marketing quality of the fruits. Queen pineapples intended for fresh fruit export are packed fairly ripe and it is known that at that stage fruits with high translucency will ferment and break down.

The nitrogen content of the leaves over the growing period can be correlated with the yield results during the first crop year. At eleven, sixteen and twenty two months after planting the leaf-N of the 600 Kg and 1000 Kg levels of ammonium sulphate was significantly higher compared with the lowest level. The former two levels also gave the highest degree of translucency, which proves the connection between the latter and leaf-N. The 600 Kg and 1000 Kg levels, compared with the 200 Kg and 400 Kg levels, did not give any increase in yield, and the 1000 Kg level actually delayed the crop. It may be concluded therefore, that applications of 600 Kg ammonium sulphate and higher are not desirable. Although the 200 Kg treatment gave a significantly higher number of fruit than the 400 Kg, the average weight per fruit was significantly higher at 0.01, in the latter. Minimum fruit size is of great importance when fruits are delivered to canneries. There was, however, no significant difference between these two treatments in the weight of fruit per plot or the degree of translucency. It can therefore, be concluded that, the results in yield and leaf-N of the 400 Kg level of ammonium sulphate must be preferred.

From planting up to eleven months growth, the 400 Kg treatment received 16.6 gm ammonium sulphate per plant. This resulted in a 1.763% leaf-N.

During the period eleven to sixteen months after planting, the 400 Kg treatment received 23.2 gm ammonium sulphate per plant, which gave 2.017% leaf-N.

The plant growth, as represented by the D-leaf length and weight twenty two months after planting, i.e. during flower differentiation, is important. The 200 Kg level gave a significant weaker growth at 0.01, compared with the three highest levels of N, whereas 400 Kg was significantly weaker than the highest N level only. This, therefore, also confirms, that the 400 Kg level, compared with the 200 Kg at the time of flower differentiation, will be desirable. The three highest levels of N will not be acceptable, even though they gave a better plant growth, because of their adverse effects on

/ yield .... 82.

yield and fruit quality.

Ammonium sulphate was not applied to any of the treatments during the period sixteen to twenty two months. There is no evidence that the leaf-N should be any higher than 1.585%, as obtained by the 400 Kg level twenty two months after planting. On the contrary, the danger exists that with additional ammonium sulphate during this period the leaf-N may be increased to too high a level and cause a delay in fruiting as was the case in the 1000 Kg treatment. It will, therefore, not be necessary to apply any more ammonium sulphate to the suckers undergoing flower differentiation.

The linear response of leaf-chlorophyll to increasing levels of N was positive and significant at 0.01, twenty two months after planting. Although these results were similar to that of the leaf-N the leaf-chlorophyll showed no differences between individual treatments. It will therefore, not be possible to use chlorophyll analysis of the leaves for an accurate determination of the nitrogen requirements of the plants.

Eleven months after planting the leaf content of K, Ca and Mg was lower for the control compared with the highest level of N. The linear response was positive and significant at 0.05 with increasing levels of N, for Ca and Mg only. Sixteen months after planting the results were still similar, with a positive linear response, significant at 0.01, for Ca and Mg, but only significant at 0.05 for K. The quadratic response of the former two was negative and significant at 0.05 at that stage. Twenty two months after planting the linear response for leaf-K disappeared and changed to a positive and significant quadratic response. The average leaf-K at twenty two months was also lower than at sixteen months, and significant at 0.01. It appears therefore, that at the early stages of growth, the plants were able to absorb adequate potassium from the soil but at flower differentiation the supply was either exhausted or the interaction with calcium and/or magnesium prevented the absorption of potassium. From a soil survey by the Division of Chemical Services, Department of Agricultural Technical Services, 1960, (Annexure B) it was found that this red soil was reasonably supplied with potassium - but not too high and showed no potassium fixation. On the other hand, the top soil was also much higher in Ca and Mg compared with K. The possibility of interaction is emphasized by the fact that at flower differentiation the leaf-K was higher for the control compared with the 800 Kg level, and significantly higher than the 200 Kg and 400 Kg levels, and significant at 0.01. The linear response of leaf-Ca and leaf-Mg to increasing levels of N on the other hand was still positive and significant at 0.01 at that stage.

Leaf-Ca at the two highest and leaf-Mg at the second highest level of ammonium sulphate were significantly higher than the three lowest levels and the control. These results were similar to those of a higher degree of translucency and a larger fruit at the two highest levels of ammonium sulphate. The heavier fruit may therefore be attributed partly to the juicy highly translucenct character. But it cannot be excluded that the high leaf-Ca and leaf-Mg may have had some effect either directly or indirectly, through the reduction of leaf-K, on the translucency, notwithstanding its correlation with leaf-N.

2. Frequency of application of ammonium sulphate.

Frequencies of four and six applications of ammonium sulphate gave significantly lower weights of fruit per plot, (1.45 and 0.97 tons per acre respectively), compared with two applications. Six applications was, however, significantly higher, 0.48 tons per acre, than four applications. The reason for the increases was the increase in the number of fruits per plot, significant at 0.01, in those treatments. From these results it appears, that a frequency of four and six applications may be responsible for a delay in fruiting.

The average weight per fruit was higher with a frequency of four applications, significant at 0.01, compared with two applications but only significantly higher at 0.05. than six applications. These results are therefore, the direct opposite to that obtained for weight and number of fruit per plot. The reason for this phenomenon may be found in the leaf-N results. The leaf-N was not affected by frequency of application up to sixteen months after planting. Twenty two months after planting the leaf-N for a frequency of two applications was 1.57% which was significantly lower than those of four and six applications, 1.65% and 1.66% respectively. In the results for levels of N the treatment with 1.703% leaf-N, compared with treatment giving 1.526% leaf-N was found to delay the crop. In both the levels and frequency of application of ammonium sulphate it was found that the higher leaf-N can retard the crop. The conclusion can thus be drawn that only one application of 25 gm ammonium sulphate per plant during the period eleven to sixteen months will be required. This was the quantity applied in the treatment with a frequency of two applications. In the results with levels of application a quantity of 23.2 gm ammonium sulphate was established for this period, which is practically the same as the 25 gm found in the frequency of application.

The effect of frequency of application on the degree of translucency also proved that high leaf-N at flower differentiation can be associated with a high degree of translucency. The linear response of degree of translucency with increasing frequency of application of ammonium sulphate was positive and significant at 0.05.

The linear response of increasing frequency of application of ammonium sulphate on leaf-chlorophyll was positive and significant twenty two months after planting. These results are similar to that of leaf-N at that time. The differences in chlorophyll content between the treatments of frequency were not significant as was the case for leaf-N. For this reason therefore, leaf-chlorophyll analysis cannot be used with the same degree of accuracy as leaf-N in assessing the nitrogen requirements of the plants.

Frequency of application of N had no significant effect on the plant growth as is shown by the D-leaf weight and length twenty two months after planting. It also had no effect on the leaf-K from planting up to the latter time.

Sixteen months after planting the leaf-Ca was significantly higher at 0.05 with a frequency of two applications compared with four and six applications. The linear response of leaf-Ca to increasing frequency of application of N was negative and significant at 0.05. Twenty two months after planting however, four applications was significantly higher at 0.01 compared with two and six applications. The average effect of increasing frequency of application of N, on leaf-Ca over the entire period from planting to flower differentiation was quadratic, with four applications giving the peak. The different frequencies of application and different levels of N had a similar effect on these elements as they had on the average weight per fruit.

/ Eleven .... 85.

Eleven months after planting the leaf-Mg was higher at the frequency of six compared with a frequency of two applications. There were no significant differences sixteen and twenty two months after planting. The results of the average leaf-Mg over the entire period up to flower differentiation gave a significantly higher value with a frequency of six compared with two applications. The mean linear response to increasing frequency of application over this period was positive and significant which was similar to that of leaf-chlorophyll and leaf-N.

4.4. (A)T-Bh. 3A:

THE EFFECT OF DIFFERENT LEVELS AND INTERVALS OF APPLICATIONS OF AMMONIUM SULPHATE ON THE GROWTH, CHEMICAL COMPOSITION AND YIELD OF QUEEN PINEAPPLE PLANTS UNDER FIELD CONDITIONS:

BATHURST, GREY SANDY SOIL

RESULTS

1. Yield.

The plant crop was harvested over the period of May 1961 to May 1962.

(a) Fruit weight per plot.

The weight of fruit per plot is given in Table 1.

TABLE 1. Weight (lb) of fruit per plot (plant crop).

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	94.90	80.45	76.36	83.90
200	110.78	61.71	69.88	80.79
400	71.99	88.80	77.15	79.31
600	97.44	50.36	79.74	75.85
800	49.32	53.19	54.21	52.24
1000	66.50	53.90	32.57	50.99
Mean	79.21	61.59	62.71	70.51

L.S.D. (P = 0.05) means of N levels = 50.687 lb C.V. 39.51%
L.SD . (P = 0.01) means of N levels = 72.097 lb
L.S.D. (P = 0.05) means of N frequency = 14.729 lb C.V. 27.82%
L.S.D. (P = 0.01) means of N frequency = 19.905 lb

There were no significant differences between the means of the levels of N.

A frequency of 2 applications of ammonium sulphate gave a higher weight of fruit per plot than 4 and 6, significant at 0.05.

The linear effect on increasing frequencies of application was negative and significant at 0.05 with an average decrease of 8.25 $\pm$ 3.269% for each additional 2 dressings.

The conversion of the yield from Table 1 to tons per acre, is given in Table 2.

/ Table 2 .... 87.

TABLE 2. Weight (tons) of fruit per acre. (plant crop)

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	8.25	7.00	6.64	7.30
200	9.64	5.37	6.08	7.03
400	6.26	7.73	6.71	6.90
600	8.47	4.38	6.94	6.60
800	4.29	4.63	4.72	4.55
1000	5.79	4.69	2.83	4.44
Mean	7.12	5.63	5.65	6.14

The significant increase in fruit weight with a frequency of 2 applications of N compared with 4 and 6 applications was equivalent to 1.49 and 1.47 tons per acre, respectively.

(b) Number of fruit per plot.

The number of fruits per plot harvested for the plant crop are given in Table 3.

TABLE 3. Average number of fruits per plot (plant crop)

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	76.00	68.67	59.00	67.89
200	71.00	46.00	48.00	55.00
400	49.00	54.33	50.00	51.11
600	62.67	32.67	43.00	46.11
800	34.33	34.00	34.00	34.11
1000	42.00	36.33	20.67	33.00
Mean	51.80	40.67	39.13	47.87

L.S.D. (P = 0.05) means of N levels = 23.595 C.V. 27.09%
L.S.D. (P = 0.01) means of N levels = 33.561
L.S.D. (P = 0.05) means of N frequency = 9.771 C.V. 15.71%
L.S.D. (P = 0.01) means of N frequency = 13.205

The control gave more fruit per plot than the two highest levels of N, and significant at 0.01. There was no other significant differences. The linear response of number of fruit per plot to increasing levels of N was negative and significant at 0.01, wit an average decrease of 6.9177 ± 1.7898% for each increment of 200 Kg ammonium sulphate.

A frequency of 2 applications of N gave a higher number of fruit per plot, significant at 0.05 compared with 4 and 6 applications. The linear response of number of fruit per plot to increasing frequency of N applications was negative and significant at 0.05, with an average decrease of

/ 6.335 .... 88.

6.535 $\pm$ 2.169% for each additional 2 dressings.

(c) Average weight per fruit.

The average weight per fruit for the plant crop is given in Table 4.

TABLE 4. Average weight (lb) per fruit. (plant crop)

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	1.25	1.15	1.24	1.21
200	1.57	1.20	1.33	1.37
400	1.46	1.62	1.59	1.56
600	1.53	1.55	1.83	1.64
800	1.41	1.45	1.58	1.48
1000	1.62	1.39	1.56	1.52
Mean	1.52	1.44	1.58	1.46

L.S.D. (P = 0.05) means of N levels = 0.457 lb C.V. 17.17%
L.S.D. (P = 0.01) means of N levels = 0.650 lb
L.S.D. (P = 0.05) means of N frequency = 0.097 lb C.V. 8.79%
L.S.D. (P = 0.01) means of N frequency = 0.131 lb

There were no significant differences between the means of the N levels.

A frequency of 6 applications gave an increase in average weight per fruit compared with 4 applications and significant at 0.01. here were no other significant differences.

2. Leaf analysis.

No comparison was made between the different sampling dates as they represent two different crops.

(a) D-leaf weights.

The average D-leaf weights were taken 21 and 38 months after planting.

The average weight per D-leaf 21 months after planting is given in Table 6.

/Table 6 .... 89.

TABLE 6. Average weight per D-leaf (gm) 21 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	21.41	20.47	20.44	20.7744
200	22.44	16.81	19.53	19.2211
400	21.43	21.92	20.51	21.9311
600	21.74	20.52	23.53	21.9311
800	19.91	19.71	21.23	20.2822
1000	22.28	18.93	21.23	20.8133
Mean	21.56	19.60	21.17	20.7698

L.S.D. ($P = 0.05$) means of N levels = 5.361 gm C.V. 14.19%
L.S.D. ($P = 0.01$) means of N levels = 7.625 gm
L.S.D. ($P = 0.05$) means of N frequency = 1.438 gm C.V. 9.22%
L.S.D. ($P = 0.01$) means of N frequency = 1.943 gm

There were no significant differences between the means of the N levels.

A frequency of 4 applications of N gave lower D-leaf weights, significant at 0.01, compared with 2 but only significantly lower at 0.05 compared with 6 applications. The quadratic response of D-leaf weight to increasing frequency of N applications was positive and significant at 0.05.

The average weight per D-leaf 38 months after planting is given in Table 7.

TABLE 7. Average weight per D-leaf (gm) 38 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	15.60	15.09	14.59	15.094
200	16.35	13.32	13.62	14.431
400	19.43	17.93	18.45	18.604
600	17.86	17.03	18.19	17.694
800	15.44	17.14	16.92	16.503
1000	19.19	13.67	15.53	16.132
Mean	17.65	15.82	16.54	16.410

L.S.D. ($P = 0.05$) means of N levels = 1.338 gm C.V. 16.28%
L.S.D. ($P = 0.01$) means of N levels = 1.809 gm
L.S.D. ($P = 0.05$) means of N frequency = 4.860 gm C.V. 10.86%
L.S.D. ($P = 0.01$) means of N frequency = 6.913 gm

The control gave lighter D-leaves than the 400 and 600 Kg levels, significant at 0.01, but only significantly lighter at 0.05 compared with the 800 Kg level. The lowest level of N was lighter, and significant at 0.01, compared with the 400, 600 and 800 Kg levels but only significantly lighter

/ at .... 90.

at 0.05 compared with the 1000 Kg level.

There were no significant differences between the frequency of applications. The quadratic response of D-leaf weight to increasing frequency of N applications was positive and significant at 0.05.

(b) D-leaf length.

The average length per D-leaf 33 months after planting is given in Table 8.

TABLE 8. Average length (inches) per D-leaf 33 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	18.36	18.73	18.21	18.434
200	19.76	16.92	18.40	18.362
400	20.90	21.35	20.63	20.958
600	21.48	19.61	22.77	21.289
800	19.66	19.84	19.53	19.674
1000	21.42	19.06	19.79	20.089
Mean	20.64	19.36	20.22	19.801

L.S.D. (P = 0.05) means of N levels = 0.042 inches C.V. 0.20%
L.S.D. (P = 0.01) means of N levels = 0.060 inches
L.S.D. (P = 0.05) means of N frequency = 0.015 inches C.V. 0.07%
L.S.D. (P = 0.01) means of N frequency = 0.011 inches

The four highest N levels gave an increase in D-leaf length significant at 0.01 compared with the control and the lowest level of N.

The 600 Kg level gave longer leaves than all the other N levels and significant at 0.01. The 400 Kg was also higher than the 800 Kg and 1000 Kg levels, and significant at 0.01.

A frequency of 2 applications gave longer D-leaves than 4 and 6 applications and significant at 0.01 but was significantly longer at 0.05 compared with 4 applications. The quadratic response of D-leaf length to increasing frequency of N applications was positive and significant at 0.05.

(c) Chlorophyll content of the leaves.

The chlorophyll content of the leaves was determined 26, 33 and 38 months after planting.

The chlorophyll content of the leaves 26 months after planting is given in Table 9.

Table 9 .... 91.

TABLE 9. Chlorophyll content (ppm) of the leaves 26 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	220	165	180	188.2
200	235	302	235	257.2
400	333	326	331	330.1
600	307	298	304	302.9
800	340	335	343	339.4
1000	324	316	316	318.8
Mean	308	315	306	289.4

L.S.D. (P = 0.05) means of N levels = 61.65 ppm C.V. 11.71%
L.S.D. (P = 0.01) means of N levels = 87.69 ppm
L.S.D. (P = 0.05) means of N frequency = 35.99 ppm C.V. 17.04%
L.S.D. (P = 0.05) means of N frequency = 48.64 ppm

The chlorophyll content in the leaves for the control was lower and significant at 0.01, compared with the four highest levels of N but only significantly lower at 0.05, compared with the lowest N level. The latter treatment was significantly lower at 0.05 compared with the 400 and 800 Kg levels. The linear response of leaf-chlorophyll to increasing levels of N was positive and significant at 0.01 with an average increase of 24.927 ± 4.6769% for each additional 200 Kg ammonium sulphate. This increase was not constant for all levels as the quadratic response was negative and significant at 0.01.

Frequency of application had no significant effect on the leaf-chlorophyll.

Leaf-chlorophyll was not affected by any treatment 33 months after planting.

The chlorophyll content of the leaves 36 months after planting is given in Table 10.

TABLE 10. Chlorophyll content (ppm) of the leaves 38 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	211	187	195	197.44
200	298	326	362	328.78
400	325	308	357	329.89
600	397	306	332	345.00
800	350	323	393	355.56
1000	348	266	335	316.22
Mean	344	306	356	312.148

L.S.D. (P = 0.05) means of N levels = 98.67 ppm C.V. 17.38%
L.S.D. (P = 0.01) means of N levels = 140.35 ppm
L.S.D. (P = 0.05) means of N frequency = 39.13 ppm C.V. 16.70%
L.S.D. (P = 0.01) means of N frequency = 52.89 ppm

The leaf-chlorophyll for the control was lower and significant at 0.01 compared with the 600 and 800 Kg N levels and also significantly lower at 0.05 compared with the other three levels of N. The linear response of leaf-chlorophyll to increasing levels of N was positive and significant at 0.05 with an average increase of 19.6957 $\pm$ 7.4856% for each additional 200 Kg ammonium sulphate. This increase was not constant for all levels as the quadratic response was negative and significant at 0.05.

A frequency of 4 applications of N gave a lower leaf-chlorophyll than 6 applications, and significant at 0.05. The quadratic response of leaf-chlorophyll to increasing frequency of application was positive and significant at 0.05.

(d) Nitrogen.

The nitrogen content of the leaves were analysed 21, 26 and 33 months after planting.

The nitrogen content of the leaves 21 months after planting is given in Table 11.

TABLE 11. Nitrogen content (%) of the leaves 21 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	1.51	1.55	1.20	1.419
200	1.55	1.54	1.59	1.560
400	1.72	1.36	1.42	1.500
600	1.55	1.74	1.49	1.594
800	1.67	1.82	1.61	1.700
1000	1.49	1.97	1.84	1.766
Mean	1.59	1.69	1.60	1.5898

L.S.D. (P = 0.05) means of N levels = 0.254% N C.V. 8.79%
L.S.D. (P = 0.01) means of N levels = 0.362% N
L.S.D. (P = 0.05) means of N frequency = 0.185% N C.V. 15.48%
L.S.D. (P = 0.01) means of N frequency = 0.250% N

The control gave a lower leaf-N, significant at 0.05, compared with the two highest levels of N. The 400 Kg level was significantly lower at 0.05 compared with the 1,000 Kg level. The linear response of leaf-N to increasing levels of N was positive and significant at 0.01 with an average increase of 0.06426 $\pm$ 0.01930% for each additional 200 Kg ammonium sulphate.

Frequency of applications of N had no significant effect on the leaf-N.

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The nitrogen content of the leaves 26 months after planting is given in Table 12.

TABLE 12. Nitrogen content (%) of the leaves 26 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	1.62	1.53	1.58	1.58
200	2.88	2.53	2.72	2.71
400	2.25	2.46	3.21	2.64
600	2.94	3.08	3.13	3.05
800	3.19	3.13	3.41	3.24
1000	2.66	3.79	2.99	3.15
Mean	2.78	2.999	3.09	2.73

L.S.D. (P = 0.05) means of N levels = 0.74% N C.V. 15.07%
L.S.D. (P = 0.01) means of N levels = 1.05% N
L.S.D. (P = 0.05) means of N frequency = 0.33% N C.V. 16.18%
L.S.D. (P = 0.01) means of N frequency = 0.45% N

All the N levels gave a higher nitrogen content in the leaves, significant at 0.01 compared with the control. The linear response of leaf-N to increasing levels of N was positive and significant at 0.01 with an average increase of 0.2814 ± 0.0567% for each additional 200 Kg of ammonium sulphate. This was not constant for all levels as the quadratic response was negative and significant.

Frequency of application had no significant effect on leaf-N.

The nitrogen content of the leaves 33 months after planting is given in Table 13.

TABLE 13. Nitrogen content (%) of the leaves 33 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	1.00	1.28	1.02	1.101
200	1.38	1.39	1.84	1.538
400	1.46	1.57	1.85	1.627
600	1.69	1.82	1.86	1.791
800	1.72	1.77	1.87	1.788
1000	1.83	2.22	1.80	1.951
Mean	1.62	1.75	1.84	1.6326

L.S.D. (P = 0.05) means of N levels = 0.345% N C.V. 11.60%
L.S.D. (P = 0.01) means of N levels = 0.490% N
L.S.D. (P = 0.05) means of N frequency = 0.163% N C.V. 13.27%
L.S.D. (P = 0.01) means of N frequency = 0.220% N

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The control gave a decrease in leaf-N, significant at 0.01, compared with the 4 highest levels of N but only significantly lower at 0.05 compared with the lowest N level. The latter was significantly lower at 0.05 compared with the highest level of N. The linear response of leaf-N to increasing levels of N was positive and significant at 0.01 with an average increase of 0.1475 ± 0.0261% for each additional 200 Kg ammonium sulphate.

A frequency of 2 applications of N gave a decrease of leaf-N, significant at 0.01, compared with 6 applications. The linear response of leaf-N to increasing frequency of application of N was positive and significant.

(e) Potassium.

The leaves were analysed for potassium, 21, 26 and 33 months after planting.

There were no significant differences in leaf-K between any of the treatments 21 and 26 months after planting.

The potassium content of the leaves 33 months after planting is given in Table 14.

TABLE 14. K content (%) of the leaves 33 months after planting.

	Frequency of application			
	2	4	6	Mean
0	1.70	1.70	1.70	1.70
200	2.07	1.77	2.27	2.04
400	2.37	2.70	2.30	2.46
600	1.87	2.50	2.40	2.26
800	2.27	2.07	2.40	2.25
1000	1.87	1.87	2.00	1.91
Mean	2.09	2.18	2.27	2.10

L.S.D. (P = 0.05) means of N levels = 0.56% K C.V. 14.52%
L.S.D. (P = 0.01) means of N levels = 0.79% K
L.S.D. (P = 0.05) means of N frequency = 0.20% K C.V. 12.70%
L.S.D. (P = 0.01) means of N frequency = 0.27% K

The control gave a significantly lower leaf-K, at 0.05, compared with the 400 and 600 Kg levels. The quadratic response of leaf-K to increasing levels of N was negative and significant at 0.05.

There were no significant differences.

(f) Sodium.

The sodium content of the leaves 21 months after planting is given in Table 15.

/ Table 15 .... 95.

TABLE 15. Na content (%) of the leaves 21 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.033	0.044	0.034	0.034
200	0.047	0.050	0.043	0.047
400	0.033	0.040	0.047	0.040
600	0.040	0.047	0.043	0.047
800	0.037	0.047	0.043	0.042
1000	0.037	0.047	0.040	0.041
Means	0.039	0.046	0.045	0.042

L.S.D. (P = 0.05) means of N levels = 0.009% Na C.V. 11.60%
L.S.D. (P = 0.01) means of N levels = 0.013% Na
L.S.D. (P = 0.05) means of N frequency = 0.007% Na C.V. 21.08%
L.S.D. (P = 0.01) means of N frequency = 0.009% Na

The control gave a lower leaf-Na, significant at 0.01, compared with the 200 and 600 Kg levels. The quadratic response of leaf-Na to increasing frequency of application was negative and significant at 0.05.

A frequency of 2 applications of N gave a lower leaf-Na compared with 4 applications, significant at 0.05. There were no further significant differences.

There were no significant differences in leaf-Na between any of the treatments at 26 and 33 months after planting.

(g) Magnesium.

The magnesium content of the leaves 21 months after planting is given in Table 16.

TABLE 16. Mg content (%) of the leaves 21 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.140	0.120	0.150	0.136
200	0.127	0.117	0.090	0.111
400	0.120	0.130	0.117	0.122
600	0.090	0.110	0.130	0.110
800	0.107	1.127	0.093	0.109
1000	0.111	0.100	0.100	0.104
Mean	0.111	0.117	0.106	0.115

L.S.D. (P = 0.05) means of N levels = 0.022% Mg C.V. 10.45%
L.S.D. (P = 0.01) means of N levels = 0.031% Mg
L.S.D. (P = 0.05) means of N frequency = 0.016% Mg C.V. 18.55%
L.S.D. (P = 0.01) means of N frequency = 0.022% Mg

The control gave a significantly higher leaf-Mg, at 0.05, compared with the 200, 600 and 800 Kg levels but significant at 0.01 compared with the 1000 Kg level. The linear response of leaf-Mg to increasing levels of N was negative and significant at 0.05 with an average decrease of 0.0051 ± 0.0017% for each additional 200 Kg ammonium sulphate.

There were no significant differences in the leaf-Mg between any of the treatments at 26 and 33 months after planting.

(h) Calcium.

The calcium content of the leaves 21 months after planting is given in Table 17.

TABLE 17. Ca content (%) of the leaves 21 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.170	0.167	0.167	0.168
200	0.123	0.100	0.100	0.108
400	0.123	0.120	0.130	0.124
600	0.123	0.097	0.157	0.126
800	0.110	0.107	0.120	0.112
1000	0.133	0.113	0.120	0.122
Mean	0.122	0.107	0.125	0.127

L.S.D. (P = 0.05) means of N levels = 0.044% Ca C.V. 19.11%
L.S.D. (P = 0.01) means of N levels = 0.063% Ca
L.S.D. (P = 0.05) means of N frequency = 0.023% Ca C.V. 24.01%
L.S.D. (P = 0.01) means of N frequency = 0.031% Ca

The control gave a significantly higher leaf-Ca at 0.05, compared with the two lowest and two highest levels of N.

There were no significant differences between the means of frequency of application.

There were no significant differences in leaf-Ca between any of the treatments 26 months after planting.

The calcium content of the leaves 33 months after planting is given in Table 18.

/Table 18 .... 97.

TABLE 18. Ca content (%) of the leaves 33 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.28	0.25	0.29	0.27
200	0.18	0.18	0.17	0.18
400	0.35	0.30	0.23	0.29
600	0.14	0.19	0.21	0.18
800	0.17	0.20	0.19	0.19
1000	0.21	0.20	0.21	0.21
Mean	0.21	0.21	0.20	0.22

L.S.D. (P = 0.05) means of N levels = 0.075% Ca C.V. 18.60%
L.S.D. (P = 0.01) means of N levels = 0.106% Ca
L.S.D. (P = 0.05) means of N frequency = 0.029% Ca C.V. 17.76%
L.S.D. (P = 0.01) means of N frequency = 0.040% Ca

The control gave a higher leaf-Ca, significant at 0.05, compared with the 200, 600 and 800 Kg levels.

There were no further significant differences between any of the treatments.

4.41 DISCUSSION AND CONCLUSIONS

It is important to know, before the discussion of the results, that all the plants in this experiment were very weak. The reasons for this may be the heavy nematode infestation and also the poor soil drainage. The results may, therefore, be partially influenced by these factors.

1. First crop year.

The yield for the first crop year was harvested from seventeen to twenty nine months after planting. The bulk of this crop was, however, harvested between twenty six and twenty nine months after planting. The few fruits harvested prior to that were from larger suckers on some of the stumps. It can, therefore, be accepted that flower differentiation for the most important part of the crop was twenty one months after planting. Only the data taken up to this latter date will be applicable to the yield in the first crop year.

(a) Levels of ammonium sulphate.

Increasing levels of ammonium sulphate had no significant effect on the weight of fruit per plot and the average weight per fruit. The number of fruit per plot, however, was significantly reduced in the two highest levels of N. It

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may, therefore, be concluded that the crop was delayed by the two highest levels of N. The latter two treatments had 1.700% and 1.766% leaf-N at flower differentiation, which was far in excess of the optimum 1.585% N established in (A) T.-Bh. 3 B. It has not been possible to establish any optimum leaf-N in this experiment, as was done in (A) T.-Bh. 3 B, becaused of the wide variation in the results with the lower levels of N.

The leaf-K was not affected by increasing levels of ammonium sulphate.

During flower differentiation the control gave a significantly lower leaf-Na compared with the 200 Kg and 600 Kg levels of ammonium sulphate. At this stage the leaf-Ca was significantly higher in the control compared with the two lowest and two highest levels of ammonium sulphate. The leaf-Mg results were very similar to the leaf-Ca. The control was significantly higher than the 200 Kg, 600 Kg and 800 Kg levels. These results indicate a possible interaction of Na with Ca and Mg as a result of increasing levels of ammonium sulphate which favoured the absorption of Na.

(b) Frequency of application of ammonium sulphate.

A frequency of two applications of ammonium sulphate gave a significantly higher weight of fruit per plot compared with four and six applications, amounting to an equivalent of 1.49 and 1.47 tons per acre, respectively. The reason for this increase was the significantly higher number of fruit per plot with a frequency of two applications. The crop was therefore delayed by four and six applications. The average weight per fruit, on the other hand, was significantly higher with a frequency of six compared with four applications.

In project (A) T.-Bh. 3 B it was found that 1.57% leaf-N, at flower differentiation, obtained from two applications of ammonium sulphate increased the yield significantly. In the experiment under discussion, the same treatment also gave a significant yield increase, but with 1.59% leaf-N. The frequency of four applications, which gave the highest leaf-N of 1.69% gave a significantly lower D-leaf weight at flower differentiation when compared with four and six applications. There was, however, no significant

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significant at 0.01 compared with the 1000 Kg level. The linear response of leaf-Mg to increasing levels of N was negative and significant at 0.05 with an average decrease of 0.0051 ± 0.0017% for each additional 200 Kg ammonium sulphate.

There were no significant differences in the leaf-Mg between any of the treatments at 26 and 33 months after planting.

(h) Calcium.

The calcium content of the leaves 21 months after planting is given in Table 17.

TABLE 17. Ca content (%) of the leaves 21 months after planting.

$(NH_4)_2SO_4$ (Kg per 10,000 plants)	Frequency of application			
	2	4	6	Mean
0	0.170	0.167	0.167	0.168
200	0.123	0.100	0.100	0.108
400	0.123	0.120	0.130	0.124
600	0.123	0.097	0.157	0.126
800	0.110	0.107	0.120	0.112
1000	0.133	0.113	0.120	0.122
Mean	0.122	0.107	0.125	0.127

L.S.D. (P = 0.05) means of N levels = 0.044% Ca C.V. 19.11%
L.S.D. (P = 0.01) means of N levels = 0.063% Ca
L.S.D. (P = 0.05) means of N frequency = 0.023% Ca C.V. 24.01%
L.S.D. (P = 0.01) means of N frequency = 0.031% Ca

The control gave a significantly higher leaf-Ca at 0.05, compared with the two lowest and two highest levels of N.

There were no significant differences between the means of frequency of application.

There were no significant differences in leaf-Ca between any of the treatments 26 months after planting.

The calcium content of the leaves 33 months after planting is given in Table 18.

/Table 18 .... 97.

significantly higher than the 600 Kg level of N. The latter level also gave the longest D-leaf at that time.

Thirty-eight months after planting, i.e. during the peak harvesting season for the second crop year, the D-leaf weights in the control and lowest level of N were still significantly lower compared with the 400 Kg, 600 Kg and 800 Kg levels.

The full value of these results can only be interpreted after the results for the second crop year are available.

(b) Frequency of application of ammonium sulphate.

The frequency of two applications which gave the heaviest D-leaves during flower differentiation for the first crop year, also gave the longest D-leaves during flower differentiation for the second crop year. This same treatment gave a significant lower leaf-N of 1.62% compared with four (1.75%) and six (1.84%) applications, and even this significantly lower leaf-N is higher than the 1.57% leaf-N established as the optimum for frequency of application in (A) T.-Bh. 3 B. It can, however, still be expected that the treatment of a frequency of two applications, will give an increased yield compared with the other two frequencies.

Frequency of application of ammonium sulphate had no significant effect on the leaf contents of K, Na, Mg and Ca thirty-three months after planting.

5. GENERAL DISCUSSION AND CONCLUSIONS

5.1 CAYENNE CULTIVAR

5.1.1. Yield. Irrespective of ~~the fact~~ whether the pineapples were planted in virgin or replanted soil, the crop was ~~nevertheless~~ significantly increased by the application of ammonium sulphate. It was evident, however, that the quadratic response became significant in both instances at 600 Kg ammonium sulphate either applied per annum or over the period from planting to flower differentiation. The increases in yield at this level were equivalent to 10.9 and 14.6 ton per acre in replanted and virgin soil, respectively, compared with no fertilisation. These increases can mainly be attributed to the increase in average weight per fruit by application of ammonium sulphate. It is doubted whether the difference of 3.56 tons in yield between the two soil types will be significant. The reason why replanted soil gave a bigger increase in yield compared with virgin soil may possibly be attributed to the different soil types. The ~~difference~~ effect of temperature, light intensity and carbondioxide supply which, according to Nightingale (1942 a) and Sanford (1962), play an important part in carbohydrate synthesis, cannot be excluded. The climatic conditions in the two localities vary considerable. The important fact remains that both soil types produced the maximum economic yield at the 600 Kg ammonium sulphate level. In both instances there was, however, no significant difference between this and the 400 Kg level. On the other hand there was a significant increase in yield of 6.10 tons per acre from the 200 Kg level to the 600 Kg level in the virgin soil, (R)T. Bh.3C, East London. This information indicated, therefore, that the 400 Kg level may be more acceptable, from an economic point of view, compared with both the 600 Kg and 200 Kg levels.

It was apparent that nitrogen levels in excess of 400 Kg were responsible for a delay in the crop in replanted soil. Py, Tisseau, Oury and Ahmada (1957) also found that flower formation was retarded by increasing applications of nitrogen and depended on the ratio of nitrate to carbohydrate in the plant. The possibility exists, therefore, that the leaf-N, as will be seen later, was too high at the higher levels of ammonium sulphate.

/ 5.1.2. Leaf-N ..... 102.

5.1.2. Leaf-N. The correlation between the production of fruit in weight per plot and the leaf-N was very similar for *

*To facilitate the study of the influence of ammonium sulphate on the pineapple plant and yield the plant crop cycle can be devided in three growth phases viz. Phase 1, period from planting to 10 months
Phase 2, period from 10 to 15 months from planting
Phase 3, period from 15 months to flower differentiation.

This period covered the first active and dormant seasons, that is the summer and up to the end of the winter. The most important results obtained were in the plant growth. In the virgin soil it was found that six months after planting the leaf growth was increased significantly by two small applications of 3.5 gm ammonium sulphate each compared with one large application during that time. This was probably due to the better utilisation of the second application of nitrogen during the second three-month period after planting, as was found by Sideris and Young (1950).

The leaf-N values at ten months after planting gave a positive and significant linear response to increased levels of ammonium sulphate but varied quite considerable individually. There were no indications of a correlation between leaf-N and the eventual yield. Although the lower ammonium sulphate levels gave significantly lower leaf-N these differences disappeared during the next spring and summer as will be seen later. The results obtained for leaf-N in the 400 Kg, which was established to be adequate for a maximum yield, viz. 1.21% and 1.37% in replanted and virgin soils respectively, should, therefore, be adequate at 10 months. The results obtained by Samuels et al (1955) showed that values below 1.66% leaf-N 8 months after planting were indicative of N deficiency and associated with lower yields. ~~are~~ This figure was, therefore, much higher than the above findings. ~~This is probably because fertiliser application was stopped 12 months after planting in the experiments by Samuels et al (1955) and a high initial leaf-N was needed to still have a sufficiently high leaf-N at flower differentiation (Nightingale, 1942 a).~~

To conclude, it appears that the most important factor during the first 10 months after planting was to stimulate plant growth. It will, however, be essential to establish the leaf-N at 10 months in order to determine the ammonium sulphate that will have to be applied during the next growth phase.

Phase 2. Period from 10 to 15 months from planting.

This period represents the most active growing months of the plant crop cycle, that is the spring and summer months before flower differentiation. It is important therefore that an optimum nutrient level be obtained in the plant to expect a maximum vigour.

In view of earlier discussions that the 400 Kg ammonium sulphate ~~Kg~~ treatment must be regarded as the desirable level, the leaf-N of this level at 15 months should be regarded as the required value. This level gave 1.963% and 1.986% leaf-N for the replanted and virgin soils, respectively. To reach these values 21.2 gm and 23.4 gm ammonium sulphate was applied, respectively. In replanted soil a frequency of two applications gave the highest weight of fruit per plot with a leaf-N of 1.958% at 15 months. Frequencies of 4 and 6 applications gave 2.026% N and 2.124% N at 15 months. In virgin soil a frequency of six applications gave the highest yield with 1.99% leaf-N at 15 months. Frequencies of 2 and 4 applications gave 1.78% and 2.03% leaf-N respectively. Because of the fact that the treatment with a frequency of 2 applications gave a lower yield, significant at 0.01,

* The leaf-N for a frequency of two applications was significantly lower at 0.01, compared with the other two frequency treatments.

in the significantly lower average weight per fruit for this treatment. § ~~On the other hand with 4 applications giving 2.03%~~

§ Furthermore, a frequency of 4 applications, with 2.03% leaf-N, gave a significant reduction in yield which indicated that this leaf-N must be too high.

~~the yield~~ later maturing fruit (see page 53) in replanted land. It appears, therefore, that the 1.958% leaf-N found in the replanted soil will be the required value under the frequency of application which is closely correlated with the 1.986% and 1.963% leaf-N for the levels of N treatments. The fact that replanted land gave a higher yield with a frequency of six applications was, therefore, mainly due to obtaining the correct leaf-N value. The reason why the virgin soil had to receive more applications of ammonium sulphate may be attributed to climatic conditions such as the drought experienced in this locality during the 10 to 15 months period. Py (1961) showed that drought can reduce the effectiveness of nitrogen application on the plant growth.

To conclude, therefore, it is apparent that a value of between 1.958% and 1.986% leaf-N should be attained at 15 months after planting. Values lower than 1.958% leaf-N were responsible for a reduction in yield and values higher than 1.986% leaf-N retarded the crop. A quantity of between 21.2 gm and 23.4 gm ammonium sulphate was needed during the period 10 to 15 months to reach these limits. The number of applications depended on climatic conditions during the period. To eliminate any possible errors that may be caused through these limiting factors it will be necessary to take regular leaf samples throughout this period to study the effect of previous ammonium sulphate applications and determine the necessity of further applications.

Phase 3. Period from 15 months to flower differentiation.

This period represents the dormant winter season immediately preceding flower differentiation.

In both replanted and virgin soils there was a highly significant drop in the average leaf-N from 15 months up to flower differentiation. This decrease was more pronounced, however, in the virgin soil because no ammonium sulphate was applied to these plants during that period. The leaf-N of 1.328% for the highest N level in the latter soil was not even as high as the leaf-N in the lowest N level viz. 1.436% in the experiment on replanted soil where ammonium sulphate was applied during that period. This value of 1.436% leaf-N was significantly lower than all the higher N levels in the same experiment. There was, however, no significant difference between any of the higher N-levels and it can therefore, be accepted that even the 1.436% leaf-N is too low. The next level of 400 Kg, which was also associated with the highest yield, with 1.633% leaf-N, should, therefore, provide the optimum leaf-N.

In the light of this discussion it appears that ammonium sulphate should have been applied in the virgin soil during the period from 15 months to flower differentiation. This was probably because the available soil-N was not of any value to the plants. Nightingale (1942 a) stated that temperatures of 68°F and lower may result in the limitation of absorption of nitrate by the roots.

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For the months of April to November, in the locality of the virgin soil experiment, the average monthly soil temperatures were all below 68°F. (Annexure A).

[illegible] sulphate application which leads to the conclusion that the plants could make use of the nitrogen in this instance where it was applied in the basal leaves.

From the results obtained in the replanted land quantities of 16.3 gm and 18.4 gm ammonium sulphate were applied in N levels and frequency of application respectively to obtain the indicated leaf-N values. These quantities were split into two separate applications.

In conclusion, therefore, it was shown that the application of ammonium sulphate was essential during the period from 15 months to flower differentiation. A quantity of from 16.3 gm to 18.4 gm ammonium sulphate was applied in two split applications to obtain the required 1.633% leaf-N at flower differentiation.

<u>Entire period from planting to flower differentiation for the plant crop</u>

From the above discussion ~~To summarise the results~~ it was shown that a total quantity of up to 50.4 gm ammonium sulphate (10.58 gm N) per plant was needed through the plant crop cycle for a maximum yield. Therefore, although the 400 Kg level was taken for the leaf-N studies, it appears that in actual fact 504 Kg will give the best yield. This difference is attributed to the additional ammonium sulphate to be applied between 15 months and flower differentiaion.
In the virgin soil planting with a spacing of 3'6"x18"x9" a total quantity of 541.3 lb N was ~~will be~~ applied per acre. In the replanted land with a spacing of 4'x2'x9" a total quantity of 451.0 lb N was ~~will be~~ applied per acre. The difference of quantity in the two soils was due to the number of plants per acre. Samuels et al (1958) found that 480 lb N per acre gave the highest yields. This value is in close agreement ~~correlation~~ with the above and small variations may be due to the number of plants per acre.

The total number of applications throughout the plant crop cycle will depend on the climatic conditions, in particular the period from 10 to 15 months after planting.

5.1.3. Leaf-Chlorophyll. The linear response of leaf-chlorophyll to increasing levels of ammonium sulphate was positive and significant, in most instances, throughout the plant crop cycle. Although this was similar to the yield response and leaf-N results it appears that the differences between individual treatments were not as marked for the leaf-chlorophyll. It will, therefore, be more accurate to make use of leaf-N as an index to the nitrogen requirements of the plants.

The reason for the poor response of leaf-chlorophyll must be as a result of the interference of iron deficiency. The detrimental effect of iron deficiency on leaf-chlorophyll was described by Sideris and Young (1944), Sideris and Young (1946), Sideris (1947) and Sideris and Young (1956). ~~Furthermore,~~ The low temperatures of the comparatively ~~the~~ severe winters, ~~and hence more pronounced dormant season,~~ may affect the nitrogen absorption resulting in an accumulation of carbohydrates at the expense of protein-N which caused ~~pronounced~~ intense yellowing of the leaves.

5.1.4. Fruit quality. Although the linear response of the degree of translucency of the fruits was positive and significant at 0.01 with increasing levels of ammonium sulphate, the quadratic response was negative and significant at 0.05. This response may affect the canning quality of the fruit adversely depending on the maximum degree of translucency allowed by the Canners. On the other hand, if a lower translucency is required, the fruits must be harvested before they ripen. Translucency only develops when the fruits are mature and on the point of ripening.

5.1.5. Plant growth. Nitrogen application was responsible

*That is, the maximum increase in growth was at the 600 Kg level and it is doubtful whether any benefit will be obtained from further increases of ammonium sulphate.

quadratic response. *

The response of D-leaf weight at the time of flower differentiation appeared to be very similar to the results with the average weight per fruit. If this relationship can be established it will provide a valuable index to determine the ultimate yield at the time of flower differentiation, that is from 4 to 7 months before harvesting.

5.1.6. Sucker production. The number of suckers present on the plants immediately after ~~the plant crop~~ cropping will determine the yield of the ratoon crop. In both the replanted and virgin soils the 200 Kg level of ammonium sulphate produced a lower number of suckers, significantly at 0.05, compared with the higher levels. In the virgin soil, however, the two highest levels gave a significant increase in suckers at 0.01 compared with the lower levels. This was not the case in the old soil which may be attributed to the fact that these plants received ammonium sulphate during the period from 15 months to flower differentiation. Sucker development should start soon after flower bud appearance. As sucker production was dependant on the level of nitrogen it ~~will appear~~ can be concluded that ~~an~~ the application shortly before flower differentiation ~~would have~~ stimulated sucker development in the virgin soil experiment. This is supported by the earlier discussion where proof was put forward that the leaf-N was too low, in this experiment, at flower differentiation.

5.1.7. Slip production. The application of ammonium sulphate was responsible for a significant increase at 0.05 in the number of slips, compared with the control. This was in accordance with the findings of Samuels et al (1955).

This increase in slip production is important because slips are considered to be the best type of plant material for the Cayenne cultivar. On the other hand, it is expected that too high a number of slips per plant may retard sucker development for the first ratoon crop.

5.1.8. K, Mg, Ca and Na content of the leaves.

In both experiments it was found that at the end of the second summer, that is approximately 15 months after planting, the values for leaf-K and leaf-Ca were higher than those at 10 months and at ~~flower differentiation~~ 22 months and were significantly ~~at~~ different from these at the 0.01% level. In the virgin soil the same result applied to leaf-Mg. This may be purely because the plants could absorb these elements freely during the active growing period from 10 to 15 months, whereas, absorption was restricted through the winter months preceding both the other two sampling dates.

The mean effect of increasing frequency of application of ammonium sulphate, over the entire plant crop cycle, on leaf-Ca and leaf-Mg was significantly negative and linear on replanted land. On virgin soil only the leaf-Mg gave a negative quadratic response. This may be due to the lower quantities of Ca and Mg in the replanted soil which were restricted by the ammonium ion.

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In virgin soil increasing levels of ammonium sulphate had a positive linear effect on leaf-Mg and leaf-Ca at 10. 15 and 20 months after planting, significant at 0.01. This linear response was more pronounced at 15 months. The mean response over the complete plant crop cycle remained linear and positive but the quadratic response became negative and significant at 0.01 with the 600 Kg treatment giving the peak. Leaf-K, however, gave a negative linear response to increasing levels of ammonium sulphate at 10 and 20 months after planting with no significant response at 15 months. In the replanted soil the response was similar for the leaf content of Mg, Ca and K except that the linear response of leaf-Mg and leaf-Ca was negative and significant at 0.05, 9 months after planting.

This obviously depressing effect of ammonium sulphate on potassium absorption was in accordance with the results obtained by Sideris and Young (1946 b) They attributed this response to the concentration of NH_4^+ ions. According to Nightingale (1942 b), the absorption of the ammonium ion is not favoured by potassium. Sideris and Young (1951) ~~also~~ later found that potassium content in the non-chlorophyllous basal section of the leaves correlated negatively with ~~those of~~ the calcium content in the nutrient solution. The high Ca in the soil of the virgin soil experiment may, therefore, lead to the impression that Ca may in some way have had an adverse effect of the absorption of K. Kanapathy (1958) found that with decreasing potassium applications Mg and, to a smaller extent, Ca replaced K in the pineapple leaf. Therefore, the argument seems to be in favour of the possibility that Mg was responsible for the decrease in leaf-K. This may be more likely in view of the relationship of Mg with chlorophyll and the increase of both by increasing the ammonium sulphate levels.

In virgin soil the mean response, over the entire plant crop period, of leaf-K and leaf-Mg to increasing frequency of application of ammonium sulphate was similar. Four applications gave significantly higher values compared with two and six. These results are similar to that obtained for the average weight per fruit. In replanted soil, however, leaf-Mg and leaf-Ca acted similarly in producing a negative linear response to increasing frequency of applications. This response followed the same pattern as the weight of fruit per plot.

5.2: QUEEN CULTIVAR

5.2.1. First crop year.

Yield. Notwithstanding the fact that the plant growth in the replanted soil was generally poor, the yield in the first crop year was comparatively higher than in the virgin soil. The reason for this was that, although the suckers on the stumps, at the time of planting, were of the same length they were more mature in the replanted land project. This resulted in a higher number of fruits and hence a higher weight of fruit per plot. The average weight per fruit was practically the same in both projects.

The application of ammonium sulphate increased the weight of fruit per plot due to an increased number of fruit, compared with the control. This increase amounted to a calculated value of 1.99 tons per acre. The quadratic response to increased levels of nitrogen was negative and significant. This indicated that one of the lowest two levels should be adequate for a maximum yield.

The crop was delayed by the 600 Kg, 800 Kg and 1000 Kg levels. Although ammonium sulphate increased the average weight per fruit significantly compared with the control, this increase was coupled with a linear increase in the degree of translucency with increasing levels of ammonium sulphate, which is undesirable for the fresh fruit market. This also indicated, therefore, that the lower levels of nitrogen should be preferable. The plant growth at the 400 Kg level was superior to the 200 Kg level at flower differentiation. From all these results it was concluded that the 400 Kg level was preferable for the period preceding the first crop year.

Leaf-N. The results obtained with the 400 Kg level can be correlated with the leaf-N. During the period from planting to eleven months 16.6 gm ammonium sulphate was applied per plant in one application. This gave a leaf-N of 1.763% at eleven months. From eleven to sixteen months a quantity of from 23.2 gm to 25 gm ammonium sulphate was applied in one application. This resulted in 2.017% leaf-N at sixteen months. No evidence could be found to prove any necessity of applying ammonium sulphate during the period from sixteen months to flower differentiation of the first crop. This may be due to the fact that the application of ammonium sulphate was continued at any rate during the early spring but to the suckers which will produce fruit during the second crop year. The leaf-N of the 400 Kg treatment was 1.585% af flower differentiation. Increases of leaf-N above this value resulted in (1) higher average weight and, therefore larger fruit (2) delay in fruiting (3) higher degree of translucency (4) heavier and longer D-leaves. Because of the adverse effects of (2) and (3) it appears inadvisable to increase the leaf-N above 1.585% as they outweigh the benefits. The latter, weight, at any rate, were not responsible for an increase in yield.

A total quantity of up to 41.6 gm ammonium sulphate per plant was needed for the whole period from planting to flower differentiation for the first crop. This quantity was split in two applications. When given in four or six applications the harvesting was delayed and was also associated with excessively high leaf-N at the time of flower differentiation.

Chlorophyll. ~~Leaf-chlorophyll analysis showed that although~~ Increasing levels of ammonium sulphate gave a positive linear response in leaf-chlorophyll at flower differentiation but no significant differences between the individual levels of Nitrogen supply. Leaf-N on the other hand gave a positive linear response together with significant differences between the various levels of ammonium sulphate supply.

... positive linear response to increasing levels of ammonium sulphate at eleven and sixteen months after planting. At flower differentiation, however, only leaf-Ca and leaf-Mg maintained this response, whereas, the leaf-K values changed to a positive and significant quadratic response. Leaf-K was, at this time, significantly higher for the control, at 0.01, than the 800 Kg level and also significantly higher for the control, at 0.01, than the 800 Kg level and also significantly higher at 0.05 than the 200 Kg and 400 Kg levels. These results can be explained in the light of the reasonable supply of available potassium in the soil (Annexure B) at the time of planting. This supply was apparently adequate for the first

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sixteen months but by the time of flower differentiation the larger quantities of Mg and Ca dominated the absorption of K.

The main effect of frequency of application on leaf-Ca showed that the treatment with four applications gave a significantly higher value which correlated with the average weight per fruit. Leaf-Mg was significantly higher at a frequency of six compared with two applications with a significantly positive and linear response to increasing frequency. This was similar to the results obtained with the leaf-N and leaf-chlorophyll. The close relation of chlorophyll with Mg will explain this similarity.

Leaf-N showed no response to any of the ammonium sulphate treatments in the virgin soil.

In the replanted soil the results with leaf-Ca and leaf-Mg were the opposite to virgin soil at the time of flower differentiation with increasing levels of N. In the former soil the control gave higher values compared with the ammonium sulphate treatments. With leaf-Na, however, the control was significantly lower than the ammonium sulphate levels.

The leaf-K was not affected by any of the levels of ammonium sulphate.

Frequency of application of ammonium sulphate had no significant effect on the leaf content of K, Ca and Mg at flower differentiation. Leaf-Na, however, was significantly decreased when two applications were given compared with four applications. This, together with the results with the levels of nitrogen indicates that nitrogen had some beneficial influence on the increased absorption of sodium. This in turn must have affected the absorption of K, Ca and Mg.

5.2.2. Second crop year. Only the results for the leaf analysis during this cycle are available. They are of interest, however, because in the Queen cultivar, fertilization was continued on the suckers adjoining those which were at that time in fruit for the first crop.

The first period represents the time from flowering, early spring, 21 months after planting, to the harvesting of the first crop in midsummer, 26 months after planting. During this period the suckers for the second crop were in their active growing stage.

The 400 Kg level, which gave the best results for the first crop, gave much higher values for leaf-N (2.64%) and leaf-chlorophyll (330.1 ppm) at 26 months, compared with the first crop at the same stage of growth viz. 2.017% and 154.03 ppm respectively. The possibility exists, therefore, that these values are excessive and may affect the yield adversely in the second crop year.

The leaf content of K, Ca, Mg and Na were not affected by ammonium sulphate applications during this period.

The second period represents the time from mid-summer, 26 months, to flower differentiation for the second crop, 33 months after planting. The required leaf-N at flower differentiation for the first crop was earlier established to be 1.585% at the 400 Kg level. This same level now gave 1.627% leaf-N at flower differentiation for the second crop and 1.538% leaf-N for the 200 Kg level. It appears, therefore, that, whereas 400 Kg may have been still too high the 200 Kg was too low. The yield data will, however, show the required content. The plant growth on the other hand, as reflected in the D-leaf length, gave the best results at the 600 Kg level.

The leaf-N results for frequency of application at flower differentiation also showed higher values compared with the first crop results. It appears that increased frequency was responsible for the excessive increase in leaf-N. Therefore, only one or two applications may give the required leaf-N. This was confirmed by the D-leaf length results where the frequency of two applications also produced longer D-leaves compared with four and six applications.

It appears, therefore, that as a result of the overlapping of fertilisation for the first and second crop year, smaller and less frequent applications of ammonium sulphate will be advisable.

At flower differentiation for the second crop the leaf-K was lower in the control compared with the 400 Kg and 600 Kg levels of ammonium sulphate. Leaf-Ca, however, was significantly higher in the control compared with the same two levels.

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7. SUMMARY

A. Investigation.

1. Four projects were carried out to establish the effect of 6 increasing levels of ammonium sulphate, applied in 2, 4 and 6 instalments, on Cayenne and Queen pineapple plants and yield. Each cultivar was planted on virgin and replanted soils. All plants were planted from November to December.

2. The possibility of establishing an index to assess the nitrogen requirements of the plants, through leaf-N and/or leaf-chlorophyll, was studied in conjunction with the plant crop yield.

3. The effects of ammonium sulphate on the leaf content of N, K, Ca, Mg and Na were studied.

B. Conclusions.

Cayenne:

1. An optimum yield was obtained at 600 Kg ammonium sulphate per 10,000 plants, during the plant crop cycle. An increase of 10.9 ton and 14.46 ton per acre was obtained in the replanted and virgin soils, respectively, compared with the control.

There were no significant differences between the total yields at the 600 Kg and the 400 Kg. levels. The former quantity (i.e. 600 Kg) however produced irregular maturation of the crop as compared with the 400 Kg treatment. The latter was, therefore, considered preferable and more economical.

3. The number of slips and suckers per plant were increased by the application of ammonium sulphate.

4. The D-leaf weight was increased linearly with increasing levels of ammonium sulphate at flower differentiation. This was similar to the results obtained for average weight per fruit.

5. A close correlation was found between leaf-N and the plant crop results. From planting to 10 months the plant growth was stimulated by two applications of 3.3 gm ammonium sulphate each, per plant. The leaf-N should be between 1.21% and 1.37% at 10 months. The leaf-N value at 15 months after planting should be between 1.958. and 1.986%, obtained by application of 21.2 gm and 23.4 gm ammonium sulphate per plant during the period from 10 to 15 months. Regular leaf analysis and studies of

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climatic conditions will be necessary to determine the number of applications the total quantity must be split into. A quantity of 16.3 gm to 18.4 gm ammonium sulphate, split in two applications, was essential from 15 months to flower differentiation. 1.638% leaf-N was obtained at the latter date.

6. From the leaf-N studies a calculated total of 50.4 gm ammonium sulphate per plant will be required from planting to flower differentiation for a maximum yield.
7. In both soil types leaf-K and leaf-Ca were significantly higher at 15 months compared with 10 months and flower differentiation. In virgin soil the same applied to leaf-Mg.
8. On virgin soil leaf-Mg and leaf-Ca were increased linearly with increasing levels of ammonium sulphate throughout the plant crop cycle. This response was quadratic, however, and the peak reached at the 600 Kg level. Leaf-K, on the other hand, was reduced linearly 10 and 20 months after planting.
9. In replanted soil the response of leaf-Mg, leaf-Ca and leaf-K was similar to virgin soil except for a linear decrease of leaf-Mg and leaf-Ca at 9 months after planting.
10. On replanted soil increasing frequency of application of ammonium sulphate decreased the leaf-Ca and leaf-Mg linearly over the entire plant crop cycle.
11. In virgin soil a frequency of 4 applications of ammonium sulphate gave a higher leaf-K and leaf-Mg compared with 2 and 6 applications. This response was similar to the average weight per fruit.

Queen:

1. Application of ammonium sulphate gave an average increase of 1.99 tons of fruit per acre compared with the control.
2. Quantities exceeding 600 Kg ammonium sulphate during the plant crop cycle delayed the fruit harvesting. The 400 Kg level was not significantly different to the 600 Kg level. Plant growth was significantly better at 400 Kg than 200 Kg. The 400 Kg level was therefore considered the optimum economical quality.
3. Optimum leaf-N values for the first crop were: 1.763% at eleven months obtained by one application of 16 gm ammonium sulphate before the first winter;

/ 2.017% .... 3.

2.017% at sixteen months obtained by one application of 23.2 gm to 25 gm ammonium sulphate during spring; 1.585% at flower differentiation. The leaf-N value in the suckers for the second crop was 2.64% at 26 months from planting and at flower differentiation for the latter crop 1.627%. Smaller quantities of ammonium sulphate applied less frequently may bring the leaf-N in second crop suckers to the required levels as for first crop suckers.

4. In virgin soil increasing levels of ammonium sulphate increased leaf-Ca and leaf-Mg linearly up to flower differentiation. Leaf-K was similar up to 16 months but afterwards changed to a positive quadratic response.
5. Leaf-Ca and leaf-Mg were highest with frequencies of application of 4 and 6 respectively.
6. In replanted soil the response of leaf-Ca and leaf-Mg to increasing levels of ammonium sulphate were the opposite to virgin soil (4) at the time of flower differentiation. Frequency of application had no effect on leaf-K, leaf-Ca and leaf-Mg in replanted soil.
7. Levels and frequency of application of ammonium sulphate had no significant effect on leaf-Na in virgin soil. In virgin soil it was increased linearly.

Cayenne and Queen.

1. Leaf-chlorophyll was linearly increased by increasing levels of ammonium sulphate but without significant differences between levels at most sampling dates. These values will, therefore, not be suitable to assess the nitrogen requirements of pineapple plants as accurately as leaf-N values.
2. The degree of translucency of the fruits was increased linearly by increasing levels of ammonium sulphate.

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ANNEXURE A

AVERAGE SOIL TEMPERATURE (^{o}F) AT 20 cm DEPTH. 8.00 am.

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1961	72.16	73.83	72.19	65.84	59.85	57.51	56.70	56.14	59.81	60.91	67.10	70.70
1962	72.81	72.59	69.78	65.80	59.70	57.16	57.63	59.72	60.35	64.94	67.05	73.80
Mean	72.49	73.20	70.99	65.82	59.78	57.34	57.17	57.93	60.08	62.93	67.08	72.25

ANNEXURE B

This annexure shows the citric acid soluble nutrient status of the soil, that is, the quantity of the nutrients that should be immediately available to the plants. The figures were taken from a soil survey of the Pineapple Research Station conducted by the Division of chemical Services, March, 1959, shortly before the commencement of the experiments.

Citric acid soluble nutrients in the soil

Soil depth (inches)	% K_2O	% CaO	% MgO	% P_2O_5
0 - 6	0.037	0.30	0.10	0.0015
6 - 15	0.033	0.18	0.10	0.0010

ANNEXURE C

EXPERIMENTAL PROCEDURE FOR THE DETERMINATION OF CHLOROPHYLL

APPARATUS:-

(i) An Evelyn Photo-electric Colorimeter. With No. 540M filter.

(ii) A Waring Blendor.

(iii) A stop watch.

REAGENTS:-

(i) Acetone, 98%

(ii) Na-K-Chlorophyllin:- Dissolve 0.5 gm Na-K-Chlorophyllin in 1,000 ml water.

PROCEDURE:-

(a) Calibration curve:- Prepare 20 dilutions of the standard Na-K-Chlorophyllin solution by diluting 2, 4, 6, 8, 10, 12 etc. up to 40 ml to 100 ml water each. These solutions will give 40, 80, 120, 160 etc. up to 800 ppm chlorophyll equivalents in fresh pineapple leaf tissue. Plot the curve with the percentage light transmitted by the colorimeter using a no. 540M filter against the different concentrations of chlorophyll solutions.

(b) Preparation of leaf solution:-
Weigh out accurately 10 grams of green leaf tissue, prepared as described in section 3.41, and transfer to the goblet of a Waring Blendor. Add 94 ml 98% acetone to the leaf material and blend for two minutes at high speed. Filter through a 15 cm Whatman no. 12 filter paper into a clean and dry erlenmeyer flask. Rinse a test tube with a small amount of the filtrate and afterwards fill the test tube. Check the adjustment of the galvonometer light spot then place the test tube with the filtrate into the tube sleeve and read the percentage light transmission. By means of the calibration curve read off the ppm of the leaf solution.

EXPERIMENTAL PROCEDURE FOR THE DETERMINATION OF NITROGEN

APPARATUS:-

(i) Macro-Kjeldahl with digestion and distillation racks, taking 12 800 ml flasks in each rack.

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REAGENTS:-

(i) H_3BO_3 solution:- Dissolve 5 gm H_3BO_3 (A.R.) in 100 ml water at 60 degrees centigrade. Allow to cool to room temperature.

(ii) NaOH solution:- Dissolve 40 lb NaOH (commercial flakes) in 20 litres water, allow impurities to settle out and pour off supernatant liquid.

(iii) Mixed indicator:- Dissolve 0.2 gm bromocresol green and 0.1 gm methyl red in 100 ml ethyl alcohol. Filter if solution is not complete.

(iv) H_2SO_4, C.P. conc.

(v) K_2SO_4, anhydrous powder, A.R.

(vi) $CuSO_4.5H_2O$, A.R.

(vii) Granulated zinc, A.R.

(viii) 0.1 N HCl, prepared as follows:
Weigh out accurately 5.3 gm Na_2CO_3 in a crucible and dry in oven at 100°C for 3 hours; Keep on weighing, using a desiccator, until a constant weight is obtained. Transfer quantitatively to a volumetric flask containing approximately 200 ml distilled water. Dissolve and make up to mark, then mix thoroughly.
Weight in grams of Na_2CO_3 = Normality of Na_2CO_3
With a micro-burette carefully tap 21.0 ml HCl, A.R., conc. into a 2,000 ml volumetic flask containing approximately 200 ml distilled water. Make up to mark and mix thoroughly. Then standardise the HCl solution against the standard Na_2CO_3 solution using the screened indicator (ix).

(ix) Screened indicator:- Dissolve 0.1 gm screened Methyl Orange in 100 ml distilled water.

PROCEDURE:-

Weigh out accurately 1 gm of the dried leaf material and transfer quantitatively to an 800 ml Kjeldahl flask. Add one teaspoon (approximately 10 gm) K_2SO_4 to the flask and then add approximately 0.2 gm $CuSO_4.5H_2O$. Then add carefully 25 ml conc. H_2SO_4. Three glass beads are dropped into the flask to prevent bumping. Place the flasks on the disgestion rack and digest until the solution is clear. Reduce the heat and let the solution simmer for one hour.

/ Allow .... 3.

Allow to cool, then add 200 ml water and one Zn pellet. To this add 50 ml conc. NaOH solution without mixing unduly by allowing the NaOH to run down the neck of the slanted flask.

To the receiving flask pipette 50 ml H_3BO_3 solution and to this add 10 drops of the mixed indicator. Place the receiving flasks on the rack.

Connect the Kjeldahl flasks to the distillation rack and mix with a swirling motion. Distill until approximately 125 ml has passed over into the receiving flask. The rate of distillation should be such that this amount passes over in approximately 30 minutes. Turn off the heat and remove the Kjeldahl flasks. Allow the condensers to drain into the receiving flasks. Titrate the distillate accurately against the 0.1 N HCl to the first tinge of red.

A graph can be drawn up with the following standards of HCl as basis:

20 ml 0.085N HCl = 2.375 % N
20 ml 0.090N HCl = 2.525 % N
20 ml 0.095N HCl = 2.65 % N
20 ml 0.1 N HCl = 2.8 % N
20 ml 0.105N HCl = 2.95 % N
20 ml 0.110N HCl = 2.95 % N
20 ml 0.115N HCl = 3.2 % N

NOTES:

(i) If sucking back should occur during the distillation process, add a further aliquot of H_3BO_3 solution and indicator to the receiving flask and continue the distillation.

(ii) A blank should be run with each batch of samples by leaving out the leaf material at the start of the digestion process.

/ .... 4.

DETERMINATION OF Na, Ca, K AND Mg.

(a) Leaf Digestion:-

(1) Weigh out accurately 2 gm dried non-chlorophyllous basal leaf material.

(2) Transfer to a wide mouth 250 ml erlenmeyer flask.

(3) Add 20 ml. conc. HNO_3 with swirling to assure thorough mixing of leaf material with the solution.

(4) Add 5 ml conc. $HClO_4$.

(5) Include a blank amongst the samples to be digested.

(6) Place on hot plate in fume cupboard.

(7) Heat very gently until brown fumes are given off. Too much heat will cause bumping of the flakes. Swirl flasks when necessary.

(8) Continue to heat for 2 to 4 hours until all solid matter has been dissolved. A brownish liquid will remain.

(9) Apply more heat. If the contents of the flask sputter, reduce the heat for a while.

(10) Soon white fumes will be given off. Keep a constant watch on the flasks and on no account allow them to boil dry as the perchlorate crystals have been known to explode.

(11) When the liquid in the flask has been reduced to approximately 2 to 4 ml remove the source of heat and allow the flasks to cool in the fume cupboard until all fuming has ceased.

(12) The flasks should then contain a small quantity of colourless liquid and crystals.

(13) If the contents are not completely colourless add 5 ml HNO_3 and repeat the steps (9) to (12). If colour still persists, repeat steps (13) and (9) to (12) once more. If still discoloured start the sample from step (1).

(14) Place a 12,5 cm Whatman No. 40 filter paper in a glass funnel and place the funnel in a waste collecting beaker.

(15) Wash the filter paper with about 25 ml of nearly boiling HCl_4 solution (10 ml conc. $HClO_4$ per litre).

(16) Replace the waste collecting beaker with a 100 ml beaker with a smear of pure grease below the lip.

(17) Smear a film of pure grease round the rim of the flask containing the sample.

(18) Add about 10 ml nearly boiling water.

(19) Swirl to mix

(20) Occasionally a sample, although perfectly colourless after completion of step (13) will turn a bright yellow

colour on the addition of the hot water. If a repetition of steps (13) and (9) to (12) are ineffective then that particular sample will have to be started again from step (1).

(21) Pour the solution into the filter paper and allow to filter.

(22) Add 10 ml nearly boiling water to the flask. Repeat steps (21) add (22) until the receiving beaker is ¾ full.

(23) Allow to cool.

(24) Transfer to a 100 ml volumetric flask.

(25) Make to the mark with water rinsing the beaker with the water.

(26) Mix thoroughly.

(b) Neutralisation:-

REAGENTS:-

(1) 10% $(NH_4)_2CO_3$: Dissolve 100 gm ammonium carbonate A.R. in litre water. Store in polythene container.

(2) Methyl orange indicator: Dissolve 1 gm methyll orange in 100 ml water.

PROCEDURE:-

(1) Pipette out 10 ml leaf solution into a 100 ml beaker.

(2) Add 2 drops of methyl orange indicator.

(3) Titrate with 10% $(NH_4)_2CO_3$ until colour just turns to yellow.

(4) Note the amount of ammonium carbonate solution.

(5) Pipette out 80 ml leaf solution into a 100 ml beaker.

(6) Add 8 times the amount of $(NH_4)_2CO_3$ solution noted in (4).

(7) Smear a film of pure grease below the lip of the beaker.

(c) DEIONIZATION.

The ion exchange column can be made from a 100 ml **burette.** Cut off the tip of the burette below the tap in order to obtain a large bore delivery tube. Wit a glass rod tamp a glass wool plug into the column of the burette just above the tap. Place sufficient De-Acidite E resin above this plug to fill the burette for about six inches. Place another glass wool plug above this and tamp it down firmly.

Ion exchange column test:

(1) Test solution: Dissolve about 0.5 gm KH_2PO_4 in 1 litre water.

(2) Pass test solution through column at 1 drop per second.

(3) Test leachate for P by the molybdenum-blue method.

/ (4) .... 6.

(4) If any blue colour develops the resin must be regenerated or replaced.

(5) 30 to 50 samples can be leached before the resin is exhausted.

Regeneration of resin:

(1) Dissolve 50 gm anhydrous Na_2CO_3 in 1 litre water

(2) Dilute 50 ml. conc. HCl to 1 litre.

(3) Place about 50 gm resin in a 500 ml erlenmeyer flask.

(4) Add 100 ml Na_2CO_3 solution.

(5) Shake well

(6) Allow to stand for half hour.

(7) Decant the liquid.

(8) Repeat steps (4) to (7) twice more.

(9) Add 100 ml water and shake well.

(10) Decant the liquid.

(11) Repeat steps (9) and (10) twice more.

(12) Add 100 ml HCl solution (2), and shake well.

(13) Leave for half hour.

(14) Decant the liquid.

(15) Repeat steps (12) to (14) twice more.

(16) Repeat step (12).

(17) Allow to stand for 2 hours.

(18) Decant the liquid.

(19) Add 100 ml water and shake well.

(20) Decant the liquid.

(21) Repeat steps (19) and (20) until supernatant liquid is colourless after being allowed to stand in contact with the resin for a half hour.

Deionization of the leaf solution:-

(1) Pour 50 ml of the leaf solution into a separate beaker and then into the ion exchange column.

(2) Keep the remaining 30 ml of leaf solution for the determination of P.

(3) Leach the 50 ml through the column at 1 drop per second into a 100 ml volumetric flask.

(4) Add a little water to the beaker and rinse into the column.

(5) Add a little water to the column now and again when necessary.

(6) Leach until the flask is filled to the mark and shake well.

(7) This solution is now ready for the determination of Ca, Na, K and Mg.

/(d) .... 7.

(d) METHODS OF DETERMINATION.

APPARATUS:

"EEL" Flame Photometer.

REAGENTS:

(i) 500 ppm Na solution:- 1.271 gm NaCl diluted to 1,000 ml.

(ii) 500 ppm Ca solution:- 1.248 gm $CaCO_3$ + 3 ml 1:1 A.R. HCl diluted to 1,000 ml.

(iii) 1,000 ppm K solution:- 1.907 gm KCl diluted to 1,000 ml.

(iv) 250 ppm Mg solution:- 2.535 gm $MgSO_4.7H_2O$ diluted to 1,000 ml.

(v) EDTA solution 0.01 N:- In 1 litre water dissolve 4 gm di-sodium salt of ethylene diamine tetra-acetic acid, and 0.75 gm NaOH pellets. Store in polythene.

(vi) Buffer solution pH 10:- Dissolve 33.7 gm A.R. NH_4Cl in about 100 ml water mixed with 285 ml conc. A.R. NH_4OH. Dilute to 500 ml and store in a polythene bottle.

(vii) Eriochrome Indicator:- Dissolve 0.2 gm Eriochrome Black T in 50 ml methyl alcohol containing 2 gm hydrochloride. Keep in absolute dark and prepare fresh every fortnight.

(viii) Screened Murexide Indicator:- Grind 0.1 gm ammonium purpurate 0.7 gm Naphtohol Green B + 12 gm A.R. K_2SO_4 to a fine and proper mixture. Store in a black painted bottle.

Standardisation of EDTA solution against Mg:-

(1) Pipette out 50 ml of Mg standard into a titration flask.

(2) Dilute to 100 ml.

(3) Add 5 ml ammonia buffer.

(4) Add 15 drops Eriochrome indicator.

(5) Titrate against EDTA until colour changes to permanent dark blue without a trace of violet on shaking.

(6) mg Mg per ml EDTA = $\frac{12.5}{\text{ml EDTA used}}$

PROCEDURE.

Make up different concentrations of the Na, Ca and K standard solutions by dilution with water and determine the flame photometer readings for these. Draw up a graph for each and determine the Na, Ca and K content in the leaf

/ solution ...... 8.

solution by comparing their flame photometer readings with their respective graphs.

The determination of Mg is done as follows:

(1) Pipette out 50 ml of the leaf solution in a titration flask.
(2) Dilute to 100 ml with water.
(3) Add 5 ml buffer solution pH 10.
(4) Add 15 drops Eriochrome indicator.
(5) Titrate against EDTA until the colour changes to a permanent blue without a trace of violet on shaking.
(6) Note the quantity used.

$$\% \, Mg = C - \frac{0.032X}{Y} \times 0.2B$$

Where: C = ml EDTA used in (6).
X = % Ca determined with flame photometer
Y = mg Ca per ml EDTA
B = mg Mg per ml EDTA

ANNEXURE D

METHOD: STATISTICAL ANALYSIS

(A)T. - Bh. 3A 20-9-1961 % N

	I	II	III	Totals	III - I	III + I - 2 II
A	0.99	0.84	1.54	3.37		
1 B	0.69	0.94	0.81	2.44		
C	0.64	0.75	1.04	2.43		
Totals	2.32	2.53	3.39	8.24	1.07	0.65
M'	-0.35	-0.09	-0.50	-0.94	-0.15	-0.67
M''	0.25	--0.29	0.96	0.92	0.71	1.79
A	1.04	0.80	1.29	3.13		
2 B	0.74	0.81	1.19	2.74		
C	1.13	1.19	0.94	3.26		
Totals	2.91	2.80	3.42	9.13	0.51	0.73
M'	0.09	0.39	-0.35	0.13	-0.44	-1.04
M''	0.69	0.37	-0.15	0.91	-0.84	-0.20
A	0.79	1.45	1.18	3.42		
3 B	0.98	1.30	1.74	4.02		
C	1.00	1.23	1.18	3.41		
Totals	2.77	3.98	4.10	10.85	1.33	-1.09
M'	0.21	-0.22	0	-0.01	-0.21	0.65
M''	-0.17	0.08	-1.12	-1.21	-0.95	-1.45
A	1.24	1.00	1.27	3.51		
4 B	1.10	1.44	1.25	3.79		
C	1.51	0.93	1.53	3.97		
Totals	3.85	3.37	4.05	11.27	0.20	1.16
M'	0.27	-0.07	0.26	0.46	-0.01	0.67
M''	0.55	-0.95	0.30	-0.10	-0.25	2.75
A	1.27	1.34	0.95	3.56		
5 B	1.57	2.00	1.51	5.08		
C	1.27	1.04	1.48	3.79		
Totals	4.11	4.38	3.94	12.43	-0.17	-0.71
M'	0	-0.30	0.53	0.23	0.53	1.13
M''	-0.60	-1.62	-0.59	-2.81	0.01	2.05
A	1.06	1.74	1.49	4.29		
6 B	1.78	1.16	1.99	4.93		
C	1.81	1.65	2.08	5.54		
Totals	4.65	4.55	5.56	14.76	0.91	1.11
M'	0.75	-0.09	0.59	1.25	-0.16	1.52
M''	-0.69	1.07	-0.41	-0.03	0.28	-3.24
Rep Totals	20.61	21.61	24.46	66.68	3.85	1.85
M'	0.91	-0.38	0.05	1.12	-0.44	2.26
M''	0.03	-1.34	-1.01	-2.32	-1.04	1.70

	A	B	C	Totals	M' (C - A)	M'' (A-C - 2B)
1	3.37	2.44	2.43	8.24	-0.94	0.92
2	3.13	2.74	3.26	9.13	0.13	0.91
3	3.42	4.02	3.41	10.85	-0.01	-1.21
4	3.51	3.79	3.97	11.27	0.46	-0.10
5	3.56	5.08	3.79	12.43	0.23	-2.81
6	4.29	4.93	5.54	14.76	1.25	-0.03
Totals	21.28	23.00	22.40	66.68	1.12	-2.32
N'				42.92		
N''				4.96		
N'''				7.82		
N'V				2.56		
N^V				-5.78		

1) Figures underlined were taken from the previous table.

2) N' = -5(8.24)-3(9.13)-1(10.85)+1(11.27)+3(12.43)+5(14.76)

3) N'' = +5(8.24)-1(9.13)-4(10.85)-4(11.27)-1(12.43)+5(14.76)

4) N''' = -5(8.24)+7(9.13)+4(10.85)-4(11.27)-7 (12.43)+5(14.76)

5) N'^V = +1(8.24)-3(9.13)+2(10.85)+2(11.27)-3(12.43)+1(14.76)

6) N^V = -1(8.24)+5(9.13)-10(10.85)+10(11.27)-5(12.43)+1(14.76)

FIGURE WORK:

1) CF = $\frac{(66.68)^2}{54}$ = 82.3375

2) SS Reps $= \frac{1}{18} \left\{ (20.61)^2 + (21.61)^2 + (24.46)^2 \right\}$ - CF = 0.4434
Check: $\left(\frac{3.85}{36}\right) + \left(\frac{1.85}{108}\right)^2$ = 0.4434

3) SSN': $\frac{(42.92)^2}{630}$ = 2.9240

4) SSN'': $\frac{(4.96)^2}{756}$ = 0.0325

5) SSN''': $\frac{(7.82)^2}{1620}$ = 0.0377

6) SSN'V: $\frac{(2.56)^2}{252}$ = 0.0260

7) SSNV: $\frac{(-5.78)^2}{2268}$ = 0.0147

8) SSN Σ : 3.0349
Check: $\frac{1}{3} \left((8.24)^2+(9.13)^2+(10.85)^2+(11.27)^2+(12.43)^2+(14.76)^2 \right)$
- CF = 3.0349

9) SS Whole Plots: $\frac{1}{3} \Big[(2.32)^2+(2.53)^2+(3.39)^2+(2.01)^2+(2.80)^2+$
$+(3.42)^2+(2.77)^2+(3.98)^2+(4.10)^2+(3.85)^2+(3.37)^2+$
$+(4.05)^2+(4.11)^2+(4.38)^2+(3.94)^2+(4.65)^2+(4.55)^2$
$+(5.56)^2 \Big]$ - CF = 4.0037

10) SS Error (a): SS Whole Plots - SSN - SS Reps. = 0.5254

Check: $\left\{ \frac{1}{6} \left[(1.07)^2+(0.51)^2+(1.33)^2+(0.20)^2+(0.17)^2 +(0.91)^2 \right] \right\} - \frac{(3.85)^2}{36} + \frac{1}{16} (0.65)^2+(0.73)^2+ +(-1.09)^2+(1.16)^2+(-0.71)^2+ (1.11)^2 \Big] \Big\} - \frac{(1.85)^2}{108}$

$= 0.5254$

11) SSM': $\frac{[1.12 - (-0.94)]^2}{30} = 0.1415$

12) SSM'': $\frac{(-2.32-0.92)^2}{90} = 0.1166$

13) SS Dummies: $\frac{(-0.94)^2}{6} + \frac{(0.92)^2}{18} = 0.1943$

14) SSM' x N: $\frac{1}{6}\left[(0.13)^2+(-0.01)^2+(0.46)^2+(0.23)^2+(1.25)^2\right] - \text{SSM}' = 0.1658$

15) SSM''xN: $1/_{18}\left[(0.91)^2+(-1.21)^2+(-0.10)^2+(-2.81)^2+ +(-0.03)^2\right] - \text{SSM}'' = 0.4500$

16) SS Error (b): $\left\{ \frac{1}{4}\left[(-0.15)^2+(-0.44)^2+(-0.21)^2+(0.01)^2 +(0.53)^2+(-0.16)^2\right]\right\} + \left\{1\frac{1}{2}\left[(0.71)^2+(-0.84)^2+ +(-0.95)^2+(-0.25)^2+(0.01)^2+(0.28)^2+(-0.67)^2+ +(-1.04)^2+(0.65)^2+(0.67)^2+(1.13)^2+(1.52)^2\right]\right\} + \left\{3\frac{1}{6}\left[(1.79)^2+(-0.20)^2+(-1.\ 5)^2+(2.75)^2+(2.05)^2 +(-3.24)^2\right]\right\}$

$+$ SS Dummies $= 1.7898$

17) Sub-plot SS: $\left\{\frac{1}{2}\left[(-0.35)^2+(0.09)^2+(0.50)^2+(0.09)^2+(0.39)^2 +(-0.35)^2+(0.21)^2+(-0.22)^2+(0.27)^2+(-0.07)^2+(0.26)^2 +(0)^2+(-0.30)^2+(0.53)^2 +(0.75)^2+(-0.09)^2+(0.59)^2\right]\right\} +\left\{\frac{1}{6}\left[(0.25)^2+(-0.29)^2+(0.96)^2+(0.69)^2+(0.37)^2+ +(-0.15)^2+(-0.17)^2+(0.08)^2+(1.12)^2+(0.55)^2+(-0.95)^2+ +(0.30)^2+(-0.60)^2+(-1.62)^2+(0.59)^2+(-0.69)^2+(1.07)^2+ +(-0.41)^2\right]\right\} = 2.6637$

18) SS Error (b) check:

Sub-plot SS - M' - M'' - M'N - M''N = 1.7898

ANALYSIS OF VARIANCE

	Source	DF	SS	MS	F
1	Reps.	2	0.4434		
	N'	1	2.9240		55.6952**
	N''	1	0.0325		
	N'''	1	0.0377		
	N'V	1	0.260		
	N^V	1	0.0147		
	Error (a)	10	0.5254	0.0525	
	Whole Plots	17	4.0037		
2	M'	1	0.1415		
	M''	1	0.1166		
	M'N	4	0.1658	0.0415	
	M''N	4	0.4500	0.1125	
	Error (b)	26	1.78 8	0.06883	
	Sub Plots	53	2.6637		

(Figures in the SS column were taken from the figure work. The MS is found by dividing the SS by the corresponding DF. The F in 1) is found by dividing the MS of N' to N^V (each respectively) by the MS of Error (a) and in 2) by dividing M' to M''N (each respectively) by the MS of Error (b). In this case only N was done; the others being non-significant).

Further figure work:

1) S(a): $\sqrt{\text{MS Error (a)}}$ = 0.22922

2) S(b): $\sqrt{\text{MS Error (b)}}$ = .

3) $\bar{y}$: $\frac{\text{Grand Total}}{54}$ = 1.235

4) CV (a): $\left(\frac{S(a)}{\bar{y}} \times \frac{100}{1}\right)\% \div \sqrt{3}$ = 10.7%

5) CV (b): $\left(\frac{S(b)}{\bar{y}} \times \frac{100}{1}\right)\%$ = 21.2%

	A	B	C	Mean
(N_1) 1				0.916
(N_2) 2	1.043	0.913	1.087	1.014
(N_3) 3	1.140	1.340	1.137	1.206
(N_4) 4	1.170	1.263	1.323	1.252
(N_5) 5	1.187	1.693	1.263	1.381
(N_6) 6	1.430	1.643	1.847	1.640
Mean	1.194	1.370	1.331	1.235

(All the figures except the mean figures, are found by dividing the corresponding figures in the second table by 3. The means are derived the usual way. The mean underlined, however, is found by dividing 8.24 by 9).

/ .... 5.

		L.S.D. 21 . . . (.05)	(.01)
SE Body of Table:	$\sqrt{\frac{1}{3}}$ (S(b)) = 0.151	0.151x2-942=0.444	x4.004 = 0.605
SE N' Mean:	$S\frac{(a)}{3}$ = 0.0764	x3.151 = 0.241	x4.482 = 0.342
SE Dressing Mean:	$S\frac{(b)}{\sqrt{15}}$ = 0.0677	x2.908 = 0.197	x3.93 = 0.266

$N_2 - N_1$	= 0.098	$-5N_1$
$N_3 - N_2$	= 0.192	$-3xN_2$
		$-1xN_3$
$N_4 - N_3$	= 0.042	$1xN_4$
$N_5 - N_4$	= 0.129	$3xN_5$
$N_6 - N_5$	= 0.259	$5xN_6$
Mean:	0.144	$N' = \frac{1}{53} \pm \frac{S\ (a)}{12.55}$

$N' = 0.13620^{**} \pm 0.0183$

**A highly significant increase of 0.13620 ± 0.0183% N in the leaves for each additional 200 Kg applied. There is no evidence that no. of dressings has any significant influence on this rate of increase.