THE INFLUENCE OF NITROGEN AND POTASSIUM FERTILIZER RATIOS ON YIELD AND QUALITY OF PINEAPPLE (ANANAS COMOSUS) MERR L. VAR. SMOOTH CAYENNE IN THE SOUTHERN FOREST-SAVANNA ECOTONE OF GHANA.

BY

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DECLARATION

I declare that this work was done by myself and under the supervision of my supervisors, and that it has not been presented in part, whole or otherwise to any University or Institution for the award of a degree, diploma or certificate.

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DEDICATION

I dedicate this work to my wife and children; Setorwu and Kekeli.

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ABSTRACT

Field trials were sited on soils belonging to the Ultisols family at three sites (Pokuase Agric. Research Station, Parrico and Silwood farms) within the southern forest-savanna ecotone to determine the influence of different N/K_2O fertilizer ratios on the yield and quality of pineapple. A split-plot design was used with two (2) P levels on main plots and six (6) N/K_2O fertilizer ratios on sub-plots was used.

Soil samples were taken from the three (3) sites. Leaf samples of the pineapple crop were also taken at the 6th, 10th, and 12th months for the different stages during the plant growth. From the physical and chemical properties of the soils, it was observed that the soils do not differ in their fertility status. However, from the rainfall distribution, Parrico and Silwood sites were observed to be wetter than Pokuase.

Except for significant treatment effects ($P < 0.05$) on leaf per cent K at Pokuase and per cent Ca and N at Parrico, there was no other significant treatment effect. There was, however, a general increment in the concerntrations of leaf K, N, Ca and Mg and decrease in the concerntration of leaf P through the growing period.

Mean fruit weight at Pokuase was lower than those at Parrico and Silwood. Most of the fruits from Parrico and Silwood were however heavier than the recommended sizes for the export market. Fruits from all sites were of good quality in terms of

acidity and sugar content. Some significant correlations were obtained between leaf nutrient concerntrations at various stages of growth and mean fruit weight, acidity and sugar content of the fruits.

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CHAPTER ONE

INTRODUCTION

The cultivation of pineapple has been going on in Ghana since the 1930s with the first ever export recorded in 1934 (Acquaye, 1990). However most of these cultivations had been on the subsistence level until the setting up of the Nsawam cannery in the 1960s.

The most important growing areas are around Nsawam in the Eastern region and other areas in the coastal savanna zone. Presently, it is common to see large pineapple farms in the interior parts of the country even in the semi-deciduous forest areas. Although the industry is growing at a very fast rate, it is saddled with many problems which result in low yields on farmers' fields. A survey conducted in 1992 by the National Agricultural Research Project in the coastal savanna zone, revealed that improper and inadequate plant nutrition constitute some of the serious problems facing the industry.

Pineapple is known to make a heavy demand on the nutritional status of the soil. Nitrogen and potassium have well been documented in the literature as the most important nutrient elements for both yield and quality of the fruits. The influence of K in particular is highly controlled by climatic conditions (Tay, 1974). The influence of other nutrient elements such as phosphorus, calcium and magnesium, is however not as striking as those of N and K.

No previous work has been carried out in the forest-savanna ecotone of Ghana, where the bulk of the crop is produced for the export market, to determine the optimum N/K_2O fertilizer ratio to aid in determining the economic fertilizer levels for the production of the crop. So far, most of the fertilizer studies with pineapple had been carried out in the forest zone of the country. Most of these studies, however, were geared towards production but not for the export market per se. According to Obeifuna et al. (1987) the response of pineapple to fertilizer application varies with locality, soil and climate. For example, Godfrey-Sam-Aggrey (1970) working with sugar loaf in the forest zone, found that nutrient combination of 40kg N/ha, 47kg P/ha and 36kg K_2O/ha resulted in maximum yield and mean fruit weight for nitrogen and potassium. Excessive nitrogen reduced the total soluble solids (TSS) content of the juice while potassium raised it (Abutiate and Eyeson, 1973).

Other studies in Nigeria (Obeifuna et al., 1987) showed significant increases in pineapple yield on ferrallitic soils with the application of 200 kg N/ha and 200kg K_2O/ha. According to Asoegwu (1987), pineapple plant requires a well balanced N/K_2O ratio for normal growth, high yield and good quality fruits. The most desireable N/K_2O ratio of the fertilizer had been recommended by several workers to be approximately 1 : 2 (Lacoeuilhe, 1971; DeGeus, 1973; Dallorf, 1975 and Valez-Ramos et al., 1991). However since the soils and ecological zones where pineapple is grown vary greatly in chemical composition and climatic conditions, adherence to a fixed N/K_2O ratio would provide inadequate amounts of nutrients for some soils or entail luxury feeding in other cases.

The objective of this study was therefore to test the influence of different N/K_2O fertilizer ratios on the yield and quality of pineapple at three different locations in the southern forest-savanna ecotone and to attempt to determine the critical leaf N, P, K and K/N levels at different stages of growth for yield and quality of the fruit.

CHAPTER TWO

LITERATURE REVIEW

2.1. The pineapple plant

2.1.1. Taxonomy and morphology

The pineapple (*Ananas comosus*) belongs to the Bromoliaceae, a large family of the American tropical plants (one species originated from Africa). Most members of the family are epiphytes and live on trees. However, the pineapple and some of its relatives live on the ground.

There are many Ananas cultivars but the predominant one is the "smooth cayenne" (Samson, 1980), hence most description of the plant is based on this cultivar. It is the main variety used in Ghana. The adult pineapple plant is about 1m to 1.2m tall and 1.5m wide. The plant comprises the following parts: stem, leaves, roots, peduncle, shoots (suckers,hapas, and slips). The shoots together with the crown on top of the fruit are used for the propagation of the plant. The number and proportions of shoots produced vary with clone and climate (Evans, 1952).

The forms of the leaves vary and depend on the position on the stem and hence on the age. Py and Tisseau, (1965) placed them in the following classes:

A: Leaves fully developed when shoot was planted.

B: Leaves present but not fully developed at planting.

2.1.2. Botanical Characteristics

The pineapple is a herbaceous, perennial, self sterile monocotyledonous plant. As in the musa, each stem flowers only once and dies after fruiting; a side shoot then takes over (Samson, 1980). Under natural conditions the pineapple thus reproduces by successive vegetative propagation. (Py *et al.*.1987).

The pineapple though being a ground plant, there are some signs of adaptation, which can be considered to be residual epiphytic characters. These are: stomata specially adapted to prevent water loss, optimum recovery of minimum precipitation, absorption of water and mineral elements by leaves and relative fragility of the root system (Py *et al.*, 1987).

The adaptation of the pineapple to prevent water loss is mainly reflected in its carbon metabolism. The closing of the stomata in the hot hours of the day does not only prevent the loss of moisture but also prevents the ordinary system of photosynthesis and the plant uses the Crassulacean Acid Metabolism (CAM) system in which CO_2 is not reduced all the way to sugars only but to organic acids (mainly citric and malic) (Samson, 1980 and Py *et al.*, 1987). The reduction to sugars is, however, completed during the day.

Night opening of the stomata required by CAM necessitates anatomical and morphological adaptations for temporary storage of absorbed gases and for reducing heating of the leaves (Py *et al.*, 1987)

The crop differs from other plantation crops in that flowering can be artificially induced. Also there is no seasonal influence on its growth cycle and flowering therefore production can be planned in advance to suit the market (Lacoeuilhe, 1971).

2.2. Ecology

2.2.1. Ecological zones

The pineapple is a typical tropical crop, hence does not tolerate frost and is mostly distributed between latitudes 25°N and 25°S (Samson, 1980 and Purseglove, 1987) There are, however, exceptions such as Assam (30°N) and South Africa (33°S). The crop is cultivated mostly on lowlands up to 600m above sea level. However, in Kenya most of the production is limited to altitudes of 1400 1800m above sea level and with favourable average temperature.

In Ghana, the crop is cultivated in almost all the ecological zones, but the coastal savanna zone, and most importantly, the Cape Coast and Nsawam areas. Presently few commercial farms are being developed on the lower altitudes of Akwapim mountains around Aburi.

2.2.2. Temperature

Being a typical tropical crop, the pineapple tolerates moderately high temperatures. Optimum growth of leaves and roots takes place between 20°C to 32°C and that little or no growth takes place below 20°C and above 36°C. However in Hawaii where pineapple is grown between latitudes 19°N and 22°N with a minimum temperature is around 10°C (Purseglove,1987).

Bartholomew and Kadzimin, (1977) reported that, high night temperatures are deleterious and difference of at least 4°C must be maintained between the day and night temperatures. High temperatures and high humidity tend to give softer leaves and larger fruits with lower acid contents. For example in Kenya (on the equator), above 1400m -1800m the fruits are too acid and at about 1150m they are too sweet, giving sugar and acid ratio of 38:1 while the best quality is 16:1 sugar to acid ratio obtained at that altitude (Purseglove, 1987). Py and Tisseau (1965) reported 25°C as the optimum for fruit ripening in Guinea and Hawaii, at higher temperatures, acid content and quality of the fruit diminish. Over heated fruits tend to suffer from sun-scald which tend to affect the keeping properties of the fruits.

2.2.3. Rainfall

The pineapple is an epiphyte which thrives on the ground hence possess special moisture storage organs. Although the plant is drought tolerant, prolonged drought tends to reduce the size and number of fruits. The crop can be grown in areas of high rainfall, but drainage is necessary where the soils are prone to water logging, since the roots of the crop are sensitive to water logging.

Optimum rainfall regarded by most authors is between 600mm to 1500m per annum but may range between 635mm 2500mm. Samson (1980) quoted potential evapotranspiration figures (reported by Bartholomew and Kadzimin (1977) for Malaysia as 1742mm and South Africa as 839mm.

It has been observed that dew and other forms of moisture contribute to the moisture supply to pineapple, especially those grown near the sea where humidity is high, however there has not been any reliable estimates of the amounts. Samson (1980) stated that unless the plant is very different from other plants, then the amount collected will not exceed 0.5mm per day.

Though the crop is drought tolerant, the least rainfall that is available should be well distributed over the growing period especially the vegetative phase, during which the size and the fruiting characteristics are determined. Water deficits at flowering has a less serious effect and may hasten fruiting and result in uniform ripening. Rains at the time of harvest may cause deterioration of fruit quality. Experience in Hawaii where rainfall exceeds 2500mm in some places shows that heavy rainfall can have deleterious effect on the quality and keeping properties of the fruits (Malan, 1954).

2.2.4 Soil

The crop can be grown on a wide range of soil types, but it has been found to grow normally and successfully on light textured soils; i.e. sandy, sandy loam, clay loam, and laterritic soils. However, the most preferred soil type reported by most authors is the sandy loam with pH between 5 and 6.5 (slightly acid to neutral). The soils should be deep and have moderately well to a well drained regime.

The crop is adversely affected by excessive water hence soils prone to water logging should be avoided as much as possible. In Malaysia and other parts of South east Asia, peat soils are used for the production of "Singapore Spanish" pineapples (Tay et al.. 1969), and also used in Hawaii (Dunsmore, 1957).

Soils high in Ca and Mn and red oxisols of the tropics with pH above 4.5 should be avoided as much as possible or spraying with iron solution is required (Samson, 1980 and Purseglove, 1987). In Ghana, reddish to yellowish deep and well drained loamy to sandy upper slope soils are mainly used, with the avoidance of soils of the lowlands which are prone to water logging.

2.3 Cultivation

2.3.1. Planting materials

The crop is mainly propagated vegetatively because the few seeds take a long time to develop to fruiting stage. The vegetative parts used for propagation are: the crown, suckers, slips and hapas.

In Ghana, the traditional planting material for new fields is the sucker. This is so because of the loss of crowns to the farmer when fresh fruits are sold on the fresh fruit market locally or as export and because of the prolonged period it takes from planting to maturity when crowns are used (Abutiate, 1975).

2.3.2. Land preparation

The crop is mainly planted on fields which have been well prepared using mechanical means. A good seed bed is needed before the planting of the vegetative part. This is possible only on flat to gently undulating low lying areas.

In areas of high altitudes, e.g. the Aburi areas where mechanical cultivation is not possible, the farmers resort to minimum tillage to protect the soil against erosion.

2.3.3. Planting distance and plant population

The planting distance determines the plant population, and the size of the fruit. It also has an effect on the quality of the fruit in terms of the sugar to acid ratio. In areas of high insolation high plant density protects the fruits from being sun-scald (Dodson, 1968).

In most countries, the double row planting system is used while the multiple row system is not common. In Ghana, the double row system has been adopted. Pinto (1989) suggested a spacing of 30 x 30 x 90cm for an expected fruit size of 1.0 to 1.5kg., giving a plant population of about 45000 per hectare. For smaller fruits, he suggested 28 x 28 x 75cm and for larger fruits >1.5kg, the within row spacing can be increased to 37cm. He also suggested staggering of the plants in the double row to allow more space for the plants.

2.4. Nutrition

Pineapple needs a lot of nutrient elements in varying quantities for good yield. Large quantities of both nitrogen and potassium and a well balanced amount of magnesium and relatively small amounts of phosphorus and calcium (Teiwes and Gruneberg, 1963) are very essential. Pineapple makes great demands on the nutrient reserves of the soil. Growing pineapple on the same plot of land for at least more than three growing cycles leads to a severe drop in the yield due to depletion of nutrient reserves of the layer of soil which the roots permeate (Dunsmore, 1957).

Each of the major nutrients affects the yield and quality of the fruits in diverse ways, so does the ratio of total cation to total anions. The ratio of N : P : K is very important in the production of pineapple. Teiwes and Gruneberg (1963) quoted the following ratios reported by the following researchers respectively:

Krauss (1928) 1 : 0.35 : 3.2

Follet-Smith and Bourne (1936) 1 : 0.81 :3.9

Boname (1929) 1 : 0.34 : 5.3

Cowie (1951) 1 : 0.27 : 2.5

The average of the ratios give the following 1 : 0.41 : 3.7.

Though the figures of the various authors vary widely, this was explained to be due to the fact that, nutrient absorption depends on the variety and also considerably influenced by the environmental conditions: soil, climate, planting density and manuring.

2.4.1 Nitrogen

Nitrogen has been found to be one of the most important nutrients for the growth of pineapple. Being an important constituent of proteins and their precursors, which form about 7% of the dry matter of the pineapple plant, a sufficient supply is therefore a preliminary necessary condition for a normal course in the plant.

There are different reports on how the nutrient affects the growth, development, yield and quality of the crop. Dodson (1968) found that N influences the growth and yield of pineapple in different ways; e.g., he showed that added N increased the total yield through increases in mean fruit weight brought about by significant increases in fruit length and diameter.

However, in the ratoon crop, an increase in added N resulted in an increase in the fruit length only. Dodson (1968) further pointed out that, increase in N does not have any significant effect on fruit set in the mother crop but rather in the ratoon crop. Abutiate and Eyeson (1973) found that large doses of N produced more vegetative growth resulting in slightly lower fruitage and relatively higher amounts of hold over plants (plants that fruit lately).

Despite the fact that formation of leaf material and weight of the plant are promoted by N applications, Sideris and Young (1950) reported that root formation does not increase in proportion to the weight of whole plant with increasing application of N.

Deficiency of N is found to lead to stunted growth with the leaves becoming yellowish green and also leads to delayed fruiting with the fruits being highly coloured. The fruits tend to be small and deformed and no slips are formed at the base of fruits. They are however sweet to taste and no suckers are produced by the plant (Kanapathy 1958).

Py et al., (1956) quoted Nightingale (1942) that the ratio of nitrate to carbohydrate in the plant controls flower formation, hence flower formation is retarded by high application of N. Py et al., (1956) further reported that the applications of more than 8 gN/plant in the form of ammonium sulphate always reduce the proportion of plants in blossom.

According to Tay (1974) the additions of N result in significant increases in plant height, from the fifth month onwards, and the greatest positive response to N during the eighth to twelfth month was between 0 to 336 kgN/ha both in terms of plant height, leaf production and leaf area.

Similarly nitrogen requirement was to be greatest between the fifth and eighth months of growth (Tay, 1974). This is the period within which maximum relative growth rate (RGR) occurs (Tay and Tan 1971) and supported by DeGeus (1973) that it is the period within which the crop uses the largest amount of N. Tay (1973) found that the response of mean fruit weight to added N was positively linear up to 896 kgN/ha . Tay (1974) further reported that the most rapid marginal increase of mean fruit weight in response to applied N was between 0 - 336 kgN/ha. He further stated that the response curve was quadratic.

Py et al., (1956) also found positive correlations between applied N and fruit size and fruit weight. Similar observations were recorded by others (Mustafa, 1988; Tay et al.,(1969) and Cannon, 1957a).

Working with Smooth cayenne, Cannon (1957b) found only limited responses to applied N using four soil types differing in their K contents. Mustafa (1988) working with Kew pineapple and Su (1960) working with Smooth cayenne all showed that there is an optimal rate for applied N in respect of mean fruit weight. However, Su (1960) stated that this optimum value differs under different conditions.

Views on the effect of N on fruit quality are diverse. Decrease in sugar content was shared by Cannon (1957b) and Abutiate and Eyeson (1973) whereas decrease in acidity with increase in applied N was noticed and reported by Dodson (1968) and Cannon (1957a).

Dodson (1968) working with the Smooth cayenne variety did not record any significant change in sugar content due to increase in applied N; this was supported by Su (1957) when working on Salenger green. Su (1957) also found that added N increased acidity

Tay (1974) further reported a linear relationship between applied N and acid and sugar contents of the fruit.

On the effect of N on quality of fruits, DeGeus (1973) stated that N applications after fruit formation will increase the juice content and decrease acidity and firmness of the fruit. It gives the fruit flesh a deeper colour but makes the skin lighter. It also aggravates the risk of lodging. It may also cause cracking of the fruits under certain climatic conditions.

Su (1960) concluded by stating the following:

(i) N requirement of pineapple plants greatly depends on the potential growth vigour of the plants that results from an interaction between environmental conditions, available soil N as well as K.

(ii) that N availability is also governed by these factors.

Lacocuilhe (1971) reported that N requirement of pineapple varies with its stage of development, and is affected both quantitatively and qualitatively by the climatic and soil conditions. Tay (1974) also concluded that, the adjustments of the N rate for different soils and climatic conditions should be considered using leaf nitrogen values as a guide.

2.4.2. Phosphorus

The requirement of pineapple for phosphorus is not as high as that for N and K; but, adequate supply is essential for good growth, flower initiation and fruit development. Phosphorus deficiency is manifested by dark green with a purple bluish tint in the leaves. Excess application of P tended to be antagonistic towards the absorption of N, and thus can be detrimental on soils low in N.

For the smooth cayenne variety in Hawaii, Nightingale (1942) observed that, yields were neither increased nor reduced if P is applied to pineapple on soils already supplied with phosphates.

The reports of Samuels, and Gandia-Diaz, (1960) and Pennock, (1949), indicated significant decreases in yield due to P application. Pennock, (1949) attributed the decrease in yield to the smaller fruit sizes.

Using 56kg P_2O_5/ha and 112kg P_2O_5/ha for their experiment, Abutiate and Eyeson (1973) also observed decreases in yield due to increasing dosage of applied P. They observed that, there was an apparent increase in mean fruit weight at 56kg P_2O_5/ha due to the very high initial level of P in the soil. This indicates that, there is a threshold value above which applied P will tend to decrease yield.

Tay et al., (1969) however stated that increasing rates of P application tended to progressively raise the mean fruit weight, but not to any significant level. This was also observed by Mustafa (1989) who worked on Kew Pineapple. He gave the optimum level to be 4g/plant. He also reported that total soluble solids and acidity decreased with increasing P additions. Total sugars also decreased whereas the ascorbic acid content increased with P additions.

On the quality of fruits, Mustafa (1989) reported that, increasing application of P results in decreases in both acid and sugar contents when compared with the control, and that the negative response was a cubic function. Pan (1957) also observed poor quality fruits of the smooth cayenne cultivar when P was added.

Yap and Parburry (1961) in Tweiwes and Gruneberg (1963), reported that in Salengor green, sugar content responded to P while acid content did not. Nightingale (1942) was quoted by Py *et al.*, (1956) that, it was necessary to place sufficient quantity of P at the disposal of the plant, particularly at the time of differentiation of the tissue of the inflorescence and at flowering, otherwise, a considerable loss in yield should be expected.

Dunsmore (1957) stated that P promoted the absorption of K by pineapple, but had no influence on the yield and quality of the fruits. Observations in Taiwan also revealed that P_2O_5 restricted the development of main roots but promoted the formation of secondary roots.

2.4.3 Potassium

Like nitrogen, potassium is highly indispensable in the nutrition of pineapple. Potassium requirement of pineapple is high and this is manifested immediately after planting and highest at the time of fruiting and ripening. However, the effect of application of K on the vegetative growth is not as striking as that of N.

Potassium occurs in the plant only in the inorganic form either free in the cell sap or also in loose combination with protein substances. It is mainly found in areas of large physiological activity particularly in the leaves and zones of growth.

The formation of sugars, starch and organic acids, also hardened tissues are all dependent on the plant having adequate supply of K (Teiwes and Gruneberg, 1963). Also dependent on adequate K is the reduction of nitrates, hence protein synthesis, also transportation of assimilates from the leaves to the organs of storage and consumption.

Potassium has been found to be an opponent of N in that whilst N controls the size and weight of the fruit, K is the quality controlling factor (Py et al., 1956).

Cannon (1957b) reported that K deficiency is manifested by brown spots on the green leaves and the leaves tend to become narrower and shorter than the normally nourished leaves. Kanapathy (1959) working on the variety "Singapore Spanish" observed that K deficiency leads to stunted plants and development of pale yellow spots on the leaves starting from the old ones.

Positive correlations between applied K, yield and quality have been reported by many authors. Su (1960) stated that, critical levels of K in the leaves depend on age, climate and N levels.

Samuels, and Gandia-Diaz, (1960) working in Puerto Rico found significant linear relationships between leaf K and yields. On a clayey soil they found that, leaf K content near 3% was associated with optimum fruit yield. Nightingale (1942) stated that, K content at flowering should not fall below 0.38% based on fresh weight and further remarked that, soils with below 0.5 m.e K per 100g soil should definitely be considered potash deficient.

There was no observed significant effect on plant growth due to K until from the sixth month upwards (Tay, 1974). The greatest response was observed between 0 to 896kg K_2O ha^{-1} beyond which plant height was reduced. Also observed was appreciable differences in leaf production between control and the various K_2O levels but only small differences within the K levels themselves.

Statistically significant increases in mean fruit weight were observed and the relationship between K levels and mean fruit weight and some quality parameters were found to be quadratic.

Increases in sugar and acid contents were also observed for K rates between 0 to 1120kg K_2O ha^{-1}, but further increases in K resulted in lower increases in these parameters.

Su (1958 1959) however stated that the total soluble solids of the juice was not always significantly affected by K additions.

The observations of Abutiate and Eyeson (1973) were similar to those of Tay et al., (1969) where K applications were found to result in significant increases in total and mean fruit weights.

Tay et al., (1969) did not observe any interaction effect on fruit quality between N and K, however, Pan (1957) noted that, such interactions had significant effect on fruit yield of Smooth cayenne variety.

The response curve reported for fruit quality by Su (1965) when working on Smooth cayenne grown on a loamy soil with exchangeable K ranging between 25 64ppm was similar to what was reported by Tay (1972) who worked on peat with exchangeable K ranging between 35 40ppm.

The fact that these experiments were performed under different climatic conditions and on different varieties, emphasises the importance of exchangeable K levels in the soil in the formulation of K fertilizer programmes for pineapples. The importance of exchangeable K in relation to mean fruit weight was also noted by Cannon (1957a).

Su (1965) proposed an optimum exchangeable K level of 140ppm. Magistad (1934) also showed that soil must contain between 160 220ppm and over of exchangeable K if the requirement of the pineapple plant is to be met, and stated that if the soil contain 40ppm of exchangeable K, then a yield increase of about 44% must be expected with K application.

The soils on which Abutiate and Eyeson (1973) worked had an exchangeable K level of 0.3 m.e K which is relatively high for a Ghanaian soil, even though it is lower than what was reported by Magistad (1934) and Su (1958 1959) as the threshold for lack of response to K addition. This is because many crops lack response to this element and the observation that most Ghanaian soils are buffered against K depletion (Ahenkorah, 1970). Lack of response to K has however been reported by Samuels and Gandia-Diaz, (1960).

The importance of P/K ratio on yield and quality was emphasised by Kanapathy (1958). In the same article, Kanapathy further quotes Cooke (1949) that, considerable emphasis must be laid on the importance of maintaining the same P/K ratio in the soil as in the healthy leaves, since high doses of P tended to upset N uptake with consequent reduction in the yield of the fruit. He recommended a P/K ratio for the tip of the leaves to be 1 : 14 and further stated that, when the ratio diverges from the figure 14 and above, the quality of the fruit is affected and this may be explained to be due to lack of N caused by the unavailability of either N or P or both.

2.4.4 Calcium

Calcium in general is antagonistic towards K, hence opposite in its actions to K, E.g. whilst K increases the water content of tissues and restricts transpiration, Ca promotes shrinkage and transpiration. As the leaf ages the amount of K reduces but Ca accumulates (Teiwes and Gruneberg, 1963).

Calcium plays vital roles in the plant but amounts needed are small compared with K and an excess of it leads to chlorosis.

The absorption of Ca by the plant is largely influenced by N and K. The N source is also very important. Nitrogen in the form of NO_3 favours Ca absorption while in the form of NH_4^+ hinders it (Sideris et al. 1947). Whilst the supply of K causes a reduction in the absorption of Ca., that of Ca has however not been found to exert any influence on the K absorption by roots.

The preferential absorption of K to Ca has been attributed to the low exchange capacity of the pineapple roots (Teiwes and Gruneberg, 1963).

Calcium deficiency according to Cibes and Samuels (1958) affects the quality of the fruits, due to the formation of blackish spots in the interior of the fruits therefore liming is favoured on very low pH soils where yields are expected to rise. Liming above pH 6 leads to decline in yield (Py et al. 1957 and Pennock, 1949).

2.4.5 Magnesium

Magnesium is an integral part of chlorophyll hence indispensable; its deficiency leads to cessation of vital processes though not needed in large quantities.

Just as in the case of Ca, the absorption of Mg is influenced by the level and form of the N treatment and by the level of K (Sideris and Young, 1945b). Mg content of the pineapple plant (referred to the fresh weight) high with low levels of N. Nitrogen in the form of NH_4^+ ion restricts the absorption of Mg and so does K.

Cibes and Samuels, (1958) stated that Mg deficiency is not common amongst pineapples although it can be a limiting factor in many sandy and strongly acid soils of the tropics.

Teiwes and Gruneberg, (1963) quoted a report on an outstanding beneficial effect of Mg on pineapples grown on a sandy soil in Peurto Rico in 1961 as follows: Mg treated plants produced 34% more per acre than plants not treated with mg, and were also more superior in fresh and dry weights than plants not treated with Mg. On an acidic sandy clay soil, the Mg treated plants were reported to produce 2.7 tons per acre more fruits than the untreated plots and that, the highest yields were associated with the highest leaf Mg levels.

Martin Prevel, (1961) was also quoted by DeGeus (1973) to have obtained the highest yields and the best quality fruits in Guinea when he applied 40kg MgO per 100kg of K_2O which gives K_2O/MgO ratio expressed in milliequivalents of about 1:1.

Experiments carried out in Guinea by Py et al., (1956) did not show any significant differences in mean fruit weight between plants receiving Mg though the tendency could be seen for a higher fruit weight with Mg treatment.

2.4.6 Potassium, calcium and magnesium proportions

The need to maintain the ratio of total cations to total anions in the pineapple plant points to the importance of the ratio of K : Ca : Mg, since these are the major controlling cations. Since the proportion of total cations to total anions is constant, where one cation is absorbed on a larger scale than in accordance with the constancy of the sum of the cations, the absorption of the others must be diminished. Sideris and Young, (1945a) have shown that higher concentrations of K lead to a reduction in the absorption of Ca and Mg.

Nitrogen supplied in the form of NH_4^+ ions tend to affect the balance between the cations and the anions by influencing the absorption of anions rather than cations (Scharrer and Jung, 1955, quoted by Teiwes and Gruneberg, 1963). Sideris and Young (1945a) also reported that the greater phosphate content of plants supplied with ammonium is due to this phenomenon. Once the NH_4^+-ions are in the nutrient medium it affects the amounts of Ca and Mg absorbed which must be less than that absorbed in the presence of NO_3^--ions.

Martin -Prevel (1961) quoted by Teiwes and Gruneberg (1963) for having conducted a series of experiments to find the effect of different K : Ca : Mg proportions on flowering, fruiting and the quality of fruits of pineapples came out with the following: that the largest proportion of flowering plants was given between the following cation ratios:42.5 50%K + 42.5 50%Mg + 0 15%Ca and the smallest proportion was between 0 25%K + 50 25%Mg + 50%Ca. Martin-Prevel (1961) stated that any combination in which the sum of K and Mg accounted for less than 85% of the total cations leads to a reduction in the effectiveness of acetylene treatment.

Martin-Prevel (1961) showed that with the sum of 0.75g equivalent of cations which is equal to the proportion, 42.5%k + 15%Mg + 42.5%Ca a yield of 41 tons per hectare was obtained, however with 0.5g equivalent yields of fruits averaging 1.525kg and over were obtained. The proportion of cations were 42.5%K + 42.5%Mg + 15%Ca and 50 : 50 : 0 respectively showing the importance of Mg and K in the nutrition of pineapples over Ca.

On the effect on diameter and stability of the fruit stalk, the following proportions were given in the order of greatest effect; 70 : 15 : 15, 50 : 50 : 0, 42.5 : 42.5 : 15. Martin-Prevel (1961) stated that, if the proportions of Mg and Ca are increased at the expense of K, then the parameters will fall; emphasising the important role of K in controlling the stability of fruit stalk.

The fact established by Py et al., (1956) that the intensity of the coloration of the fruit skin increases with increasing application of potash has been confirmed and expanded by Martin-Prevel et al., (1961) that, with the same applications of potash, a preponderant proportion of Mg enhances the colour intensity than a preponderant proportion of Ca. Martin-prevel et al., (1961) stated further that, the red and brown pigmentation of the fruit is linked with the cation nutrition. The desired orange colour is enhanced with higher potash dressing and the undesired accumulation of brown pigments in the neighbourhood of the 'eyes' is greater the higher the proportion of

Ca.

Higher proportions of potash in the cation mixture has been associated with decrease in sugar content and an increase in acidity and that, increase in the sum of the cations from 0 to 0.75g equivalent contributed to an improvement of taste. Martin Prevel et al.,(1961) concluded that, the highest yield and best quality are attained with the same quantity and proportion of cations, but under only the same climatic condition.

Teiwes and Gruneberg (1963) concluded that, the maintenance of an optimum proportion of nutrients, especially of the cations K : Mg : Ca is a prerequisite for high yields of good quality pineapples.

2.4.6 Nitrogen - potassium ratio

Nitrogen and potassium have been identified by many authors as the two most important elements in the nutrition and development of pineapple. However, the proportions in which they must be combined to give the desired growth, yield and quality have not received much attention.

Few workers mentioned the ratios in which these two elements can be combined. DeGeus (1973) stated that due to the importance of K in off-setting the drawbacks of N, a well balanced N/K_2O ratio is important with at least as much K_2O as N. DeGeus (1973) further stated that, in view of the favourable influence of K_2O on skin colour and firmness of the fruits, the N/K_2O ratio is often about 1 : 2 for the fresh fruit market.

Abutiate and Eyeson (1973) and Tay (1974) worked on pineapple with N, P, and K but did not record any interaction between N and K hence were not able to give any optimum N/K_2O ratio. Abutiate and Eyeson (1973) however concluded that N and K play major roles in determining the yield and quality of pineapples.

Lacoeuilhe, (1971) stated that the N/K_2O ratio should be increased with the rate of growth and age of the plant, the quantity of N, and increase in sunshine. In poor soils Dalldorf (1975) reported that, the quantity of K_2O supplied should be the same as N.

2.4.7 Micro - nutrients

Micro-nutrients such as Zn, Fe, Cu and B are all important in the nutrition of pineapples to varying degrees. Their deficiency or toxicity tend to affect the yield and quality of the fruits.

Zinc deficiency is common in Guinea and in Queensland, there is often a combined Zn and Cu deficiency which leads to the so called cook-neck (Cannon, 1960). Apart from the combined Zn-Cu deficiency, Cu deficiency can occur alone and this is designated as the green die-back. The symptoms are a brighter green colour of the leaves which become thinner and narrower than in the healthy plants.

Iron deficiency which is associated with pH above 6.5 and a high Ca content in the soil produces chlorosis of the leaves, which assume a pale yellow to reddish-yellow colour and become almost white in severe cases. This is because of the role it plays in the formation of chlorophyll (Teiwes and Gruneberg, 1963).

Py et al., (1957) quoted by Teiwes and Gruneberg, (1963) differentiated between Fe and N deficiencies, that while that of Fe occurs on young leaves, N deficiency occurs on older leaves. Concentration of Mn can lead to Fe deficiency due to the formation of precipitates of Fe in the exodermis which considerably hinders the translocation of Fe to the leaves.

Boron believed to be the regulator of the permeability of the plasma, promotes the absorption of cations, but on the other hand represses the absorption of anions. Its deficiency leads to the accumulation of products of assimilation; reducing sugars and soluble compounds.

There are physiological connections between the functions of B and Ca. This is because the excess of one can be eliminated by the addition of the other (Teiwes and Gruneberg, 1963) and both Ca and B deficiencies manifested by the death of the vegetative parts.

Sulphur and chlorine are important anions in the nutrition of pineapples. Excess of chlorine, is manifested in the depression of yield and quality of fruits due to its repressive action on the physiological action of K (Sideris and Young, 1954), and tend to promote the absorption of Ca due to its high hydration envelop (Scheffer and Welte,1955 quoted by Teiwes and Gruneberg, 1963).

Sideris and Young (1954) ascribed the leaf necrosis of pineapple, which is often exhibited in the coastal regions to chlorine damage with simultaneous deficiency of Potash. Sulphur being a constituent of some amino acids and hormones of great physiological importance is an indispensable nutrient for the plant. Sulphur deficiency is not common since sufficient quantities of this nutrient reach the soil as side constituents of the usual fertilizers, and also carried by rain to the soil. In tropical regions however, the application of fertilizers containing sulphate is of great importance (Teiwes and Gruneberg, 1963).

2.5. Plant analysis

Plant analysis has been used in soil fertility studies as an indication of the supply of particular nutrients and as such is directly related to the quantity in the soil (Tisdale *et al*., 1990).

Aldrich (1990) separated plant analyses into two main categories:

a) total or quantitative (total chemical analysis or spectrographic analysis)

b) relative quantity or semi-quantitative (rapid tissue test).

The total or quantitative method measures both the element that have already been incorporated into the plant tissues and those that are still present as soluble constituents of the plant sap, while the rapid tissue test measures the unassimilated soluble contents of the plant sap. In essence, the constituents that are measured are en route from the point of entry to the site of utilization. In the case of K for example, it is the total amount which is measured.

Aldrich (1990) went on to give the general purposes of plant analyses as follows:

a) To diagnose or confirm diagnoses of visible symptoms.

b) To identify hidden trouble.

c) To locate areas of incipient deficiencies.

d) To indicate whether applied nutrients entered the plant.

e) To locate interactions or antagonisms among nutrients.

f) As an aid to understanding internal functioning of plants.

g) To suggest additional test to identify the trouble.

He also enumerated the troubles inherent in plant analyses as follows:

a) Techniques for sampling, washing and preserving.

b) Suitable standards.

c) Analysis sometimes fail to indicate the cause of trouble.

d) Plant analyses are usually postmortems.

e) Interpretation is often difficult.

Aldrich (1990) concluded that, plant analyses provide useful, but limited information. The results of plant analyses will not truly serve the interests of farmers unless reference standards are available, the samples carefully taken and processed, and the interpretations made by competent persons.

Lacoeuilhe, (1979) also stated that, plant analysis is a valuable way of monitoring and improving on the initial recommendations in the light of the actual path taken by the plant soil climate management complex.

Godfrey-Sam-Aggrey (1970) writing on the usefulness of plant analysis, stated that, the agronomic value of leaf analysis is based on the contention that, the leaf is the principal site of metabolism, that changes in nutrient supply are reflected in the nutrient compositions of the leaf and that, nutrient concentrations in leaf at specific growth stages are related to the performance of the crop.

The approach to leaf analysis in pineapples was different from that developed by Lagatu and Maume (1930) in France for other plants, this is because that approach was mainly designed for temperate conditions, and the pineapple plant is a native of the tropics where seasonal climatic conditions are less well differentiated. In line with this, Nightingale (1942) tried to define indices of nutritional status which were independent of seasonal conditions and annual differences and which will apply in all locations and at all times of the year.

He based his investigations on the following points:

1) The reserves of carbohydrates, which reflect the intensity of photosynthesis

2) The relationship between nitrate concentration in the plant and the carbohydrate reserves.

3) The need to explain a nutrient deficiency as well as measure it.

Based on 2 above, Sanford (1962) came out with a relationship between leaf colour, texture and the carbohydrate : protein ratio and defined indices for the different colours.

Index	Colour	Texture	Carbohydrate/Protein
0	yellow	firm	ill defined
1	yellow/green	firm	high
2	olive-green	intermediate	moderate
3	dark green	soft	low

The optimum relationship between leaf colour, reflecting N status, and carbohydrate synthesis occurs at colour indices 1 and 2 and this is influenced by temperature, solar radiation and carbon dioxide levels.

Apart from climate, there are other factors which also affect the colour indices. Colour index 1 for example indicates an optimum N : P ratio while index 3 indicates an excess of N or lack of P.

K nutrition also affects leaf colour, since it is essential for the conversion of reducing sugars to sucrose and starch and for the transfer of protein N from the leaves to the stems (Sideris and Young, 1945b). This relationship is also influenced by climatic conditions (Lacoeuilhe, 1979).

2.5.1 Leaf Analysis

In pineapple plant analysis, leaf analysis is used in conjunction with leaf colour index to get a clear assessment of the nutrient status of the plant.

During the development of leaf analysis for pineapples, there was a controversy about the part of the leaf to be used; While workers in Hawaii (Nightingale, 1942) chose to analyze the median third of the basal chlorophyll-free portion of the D-leaf, workers in the Institute of Researchers on Fruits and Agronomy (1954) concentrated on the use of the entire D-leaf (latest fully matured leaf).

The advantage in using the basal portion is in its consistent moisture content, which enables the results to be readily expressed on a dry matter basis. According to Lagatu and Maume (1930), the chlorophyll containing section of the leaf is the plant laboratory where the amount of nutrient present must be adequate for optimum physiological activity under the prevailing climatic conditions.

Therefore any change in the nutrient content must be minimal and less rapidly, than those in the leaf base.

Sideris and Young (1951) using the basal portion, found that the sugar content is inversely related to the NO_3-N and K contents. Also some workers reported a fall in the contents of K, Ca, Mg and rise in P content with age and size of the plant using the basal portion of the leaf (Sanford, 1962; Su, 1960).

The basal part of the leaf has a conductive role between the leaf and other parts of the plant, therefore its nutrient composition reflects the movement of nutrients into the plant hence very sensitive to mobile nutrients like N, P, K (Lacoeuilhe, 1979). Sideris et al. ,(1938), stated further that these movements are diurnal and are influenced by the concentration of the soil solution, hence it is important to record the sampling conditions, viz: time of day and climatic conditions.

Using the entire D-leaf for analysis, Martin-Prevel (1959) stated that, N in excess of 1% of dry matter is available for growth of the plant and Marchal et al. ,(1972) said the N concentration in successive leaves at D stage is inversely related to the leaf size.

The analysis of the entire leaf provides a measure of the amount of N available for growth, by calculation from N concentration and leaf dry matter weight. From this, rate of growth can be related to N uptake (Lacoeuilhe, 1979).

The following are the norms used by the Institute of Researchers on Fruits and Agronomy (IRFA).(1989) for leaf-D composition at floral initiation (% of DM)

N	> 1.2
P	> 0.08
K	> 2.8
Ca	> 0.10
Mg	> 0.18

To obtain optimum quality, the K norm may need adjustment for climatic conditions.

Leaf analysis on samples from many fertilizer experiments has shown that, when leaf-D contains at least 10mgN at floral induction, a fruit weight (without crown) of 1.8 kg may be expected. This level of N is adequate for leaf growth up to flowering and for optimum production of suckers (Lacoeuilhe, 1979).

A critical K content cannot be defined readily as that for N; for the following reasons:

1) Active K uptake continues throughout fruit development period, and critical content therefore tend to vary with supply.

2) K has a dominant role in cation nutrition. Total cation content in the leaf increases with K content, and there are marked K/Ca and K/Mg antagonisms.

3) Its role is important in metabolic functions including

control of stomatal opening and the transport of sugars and organic acids.

Nightingale (1942) reported that, where the requirement of NO_3 is elevated, then the amount of K needed to facilitate nitrate uptake is increased.

Lacoeuilhe (1979) gave 2.7% of dry matter as the critical K content of the D-leaf at flower initiation for fruit production but stated that, the quality is always increased by K supply with much influence from the climatic conditions.

Martin-Prevel (1961) stated that the effects of K and other cations on yield are consistent with the effects on quality but the leaf content needed for optimum quality is always higher than that required for growth and yield. He went further to state that K content and the K/N ratio are most critical for fruit quality in warm, high rainfall conditions with a short growth cycle and high yields and gave K/N = 3 as the critical ratio value in the D-leaf at flower initiation under the particular conditions.

The following critical levels were given by the various workers in the leaf at flower initiation based on dry matter.

P : 0.08% (Marchal, 1971)

Ca : 0.10% (IRFA, Unpublished)

Mg : 0.18% (Martin -Prevel, 1967)

Mustafa (1988) quoted Marchal (1971) that, higher P levels increased the leaf N due to P-N synergism, which could also be the reason for increased fruit weight and yield.

The P application was also found to reduce the leaf K, Ca and Mg contents which may be due to antagonism between P-K, P-Ca and P-Mg. Mustafa (1989) recorded the same trend for Kew Pineapple and recorded the maximum K, Ca and Mg where no P was applied.

On the effect of N application on leaf nutrient content, Mustafa (1988) found an increase in leaf N, P Ca and Mg and quoted a similar report from Subramanian et al., (1977) to support his findings. He found a decrease in leaf K content which corroborated the results of Tay et al., (1968).

Godfrey-Sam-Aggrey (1970) analyzed the basal and mid section of the D-leaf separately and stated that the values in the basal section were more consistent than those of the mid section.

Godfrey-Sam-Aggrey (1970) observed that the smaller the N/K ratio the lower the percentage lodging of plants, and gave a range of ratio of 0.4 0.7 corresponding to almost 40% lodging. As the ratio exceeded a value of 0.7 the lodging percentage also increased. This supports the view that K strengthens the pineapple peduncle whereas excess N increases lodging (DeGeus, 1973; Py et al., 1956 and Abutiate and Eyeson, 1973).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Project sites

The project was located at three sites;

a) Pokuase Agriculture Research Station:- on-station experiment.

b) Two on-farm experiments at the Paricco and Silwood farms. Both farms are located on the piedmont slopes of the Aburi mountains bordering the coastal savanna zone.

3.2 Ecological zones

A) Pokuase:- The station is located on the boundary of the coastal savanna zone

B) The Parrico and Silwood farms are located in the wet southern forest-savanna ecotone.

3.3 Climate

3.3.1 Rainfall

All the sites fall in the bimodal rainfall regime. However, rainfall at Parrico and Silwood is higher than that at Pokuase.

Rainfall figures were collected from the Meteorological Services Department, Legon.

Table 2 and Fig. 1 shows the total monthly rainfall(mm) distribution during the cropping cycle (June, 1992 to December,1993) at Pokuase, Aburi and Nsawam. The Aburi and Nsawam data are used as a representative of the rainfall amounts received at the Parrico and Silwood farms.

3.3.2 Temperature

All the sites fall within the iso-thermic temperature regime with differences between the mean minimum and maximum temperatures not exceeding 10°C in most cases.

Table 3 shows the mean maximum and minimum temperatures at the sites during the growing cycle.

3.4. Soils

Under the USDA Soil Taxanomy, the soils at Pokuase belong to the Ustalfs great group while those found at the Parrico and Silwood farms belong to the Udalfs great group (Soil Survey Staff, 1987) and under the UNESCO/FAO classification of 1988 they belong to the class of Lixisols.

Composite soil samples were taken from the three sites at a depth of 0 15cm, where most of the roots of pineapples are usually found, (Samson, 1980).

The samples were air-dried, crushed, passed through 2mm sieve and stored for laboratory analyses.

3.4.1 Laboratory Methods

The following methods were used for the determination of the parameters:

(a) Soil pH was determined in a 1 : 1 soil : water and 1 : 2 soil : 0.01M $CaCl_2$ using the pH meter (MV88 Prazisions-Labor-pH- messgarat).

(b) Organic Carbon was determined using the wet oxidation method as described by Walkley Black (1934).

(c) Total Nitrogen was determined using the Micro Kjeldahl method as described by Bremner (1965).

(d) Available Phosphorus content of the soils were determined by extraction with 0.5M $NaHCO_3$ (pH 8.5) and the P concerntration measured by molybdate blue method as described by (Watanabe and Olsen, 1965)

(e) Exchangeable bases (K, Na, Ca, and Mg) were displaced with 1N ammonium acetate at pH 7. Potassium and Na in solution were determined using flame photometer (PFP 7 Jennray) and Ca and Mg determined using EDTA titration method as described by Moss, 1961.

3.4.2 Methods of Physical analysis

(a) Particle size distribution was determined by the Hydrometer method after dispersion of the soils with Sodium hexametaphosphate (Day, 1965).

3.5 Cropping history of the sites

The experimental plot at Pokuase had been cultivated to different types of crops since 1952 with the last crop being maize planted in 1991. In the case of the on farm plots, they had been cropped to pineapple for not more than 3 cropping cycles. The plots were initially cleared of secondary forest for the first crop of pineapple.

3.6 Experimental design

The experimental design was a split plot. There were 2 main plots which had the P levels and 6 sub plots contained the N/K_2O ratios.

Size of plots :- each sub plot measured 2.4 x 6m = $14.4m^2$ i.e. $1.44x10^{-3}$ ha.

3.6.1 Planting distance

The double row system of planting pineapple was used with the planting distance of 30 x 30 x 90cm (Pinto, 1989).

Plant population :- Plant population per treatment was 80, giving a plant population of 55,000 per hectare.

3.6.2 Treatments

The treatments consisted of two P levels (0 and 50kg P_2O_5/ha) and two levels of N (224 and 336kg N/ha). Each level of N was combined with three different levels of K_2O to give two sets of N/K_2O ratios of 1 : 1.5, 1 : 2.0 and 1 : 2.5. There were six different combinations of N/K_2O ratios. The ratios were combined with and without the P levels to give twelve treatments. The P levels were randomised in the main-plots and the N/K_2O in the sub-plots as split-plot over the main-plots.

Below is the various N/K_2O ratios :

1.	N1 : K_2O	= 1 : 1.5	= 224kgN + 336kgK_2O
2.	N1 : K_2O	= 1 : 2	= 224kgN + 448kgK_2O
3.	N1 : K_2O	= 1 : 2.5	= 224kgN + 540kgK_2O
4.	N2 : K_2O	= 1 : 1.5	= 336kgN + 504kgK_2O
5.	N2 : K_2O	= 1 : 2	= 336kgN + 672kgK_2O
6.	N2 : K_2O	= 1 : 2.5	= 336kgN + 840kgK_2O

There were three replicates at Pokuase and two each at Parrico,and Silwood sites for the on farm trials. This was due to the limited land space provided by the farmers.

The following fertilizer sources were used

a) P ....Single Superphosphate ($18\%P_2O_5$)

b) N ....Ammonium Sulphate (21%N)

c) K ....Sulphate of Potash ($50\%K_2O$)

3.7 Cultural practices

3.7.1 Land preparation

At Pokuase the land was ploughed and harrowed to prepare a good seed bed. However, at the on-farm sites at Silwood and Parrico the plots were prepared using the slash and burn method this is because of the topography of the sites.

3.7.2 Planting.

Planting material (suckers) of uniform size and weight (450g) were selected and planted on the following dates:

Pokuase :- 16th June, 1992

Paricco :- 3rd August, 1992

Silwood :- 1st September, 1992

3.7.3 Weed control

Clearing of weeds from the plots was done whenever necessary using the hand hoe.

3.7.4 Fertilization

At Pokuase, the first fertilizer application was combined with the second because of adverse weather conditions which delayed the first application. However the various applications were done seprately for the other sites.

The fertilizer application dates were as follows;

Pokuase :-	1st and 2nd	18th September, 1992
	3rd	3rd February, 1993
Paricco :-	1st	9th October, 1992
	2nd	12th February, 1993
	3rd	20th April, 1993
Silwood :-	1st	10th November, 1993
	2nd	11th March, 1993
	3rd	22nd April, 1993

All fertilizer mixtures were applied into the basal leaf axil of the plants, which is the normal practice for the crop. A measured volume of the appropriate mixture was applied with a small metal scoop designed to hold the requisite quantity for each plant.

Proportions and times of application of fertilizers

The following fertilization programme was followed:

	Applications		
	6 weeks	4 months	6 months
N	1/6	1/2	1/3
P	1	0	0
K	1/6	1/3	1/2

3.7.5 Disease Control

Except for Parrico where the pineapple mealy bug wilt was detected and treated with Perfecthion (EC) at a rate of 25cc/15l (v/v) to 300 plants no other disease incidence occurred.

3.7.6 Artificial flower induction

The plants were forced to flower ten months after planting with the application of calcium carbide at the rate of 50cc/plant of 2kg/500l (w/v) mixture (Abutiate,1977).

3.8 Leaf analysis

3.8.1 Sampling

Before sampling in the field, the colour of the leaves were observed and recorded according to the criteria of Sanford (1962).

Leaf samples were taken from 10 randomly selected plants per sub-plot treatment from the middle double row (Lacoeuilhe, 1971). The D-leaf (the latest fully matured leaf) was selected according to the Length and position in the rosette (Lacoeuilhe, 1971). Ten plants were randomly sampled per treatment to form a sample . Two samples were taken from Pokuase plot at the sixth and tenth months after planting. Nonstheless, from the on-farm plots, three samples each were taken at the sixth, tenth and twelveth (at flowering) month after planting.

Samples were taken between 9 a.m. and 12 noon on each occasion.

3.6.2 Leaf Sample treatment

Leaf samples from the field were kept in the cold room over night, washed and fresh weights taken immediately after washing.

Samples were then cut into between 1 to 2cm wide strips and dried in the oven at a temperature of 85°C (Lacoeuilhe, 1971), until there was uniform dryness.

The weights of the dry samples were determined and recorded as dry matter in grams per sample. The samples were then milled and stored in poly-bags to prevent absorption of moisture from the atmosphere.

3.8.3 Analyses

Chemical analyses were carried out on the milled samples to determine the total nitrogen, phosphorus, potassium, calcium and magnesium expressed as a percentage of the dry weight of the sample.

3.8.3.1 Nitrogen

A 0.25g of the milled sample was digested with 10ml concerntrated sulphuric acid. Percentage nitrogen was determined from the digest using the micro-Kjeldahl distillation method.

3.8.3.2 Phosphorus, Potassium, Calcium and Magnesium

A 0.5g of the plant material was weighed into 250ml conical flask, 5ml of concentrated nitric acid was added and heated on a sand bath until the brown fumes of nitrous oxide ceased to escape.

The flask was cooled and 5ml of ternary mixture (of nitric acid (conc), sulphuric acid (conc) and 60% perchloric acid in the ratio of 10 : 1 : 4) added and heated again at high temperature until the white fumes of perchloric acid ceased to escape leaving a white precipitate in the flask. The precipitate was then dissolved in distilled water, filtered into 100ml volumetric flask and made to the volume with distilled water.

The various nutrients were then determined in the extract using the methods outlined in section 3.4.1.

For phosphorus, 1ml aliquot was used instead of 5ml used for the soil samples, because of the perceived high P content of the leaf samples.

3.9 Flower count

Two months after the artificial flower induction, flower count was done at all sites. Based on the plant population of each treatment per cent flowering was calculated.

3.10 Fruits

3.10.1 Harvesting of fruits

Fruits were harvested between the fifth and sixth month after flower induction. The fruits were harvested sequentially at 1/3 ripe stage. Ten fruits were harvested randomly from each treatment for mean fruit weight(kg). The fruits were weighed with the crowns.

3.10.2 Fruit quality

Five fruits per treatment were analysed to determine acidity (%citric acid equivalent) and Total Soluble Solids (°brix). The fruit analysis was done by the Foods Research Institute of the Council for Scientific and Industrial Research, Accra.

3.11 Data analyses

A 2-factor analysis of Variance (ANOVA) was performed on data collected using the Randomised complete block design (RCBD) for factor A (P-level) and factor B (ratios) a split-plot on A.
All data collected were analysed seperately for each site.

A correlation analysis was also performed between leaf nutrient levels at various sampling times and mean fruit weight, acidity and total soluble solids.

CHAPTER FOUR

RESULTS

4.1 Soil physical and chemical properties

Table 2 shows the soil physical and chemical properties of the composite samples from the three experimental sites namely: Pokuase, Parrico and Silwood farms.

The texture of the soils at all sites was loamy sand. Such well drained conditions serve as a good soil for pineapple cultivation.

The soils were generally not very different from each other in terms of both physical and chemical properties. They were generally low in organic carbon and total nitrogen. The exchangeable K was lower than 0.35 cmol/kg. This was lower than what Magistad (1934) and Su (1958) reported as threshold value for lack of response to K addition. Generally, the available P of the soils at the sites was equally low.

There were differences in rainfall patterns between Pokuase and those from Parrico and Silwood as shown in Table and Fig.1. Parrico and Silwood lie between Aburi and Nsawam it was therefore reasonably assumed that rainfall patterns at the two experimental sites would be covered by the range of rainfall patterns between Aburi and Nsawam. The rainfall at Pokuase was lower than those at Parrico and Silwood.

Table 2
Monthly rainfall distribution at the sites during the growing cycle (June, 1992 - December, 1993)

Months	Pokuase 1992	Pokuase 1993	Aburi 1992	Aburi 1993	Nsawam 1992	Nsawam 1993
January		8.1		0.0		3.5
February		40.4		18.9		47.4
March		38.7		106.0		36.4
April		59.2		148.2		88.9
May		46.8		57.1		100.8
June	31.3	173.3	52.4	276.7	55.3	218.4
July	28.9	33.9	126.0	30.7	138.6	103.6
August	6.6	46.8	42.2	52.0	8.9	88.3
September	183.2	78.3	131.7	198.4	169.7	190.3
October	67.4	50.7	158.9	159.0	151.2	118.7
November	128.6	94.7	72.0	83.8	55.6	68.4
December	16.5	18.5	87.5	37.8	46.5	28.4
Total	**462.5**	**689.4**	**670.7**	**1168.6**	**625.8**	**1093.1**

Source: Meteorological Services Department, Legon Accra, (1994)

Table 3

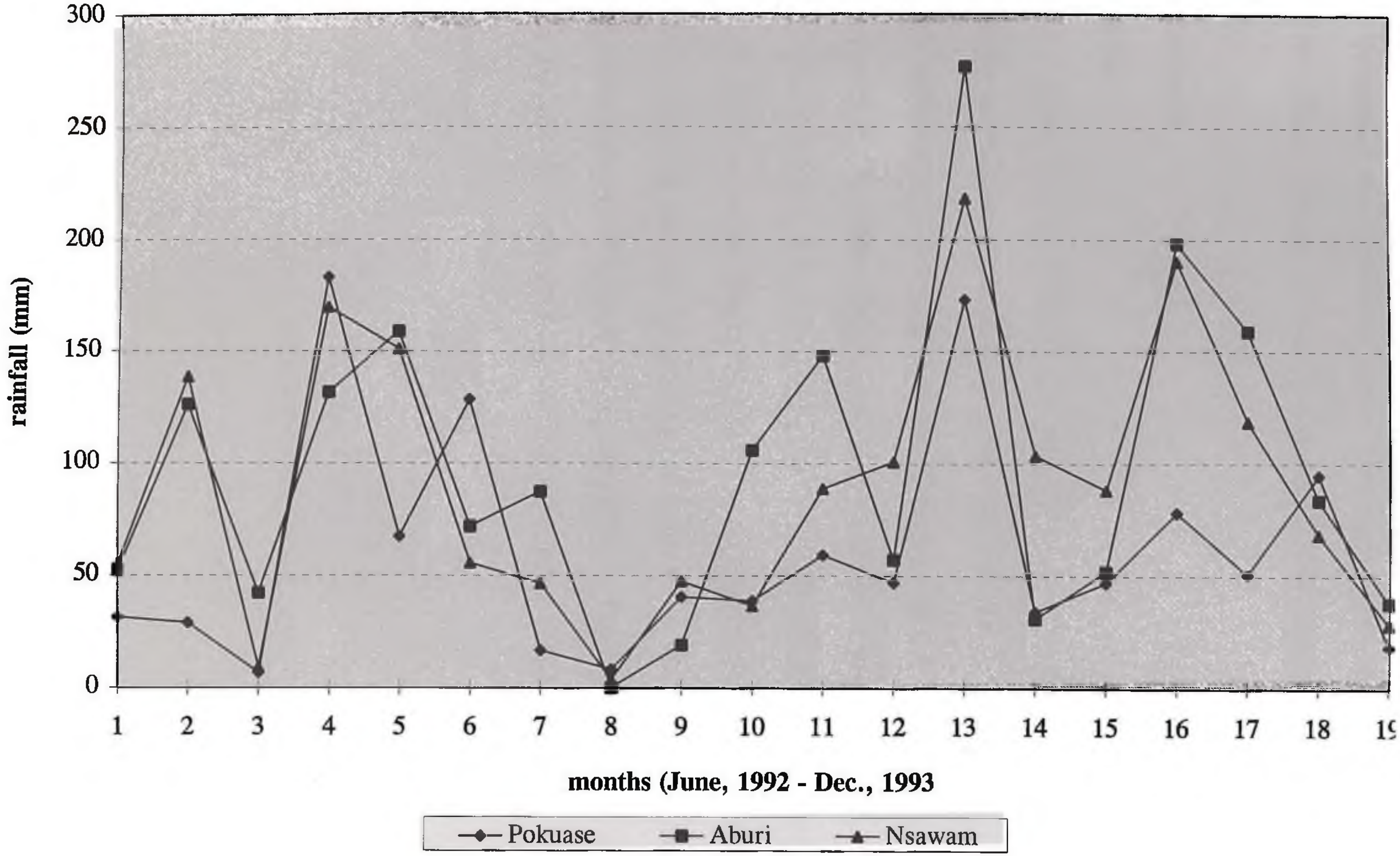
Mean maximum and minimum temperatures at the sites

Sites	Maximun	Minimum
Pokuase :	30°C -- 33°C	21°C -- 23°C
Aburi :	27°C -- 29°C	19°C -- 21°C
Nsawam :	31°C -- 33°C	20°C -- 22°C

Source: Meteorological Services Department, Legon, Accra, (1994).

4.2 Plant growth: Plant growth at Pokuase was not vigorous especially during the first six months after planting. Growth picked up in the later stages. The plants recorded leaf colour indices of between 0 and 1 (Sanford, 1962) throughout the growing season, with index 0 being dominant

Fig. 1: Monthly rainfall in mm from the three sites



Source: Meteorological Services Department, Accra.

during the early stages of growth.

Plant growth at both Parrico and Silwood on the other hand was very vigorous, throughout the growing season. The plants from these sites recorded leaf colour indices of mostly between 2 and 3 with the leaves being soft.

4.3 Leaf analysis

4.3.1 Pokuase

Table 4 shows results of leaf analyses at the 6th month after planting (MAP) at Pokuase with respect to the various N/K_2O fertilizer ratios. Dry matter yield per sample of ten leaves ranged from 19 to 25g. Values for per cent Nitrogen, Phosphorus and Potassium ranged between 0.9 1.4, 0.1-0.2 and 1.4-1.7 respectively. Values for %Ca fell in the range 0.1 0.2 and those of %Mg averaged 0.1. No significant effect of N/K_2O fertilizer ratios and the interaction between N/K_2O fertilizer ratios and P-level were observed on the response variables. There was however a significant effect ($P < 0.05$) of N/K_2O fertilizer ratios on K/N ratio of leaf.

Table 4. Effect of N/K_2O ratios and P-level on D-leaf nutrients at 6 months at Pokuase.

P_2O_5 (kg/ha)	N (kg/ha)	N/K_2O ratios	DM (g/sample)**	N	P	K (per cent)	Ca	Mg	K/N ratio
0	224	1 : 1.5	19.5	1.2	0.1	1.5	0.2	0.1	1.4
0	224	1 : 2.0	19.4	0.9	0.1	1.6	0.2	0.1	1.7
0	224	1 : 2.5	24.1	1.3	0.2	1.5	0.2	0.1	1.2
0	336	1 : 1.5	22.3	1.4	0.1	1.5	0.1	0.1	1.2
0	336	1 : 2.0	22.3	0.9	0.1	1.4	0.2	0.1	1.7
0	336	1 : 2.5	22.8	1.3	0.1	1.5	0.2	0.1	1.2
50	224	1 : 1.5	20.5	0.9	0.2	1.5	0.2	0.1	1.6
50	224	1 : 2.0	21.2	0.9	0.2	1.5	0.2	0.1	1.6
50	224	1 : 2.5	25.4	1.1	0.1	1.7	0.2	0.1	1.5
50	336	1 : 1.5	18.7	1.0	0.2	1.6	0.1	0.1	1.6
50	336	1 : 2.0	22.9	1.0	0.2	1.6	0.2	0.1	1.6
50	336	1 : 2.5	20.6	1.1	0.2	1.6	0.2	0.1	1.5
		MEAN	21.6	1.1	0.2	1.5	0.2	0.1	1.5
		CV(%)	17.9	18.8	18.9	3.63	18.0	12.4	13.9
		SE ±	2.2	0.1*	0.02	0.03	0.02	0.01	0.12*

* --------- significant ($P<0.05$).
** -------- Sample of 10 leaves/treatment

Results of leaf analyses at 10 months after planting are presented in Table 5. There was an increased vegetative growth as evidenced by the rise in dry matter yield per sample of ten leaves from 39 to 51g in the 10th month due to the effect of N/K_2O ratios and P-level; and this increase was more than 100% over mean dry matter yield at the 6th month.

The range of values for per cent nitrogen (0.7 1.1), phosphorus (0.1-0.2) and potassium (1.4-1.6) were not much different from those of the 6 months sampling

Table 5. Effect of N/K_2O ratios and P-level on D-leaf nutrients at 10 months at Pokuase

P_2O_5 (kg/ha)	N (kg/ha)	N/K_2O ratios	DM (g/sample)	N	P	K (per cent)	Ca	Mg	K/N ratio
0	224	1 : 1.5	39.2	0.8	0.1	1.4	0.2	0.2	1.9
0	224	1 : 2.0	43.4	0.8	0.1	1.4	0.2	0.2	1.8
0	224	1 : 2.5	46.8	0.8	0.1	1.5	0.3	0.2	1.8
0	336	1 : 1.5	48.2	0.7	0.1	1.4	0.2	0.2	2.1
0	336	1 : 2.0	47.9	1.0	0.1	1.5	0.2	0.2	1.5
0	336	1 : 2.5	45.5	0.7	0.1	1.4	0.3	0.2	2.0
50	224	1 : 1.5	48.3	1.1	0.2	1.5	0.2	0.2	1.3
50	224	1 : 2.0	51.3	0.8	0.1	1.5	0.2	0.2	1.9
50	224	1 : 2.5	47.1	0.8	0.2	1.5	0.3	0.2	1.9
50	336	1 : 1.5	39.8	0.7	0.1	1.4	0.2	0.2	2.0
50	336	1 : 2.0	48.4	0.6	0.1	1.4	0.2	0.2	2.4
50	336	1 : 2.5	46.9	0.9	0.2	1.6	0.2	0.2	1.8
		MEAN	46.1	0.8	0.2	1.4	0.2	0.2	1.9
		CV(%)	9.4	22.8	16.2	3.7	7.5	11.9	20.9
		SE $\pm$	2.5	0.1	0.01	0.03	0.01	0.01	0.2*

*....................Significant ($P<0.05$)

(Figs. 2, 3 & 4 Appendix). However values for per cent Ca and per cent Mg increased to (0.2-0.3) and 0.2 indicating a rise of 60% and 100% respectively.

The significant differences between the K/N ratios of the leaves among the N/K_2O fertilizer treatments observed for the 6th month sampling were repeated in the subsequent sampling.

4.3.2 <u>Parrico</u>

Table 6 shows the results of leaf analyses at 6months after planting (MAP) at Parrico.

Values for dry matter ranged beteen (38.1-47.8g). Nutrient levels in the leaves were as follows: per cent nitrogen (0.8 1.2), phosphorus (0.1-0.2) and potassium (1.5 1.8). Per cent Ca was around 0.2 and Mg had values within the range (0.2-0.3). The interaction between the N/K_2O fertilizer ratios and P-levels had a significant effect ($P< 0.05$) on %Ca content of the leaves.

Values for leaf analysis at 10 months after planting are presented in Table 7. Dry matter yield values ranged between (55 63g) which are 41% higher than those at the 6th month. This follows the same trend as at Pokuase.

Table 6. Effect of N/K_2O ratios and P-level on D-leaf nutrients at 6 months at Parrico.

P_2O_5	N (kg/ha)	N/K_2O ratios	DM (g/sample)	N	P	K (per cent)	Ca	Mg	K/N ratio
0	224	1 : 1.5	38.1	0.9	0.2	1.6	0.2	0.2	1.7
0	224	1 : 2.0	42.4	1.0	0.1	1.6	0.2	0.2	1.6
0	224	1 : 2.5	47.8	1.0	0.1	1.6	0.2	0.3	1.6
0	366	1 : 1.5	45.1	0.8	0.1	1.7	0.2	0.3	2.1
0	336	1 : 2.0	41.8	1.0	0.2	1.8	0.2	0.2	1.8
0	336	1 : 2.5	43.5	1.0	0.1	1.7	0.2	0.3	1.7
50	224	1 : 1.5	37.4	1.0	0.2	1.5	0.2	0.3	1.5
50	224	1 : 2.0	39.7	1.0	0.1	1.7	0.2	0.2	1.9
50	224	1 : 2.5	38.2	1.1	0.2	1.6	0.2	0.3	1.7
50	336	1 : 1.5	39.4	1.2	0.1	1.5	0.2	0.2	1.3
50	336	1 : 2.0	45.8	1.1	0.2	1.7	0.2	0.3	1.6
50	336	1 : 2.5	35.2	1.0	0.1	1.7	0.2	0.3	1.7
	MEAN		41.2	1.0	0.1	1.6	0.2	0.3	1.7
	CV(%)		13.2	13.5	26.9	5.6	6.7	10.2	15.5
	SE ±		3.8	0.09	0.03	0.07	0.01	0.01	0.18

Table 7. Effect of N/K_2O ratios and P-level on D-leaf nutrients at 10 months at Parrico.

P_2O_5 (kg/ha)	N (kg/ha)	N/K_2O ratios	DM (g/sample)	N	P	K (per cent)	Ca (per cent)	Mg	K/N ratio
0	224	1 : 1.5	58.0	0.9	0.1	1.8	0.2	0.2	2.3
0	224	1 : 2.0	55.7	0.9	0.1	1.9	0.2	0.2	2.2
0	224	1 : 2.5	57.2	0.8	0.1	1.9	0.3	0.3	2.3
0	336	1 : 1.5	63.1	0.9	0.1	1.9	0.3	0.3	2.1
0	336	1 : 2.0	60.0	0.9	0.1	1.9	0.3	0.3	2.1
0	336	1 : 2.5	58.6	0.9	0.1	2.0	0.2	0.2	2.3
50	224	1 : 1.5	54.0	1.0	0.1	1.7	0.3	0.3	1.8
50	224	1 : 2.0	59.0	0.7	0.1	1.9	0.3	0.3	2.6
50	224	1 : 2.5	55.2	0.8	0.1	1.8	0.2	0.3	2.2
50	336	1 : 1.5	56.5	1.0	0.1	1.8	0.2	0.2	1.8
50	336	1 : 2.0	58.9	0.7	0.1	1.9	0.3	0.3	2.6
50	336	1 : 2.5	62.4	0.8	0.1	2.0	0.2	0.2	2.4
	MEAN		58.2	0.9	0.1	1.9	0.3	0.3	2.2
	CV(%)		6.03	6.25	14.9	6.9	9.4	18.04	11.3
	SE ±		2.48	0.04*	0.01	0.09	0.02	0.03	0.17

*...............Significant ($P<0.05$)

Values for per cent N (0.7-1.0) and around 0.1 for per cent P were 10% and 15% lower than those at the 6th month (Figs. 5 and 6 Appendix I). The interaction between N/K_2O fertilizer ratios and P-level treatments had a significant effect ($P<0.05$) on %N in the leaves. In the case of per cent K, the values (1.8-2.0) increased by 18% above those of the 6th month (Fig. 7 Appendix I). The values of per cent Ca increased by 50% over those of the 6th month sampling whilst per cent Mg maintained almost the same range (0.2- 0.3).

Table 8. Effect of N/K_2O ratios and P-level on D-leaf nutrients at 12 months at Parrico.

P_2O_5 (kg/ha)	N (kg/ha)	N/K_2O ratios	DM (g/sample	N	P	K (per cent)	Ca	Mg	K/N ratio
0	224	1 : 1.5	72.6	1.1	0.1	2.4	0.3	0.2	2.2
0	224	1 : 2.0	75.8	1.2	0.1	2.4	0.3	0.3	2.0
0	224	1 : 2.5	87.4	1.2	0.1	2.4	0.3	0.3	2.1
0	336	1 : 1.5	69.9	1.3	0.1	2.4	0.3	0.3	1.8
0	336	1 : 2.0	76.7	1.1	0.1	2.6	0.3	0.3	2.4
0	336	1 : 2.5	77.2	1.3	0.1	2.6	0.3	0.3	2.1
50	224	1 : 1.5	73.9	1.1	0.1	2.4	0.3	0.3	2.1
50	224	1 : 2.0	71.7	1.3	0.1	2.5	0.3	0.2	1.9
50	224	1 : 2.5	73.1	1.0	0.1	2.3	0.3	0.2	2.5
50	336	1 : 1.5	62.1	1.2	0.1	2.2	0.3	0.3	2.0
50	336	1 : 2.0	70.2	1.2	0.1	2.5	0.3	0.3	2.1
50	336	1 : 2.5	73.6	1.2	0.1	2.8	0.3	0.3	2.4
		MEAN	73.7	1.2	0.1	2.5	0.3	0.3	2.1
		CV(%)	7.3	7.9	16.8	5.3	9.3	5.4	11.5
		SE ±	3.8	0.07*	0.01	0.09*	0.02	0.01	0.17

*----------significant at 5% ($P<0.05$)

Table 8 shows the results of leaf analysis at flowering (i.e 12 months after planting). Values for dry matter yield (62 87g) increased 27% over the mean values of the 10th month, but 79% over the 6th month. This shows that, there was still vegetative growth after the tenth month.

Values for per cent N (1.0-1.3) and per cent K (2.2- 2.8) similarly increased by 33 and 32 per cent respectively above those of the 10th months (Figs. 5 and 7 Appendix I), but not much difference between the values of per cent P which averaged 0.1 and those at 10 months (Fig. 6 Appendix I). Significant effects were observed with per cent K due to he $/K_2O$ fertilizer ratios and also the interaction between the ratios and

P-levels at the 5% level.

Values of per cent Ca increased slightly over those of the 10th month to 0.3 while values of per cent Mg maintained almost the same values. Variations in the individual leaf nutrients with respect to different N/K_2O fertilizer ratios and P fertilizer treatments over the sampling periods are shown by figures 5, 6 and 7 (Appendix I)

4.3.3 Silwood

Table 9 shows results of leaf analyses at 6 months after planting. Values of the dry matter yield were from 31 to 39g. Values for nutrients in the leaves were per cent N (0.7-0.9), per cent P (0.1-0.2) and per cent K (1.29 1.55). Per cent Ca and Mg had the following ranges 0.2-0.3 and 0.2 0.3 respectively.

Table 10 presents the values of leaf analysis at 10 months. Dry matter yield values showed mean increase of 61% above those at 6 months. Values of N and K were 25 and 36 per cent respectively higher than those observed at 6 months (Figs. 8 and 10 Appendix I).

Significant differences were observed at ($P<0.05$) for per cent N due to the effects of N/K fertilizer ratios and the interaction between these ratios and P-level.

Values of per cent P decreased marginally below the corresponding values at 6 months (Fig. 7 Appendix I) with values around 0.1. Percentage Ca (0.2-0.3) and Mg (0.2-0.3) maintained almost the same range of values as compared to those of the 6 months sample.

Table 9. Effect of N/K_2O ratios and P-level on D-leaf nutrients at 6 months at Silwood.

P_2O_5 (kg/ha)	N	N/K_2O ratios	DM (g/sample)	N	P	K	Ca	Mg	K/N ratio
				(per cent)					
0	224	1 : 1.5	31.9	0.8	0.1	1.4	0.3	0.2	1.7
0	224	1 : 2.0	35.8	0.8	0.1	1.5	0.3	0.2	2.0
0	224	1 : 2.5	32.5	0.8	0.1	1.5	0.3	0.2	1.9
0	336	1 : 1.5	38.2	0.8	0.1	1.4	0.3	0.2	1.7
0	336	1 : 2.0	37.0	0.8	0.2	1.4	0.3	0.2	1.8
0	336	1 : 2.5	35.0	0.8	0.2	1.6	0.3	0.2	2.0
50	224	1 : 1.5	34.8	0.9	0.1	1.5	0.3	0.3	1.7
50	224	1 : 2.0	33.5	0.8	0.2	1.4	0.2	0.2	1.7
50	224	1 : 2.5	30.8	0.9	0.1	1.4	0.3	0.2	1.6
50	336	1 : 1.5	38.5	0.8	0.1	1.3	0.3	0.2	1.7
50	336	1 : 2.0	34.2	0.8	0.2	1.3	0.3	0.3	1.7
50	336	1 : 2.5	32.4	0.7	0.1	1.5	0.3	0.2	2.1
		MEAN	34.6	0.8	0.1	1.4	0.3	0.2	1.8
		CV(%)	11.1	11.07	14.7	6.3	12.3	14.2	11.4
		SE ±	1.9	0.06	0.01	0.06	0.02	0.02	0.14

Table 10. Effect of N/K_2O ratios and P-level on D-leaf nutrients at 10 months at Silwood.

P_2O_5 (kg/ha)	N	N/K_2O ratios	DM (g/sample)	N	P	K	Ca	Mg	K/N ratio
				(per cent)					
0	224	1 : 1.5	54.6	1.0	0.1	1.7	0.3	0.2	1.8
0	224	1 : 2.0	55.6	0.9	0.1	1.8	0.3	0.2	2.0
0	224	1 : 2.5	54.0	1.0	0.1	1.9	0.2	0.2	2.0
0	336	1 : 1.5	58.8	0.8	0.1	1.9	0.3	0.2	2.3
0	336	1 : 2.0	52.1	1.1	0.1	1.8	0.2	0.2	1.7
0	336	1 : 2.5	59.8	1.0	0.1	2.1	0.3	0.2	2.1
50	224	1 : 1.5	52.1	1.2	0.1	1.8	0.3	0.2	1.5
50	224	1 : 2.0	58.5	0.7	0.1	1.8	0.3	0.2	2.5
50	224	1 : 2.5	54.5	1.2	0.1	2.0	0.3	0.2	2.5
50	336	1 : 1.5	59.7	1.2	0.1	1.9	0.3	0.3	1.6
50	336	1 : 2.0	53.8	1.0	0.1	1.9	0.3	0.2	1.8
50	336	1 : 2.5	54.1	0.9	0.1	1.9	0.3	0.3	2.0
		MEAN	55.6	1.0	0.1	1.9	0.3	0.2	1.9
		CV(%)	6.9	6.83	19.5	7.95	5.76	16.6	8.0
		SE ±	2.7	0.05*	0.01	0.01	0.02	0.0	0.2

* ---------- significant ($P<0.05$)

Table 11 shows results of leaf analyses at 12 months. Values obtained for all the response variables increased over those of the previous sampling periods (Figs. 8, 9 and 10 Appendix I). For example, the respective percentage increases over values of the 10th month were as follows: dry matter (30%), N (30%), K (32%), P (0%), Ca (0%) and Mg (50%). A significant difference ($P<0.05$) was observed with per cent N due to the effect of the fertilizer ratios and P-level interaction.

Table 11. Effect of N/K_2O ratios and P-level on D-leaf nutrients at 12 months at Silwood.

P_2O_5 (kg/ha)	N (kg/ha)	N/K_2O ratios	DM (g/sample)	N	P	K (per cent)	Ca	Mg	K/N ratio
0	224	1 : 1.5	70.1	1.3	0.1	2.4	0.3	0.3	1.8
0	224	1 : 2.0	70.9	1.4	0.1	2.6	0.3	0.2	1.9
0	224	1 : 2.0	78.0	1.2	0.1	2.7	0.3	0.3	2.2
0	336	1 : 1.5	67.2	1.2	0.1	2.5	0.3	0.3	2.0
0	336	1 : 2.0	70.6	1.5	0.1	2.5	0.3	0.3	1.7
0	336	1 : 2.5	78.5	1.3	0.1	2.6	0.3	0.2	2.0
50	224	1 : 1.5	69.7	1.5	0.1	2.4	0.3	0.3	1.6
50	224	1 : 2.0	74.8	1.2	0.1	2.5	0.3	0.3	2.1
50	224	1 : 2.5	73.0	1.2	0.1	2.4	0.3	0.3	2.1
50	336	1 : 1.5	74.1	1.5	0.1	2.4	0.3	0.3	1.6
50	336	1 : 2.0	70.5	1.1	0.1	2.5	0.3	0.2	2.2
50	336	1 : 2.5	73.4	1.2	0.1	2.5	0.3	0.2	2.1
	MEAN		72.6	1.3	0.1	2.5	0.3	0.3	1.95
	CV(%)		6.06	11.26	19.0	4.15	12.02	5.32	11.49
	SE ±		3.11	0.1*	0.02	0.07	0.02	0.0	0.15

* ------------- significant ($P<0.05$)

4.4 Flower Count

Table 11 shows values for flower count from the three sites. Pokuase had the highest total percentage floral count 42%, followed by Silwood 39%

and Parrico 19% in that order (Fig. 11 Appendix I). The lowest flower count at Parrico was recorded on plots treated with 336kgN + 504kgK_2O + 0kgP and 336 kgN + 672 kgK_2O + 0 kgP per hectare.

4.5 Mean fruit weight

Table 12 shows mean fruit weights from all the three sites. Except for the differences between the various sites, (Fig. 12 Appendix I) no significant differences were observed among the various treatments on all the sites.

4.6 Fruit quality: Fruit quality refers to the shape, skin colour, total soluble solids, acidity and shelf life of the fruit.

This work considered all these characteristics except the shelf life. The shape of most of the fruits were cylindrical. Some of the fruits from Silwood had twin crowns.

The acidity was measured as per cent citric acid equivalent, and sugar content as total soluble solids (TSS) measured as ^{o}brix.

Table 14 shows values of the acidity from the three sites. No significant differences were observed between the various treatments from the sites (Fig. 13 Appendix I). The range of values from the sites were as follows: Pokuase (0.6-0.7), Parrico (0.7-1.0) and Silwood (0.7-0.9).

Table 12. Effect of N/K_2O ratios and P-level on flowering at the three sites.

P_2O_5 (kg/ha)	N (kg/ha)	N/K_2O ratios	POKUASE	PARRICO (flower count)	SILWOOD
0	224	1 : 1.5	29	17	32
0	224	1 : 2.0	33	12	31
0	224	1 : 2.5	33	25	30
0	336	1 : 1.5	34	8	28
0	336	1 : 2.0	30	7	31
0	336	1 : 2.5	32	16	27
50	224	1 : 1.5	34	12	24
50	224	1 : 2.0	34	21	32
50	224	1 : 2.5	34	10	33
50	336	1 : 1.5	35	12	30
50	336	1 : 2.0	35	11	30
50	336	1 : 2.5	32	16	27
		MEAN	32.0	13.9	29.4
		CV(%)	8.3	39.1	19.3
		SE ±	1.6	3.9	4.0

Table 13. Effect of N/K_2O ratios and P-level on fruit yield from the three sites.

P_2O_5 (kg/ha)	N (kg/ha)	N/K_2O ratios.	POKUASE	PARRICO (mean fruit weight, kg)	SILWOOD
0	224	1 : 1.5	1.2	2.7	2.6
0	224	1 : 2.0	0.9	2.9	2.2
0	224	1 : 2.5	1.3	2.7	2.9
0	336	1 : 1.5	1.4	2.5	2.9
0	336	1 : 2.0	1.4	2.7	2.8
0	336	1 : 2.5	1.2	2.7	2.8
50	224	1 : 1.5	1.4	2.7	2.7
50	224	1 : 2.0	1.5	2.8	2.5
50	224	1 : 2.5	1.7	3.0	2.7
50	336	1 : 1.5	1.3	3.1	2.8
50	336	1 : 2.0	1.5	2.6	2.8
50	336	1 : 2.5	1.5	2.4	2.4
		MEAN	1.35	2.72	2.67
		CV(%)	16.6	10.07	15.6
		SE ±	0.13	0.19	0.3

Total soluble solids (TSS) measured as °brix for Pokuase (16.9-19.2), Parrico (16.9-20.0) and Silwood (16.7-18.5) are summarised in Table 15. As in the case of the acid content, no significant difference was observed between the various treatments within the respective sites. (Fig. 14 Appendix I).

Table 14. Effect of N/K_2O ratios and P-level on Acidity content of fruits from the three sites.

P_2O_5	N	N/K_2O ratios	POKUASE	PARRICO	SILWOOD
(kg/ha)			(acidity as %citric acid equivalent)		
0	224	1 : 1.5	0.7	0.7	0.7
0	224	1 : 2.0	0.7	0.8	0.9
0	224	1 : 2.5	0.7	0.9	0.7
0	336	1 : 1.5	0.7	0.8	0.7
0	336	1 : 2.0	0.6	0.9	0.7
0	336	1 : 2.5	0.7	0.7	0.8
50	224	1 : 1.5	0.7	0.7	0.7
50	224	1 : 2.0	0.7	0.8	0.8
50	224	1 : 2.5	0.6	0.7	0.8
50	336	1 : 1.5	0.6	0.7	0.7
50	336	1 : 2.0	0.6	0.8	0.9
50	336	1 : 2.5	0.7	1.0	0.8
		MEAN	0.66	0.79	0.77
		CV(%)	10.99	20.22	6.11
		SE $\pm$	0.04	0.11	0.03

Table 15. Effect of N/K_2O ratios and P-level on sugar content fruits from the three sites.

P_2O_5	N (kg/ha)	N/K_2O ratios	POKUASE TSS	PARRICO TSS	SILWOOD TSS
0	224	1 : 1.5	18.7	16.9	17.9
0	224	1 : 2.0	19.0	18.6	17.4
0	224	1 : 2.5	18.1	20.0	17.0
0	336	1 : 1.5	19.2	17.9	16.7
0	336	1 : 2.0	18.3	19.3	16.7
0	336	1 : 2.5	18.2	19.7	17.6
50	224	1 : 1.5	18.4	18.2	17.2
50	224	1 : 2.0	19.2	19.1	17.7
50	224	1 : 2.5	17.4	18.1	18.5
50	336	1 : 1.5	16.9	17.3	18.1
50	336	1 : 2.0	17.6	17.7	17.9
50	336	1 : 2.5	19.1	19.0	17.2
		MEAN	18.33	18.47	17.49
		CV(%)	5.7	8.3	5.8
		SE $\pm$	0.6	1.08	0.72

4.7 Correlation analyses

A correlation analysis was performed between the per cent N, P, K contents and corresponding K/N ratios of the leaf, on one hand and mean fruit weight (MFW), acidity (AC) and total soluble solids (TSS) on the other. Table 15 shows the correlation coefficients between the various parameters.

Per cent N correlated negatively ($P< 0.05$) with acidity at Pokuase (6 months) and at Silwood (12 months). A positive correlation ($p<0.05$) was observed between %K (10 months) and mean fruit weight at Silwood. At Pokuase leaf K/N ratio correlated positively ($P< 0.05$) with acidity at but negatively with total soluble solids for the 6th and 10th month samples respectively. A positive correlation ($P< 0.05$) was also observed between the K/N ratio (12 month) and total soluble solids at Silwood.

Table 16. Results of correlation analysis of leaf nutrient contents and fruit quality at the three different sampling times and sites.

	6. Months			10 Months			12 Months		
LNC	MFW	AC.	TSS	MFW	AC.	TSS	MFW	AC.	TSS
				Pokuase					
%N	0.02	-0.40*	0.22	-0.02	-0.01	0.29			
%P	0.12	-0.20	0.04	-0.08	0.26	-0.23			
%K	0.32	-0.13	0.11	0.28	0.04	0.07			
K/N	0.06	0.40*	-0.15	0.05	-0.02	-0.37*			
				Parrico					
%N	0.22	0.10	-0.05	0.08	-0.02	-0.15	-0.23	0.18	0.08
%P	0.19	-0.05	-0.07	-0.09	-0.07	-0.20	-0.13	0.30	0.04
%K	-0.15	0.29	0.21	-0.09	0.31	0.29	-0.27	0.36	0.34
K/N	-0.19	0.03	0.09	-0.09	0.14	0.23	0.08	0.04	0.07
				Silwood					
%N	0.19	-0.26	-0.26	0.14	-0.03	0.18	0.18	-0.42*	-0.22
%P	0.11	-0.19	0.08	-0.30	0.03	-0.06	-0.06	0.30	-0.13
%K	-0.06	-0.30	0.08	0.43*	0.18	-0.14	-0.02	0.17	-0.03
K/N	-0.41	0.05	-0.09	0.05	0.09	-0.28	-0.18	0.44*	0.21

MFW --- Mean fruit weight
Ac. --- Acidity (%citric acid equivalent)
TSS --- Total soluble solids (%brix)
LNC --- Leaf nutrient content (per cent)
* ---- Significant ($P< 0.05$)

Chapter Five

DISCUSSION

5.1 Plant growth : Dry matter yield from the three sites increased with age of the crop. Since there was not much difference between the sites, in terms of the soil physical and fertility status, the vast differences observed between values from the sites might be due mainly to the differences in the soil moisture. This was well manifested at Pokuase where total rainfall amount during the growing season was only 988mm and the corresponding dry matter produced was least.

The highest relative growth rate of the pineapple was obtained between 5th and 10th months. This observation is similar to what Tay (1974) observed.

5.2 Leaf Analysis

The fall in the values of per cent N at 10 months below those of the 6th month sampling at Pokuase and Parrico might be due to the higher N requirement of the crop between the 6th and 10th months after planting (Tay, 1974). No immediate explanation can, however, be given for the increase at Silwood.

The general increasing trend in the values of per cent K over the sampling periods follows the fertilization programme and implies that as the crop matures the K levels increase. This agrees with Su (1965) who reported that, the critical level of K in the leaves depend on the age of the plant.

The increase in the per cent N and K at 12 months might be due to their low utilisation by the crop at this flowering stage where vegetative growth is minimal in favour of the on set of fruit formation. The increases in the value of per cent K with age of the plant is not consistent with the findings of Velez-Ramos et al. (1991) who observed a decline with age. This difference might be due to the different fertilization programmes followed.

The marginally higher levels of per cent P from all the sites at 6 months compared to the other sampling times suggest low utilisation of the nutrient at this growth stage. The increase in the values of per cent Ca and Mg in the leaves follows that of per cent K. Martin-Prevel et al (1961) reported that an increase in the value of K in the leaves is accompanied by corresponding increases in the leaf Ca and Mg contents. In this work it was observed that this increase favours per cent Ca more than Mg.

Even though Mustafa (1988) used Kew pineapple and analysed the non-chlorophyllous base of the leaves, values he reported are similar to those for per cent N, K, and P at the 12th month. Also results of this work are similar to those reported by Godfrey-Sam-Aggrey (1970) even though the analyses were done after fruit harvest. This might be due to the higher levels of N and K used in this work.

The values obtained at floral induction fell below those reported by IRFA (1989) for D-leaf composition. This is probably because their time of the floral induction was 12 months after planting. Even though the trend of values agrees with the fertilization programme, the values of K/N ratios in the leaves from the three sites fell below the value of 3 quoted by Martin-Prevel (1959). This has, however, not affected the yield and quality of the fruits.

5.2 Flower count

The higher percentage flowering at Pokuase compared to the other two sites may be attributed to the comparatively low moisture regime which does not favour high vegetative growth. There was however enough moisture at Pokuase at the time of flowering. The lower percentage flowering at Parrico and to some extent at Silwood may be attributed to the high vegetative growth at these sites. This corroborates with Abutiate and Eyeson (1973) who reported that high vegetative growth leads to delay in flowering. The very low figures recorded particularly at Parrico might also be due to environmental conditions such as high rainfall or high temeperatures just after the application of the inductant. These conditions normally render the inductant ineffective.

5.3 Mean fruit weight

The qualitative differences in the vegetative growth brought about by moisture differences at various sites were well reflected in the mean fruit weight values at the sites (Table 12). This observation agrees with the findings of Asoegwu (1987).

The non-significant effect of the fertilizer treatments may imply that either the soil was initially nutrient sufficient or that the amount of nutrient applied exceeded but was not detrimental to the normal requirement of the crop. Abutiate and Eyeson (1973) gave an optimum nitrogen application rate of 112kg/ha and attributed the non-significance of K treatments to the buffering capacity of Ghanaian soils to K depletion (Ahenkorah, 1970). The lowest rates of N and K used in this work were 224kg N/ha and 336kg K_2O/ha respectively.

Except for fruits from Pokuase, most of the fruits from Parrico and Silwood did not qualify for the fresh fruit export market. COLEACP (1993) gave a range of 0.74-2.4kg for the fresh fruit market in Europe.

With the significant positive correlation between leaf K content and mean fruit weight observed at Silwood, it is suggested that the levels of nutrients (especially N and K) when reduced could help bring the weight of the fruits from Silwood and most probably Parrico, to the acceptable levels for the fresh fruit export market. It is from these sites that the bulk of the fruits were found to be far in excess of the exportable fruit weight. Asoegwu (1987) reported that reduction in fertilizer requirements may concomitantly effect reduction in the fruit weight.

At Silwood the relation was represented by $Y = 0.54 + 1.14X$, ($r = 0.43$*) where Y = mean fruit weight (kg) and X =leaf K content. The non significant correlation between leaf N and mean fruit weight is inconsistent with the findings of Subramanian et al (1977) who observed a signifcant relationship ($r = 0.564$) between leaf N and yield. The data is however consistent with the findings of Tay et al., (1969) who observed no relationship between leaf N and yield.

5.4 Fruit Quality

The values for total soluble solids (TSS) and acidity fell within the acceptable range for the export market. COLEACP (1993) gave the following ranges TSS (5 18 °brix) and acidity (0.5 1.0 %citric acid equivalent).

Even though the trend of the K values in the leaves followed the fertilization program, the respective values (K = 2.5% and K/N = 2.1) at Parrico and Silwood were lower than those given as critical levels (K = 2.7%) by Nightingale (1942) and K/N = 3 by Martin-Prevel (1959). The lower values obtained in this work did not affect the flowering, yield and quality of the crop, because of the shorter growth period associated with high rainfall climates.

Even though Tay (1974) and Mustafa (1988) reported significant positive correlation between applied N and fruit weight, whilst Samuels Gandia Diaz (1956) recorded negative relationship, none of these relations was obtained in this work. A possible explanation is that, applied nutrient on soil may not always reflect in the mean fruit weight measurements but most probably reflect on the leaf nutrient contents.

It is to be noted that significant negative linear relationships were observed between leaf N and acidity at both Pokuase (6 months) and Silwood (12 months), implying that increase in leaf N which is a reflection of the available N adversely affect the acidity. The linear relationships were as follows:

$$Y = 0.77 \quad 0.115X \quad (r = -0.398^{*}) \text{ at Pokuase}$$

$$Y = 1.0 - 0.179X \quad (r = -0.42^{*}) \text{ at Silwood}$$

where Y is acidity and X per cent leaf N.

Tay, (1974) also reported negative linear relation between applied N and acidity

The value of the K/N ratio has been used as an index for fruit quality. Positive linear relationships were obtained between leaf K/N ratio and acidity at both Pokuase and Silwood, with the following respective equations: $Y = 0.47 + 0.116b$ ($r = 0.40^{*}$) and $Y = 0.53 + 0.12b$ ($r = 0.44^{*}$), where Y is acidity and b is K/N ratio. However, it is to be noted that whilst the influence of N alone is negatively correlated, that of K/N ratio is positive with respect to the acidity. Contrary to what Dodson (1975) and Cannon (1957) reported, no significant relation was observed between these leaf nutrients and the sugar content. Rather a significant negative linear relation ($r = -0.40^{*}$) was observed between K/N and sugar content at Pokuase.

From the observations, there is the need to maintain a balanced K/N ratio in order to ensure an acceptable palatability of the pineapple fruit.

CHAPTER SIX

SUMMARY AND CONCLUSION

The trial was designed to determine the influence of different nitrogen and potassium fertilizer ratios on yield and quality of pineapple fruits. The trial was sited on Udults and Ustults great groups in southern forest-savanna ecotone of Ghana. A split plot design with two P levels on main plots and six N/K_2O fertilizer ratios on sub-plots was used.

Growth was generally poor at Pokuase as compared with either Parrico or Silwood. Differences in leaf colour indices and dry matter levels were mainly attributed to differences in the rainfall at the three sites.

There were significant effects ($P<0.05$) of the N/K_2O fertilizer ratios on the percentage leaf contents of K at Pokuase and those of N and Ca at Parrico and Silwood at 10 months sampling.

Flowering at Pokuase was >Parrico >Silwood. Mean fruit weight at Pokuase was within the export range whereas the bulk from Parrico and Silwood exceeded the recommended range (0.7 to 2.4 kg) range for the export market. It was suggested that levels of N and K be reduced to achieve the desired fruit weight for the export market. Fruit quality at all sites was good when compared with values given by COLEACP (1993) for acidity and sugar levels.

Significant negative linear relationships were found between per cent N and the acidity at both Pokuase for 6 months ($r = -0.40^*$) and Silwood for 12 months (-0.42^*) samples. Linear relationship was established between per cent K and mean fruit weight at Silwood (r=0.43). It was observed that the leaf K/N ratios were positively correlated with the acidity but negatively related with the total soluble solids. The leaf K/N relationships with these fruit quality parameters were highly consistent for the growth periods between 6 and 10 months at Pokuase. It is emphasised that all the relationships were found to be location specific.

Leaf nutrient concerntrations at 10 months appeared to be a better diagnostic guide for the nutritional status of the pineapple at the three sites than those of the other growth stages of the plant.

At 50 kgP_2O_5/ha, the ratio of N/K_2O fertilizers can be maintained at 1:2 to satisfy growth, yield and quality of the fruits produced at the three sites.

6.1 SUGGESTED FURTHER WORK

It is recommended that this work be carried out for at least another growing cycle in the southern forest-savannah ecotone to concretise the present findings. This should be done restricting the level of P to 50 kgP_2O_5/ha and the nitrogen level to 224 kgN/ha while varying the K_2O within the present range of nitrogen to potassium ratios. More sites should be investigated.

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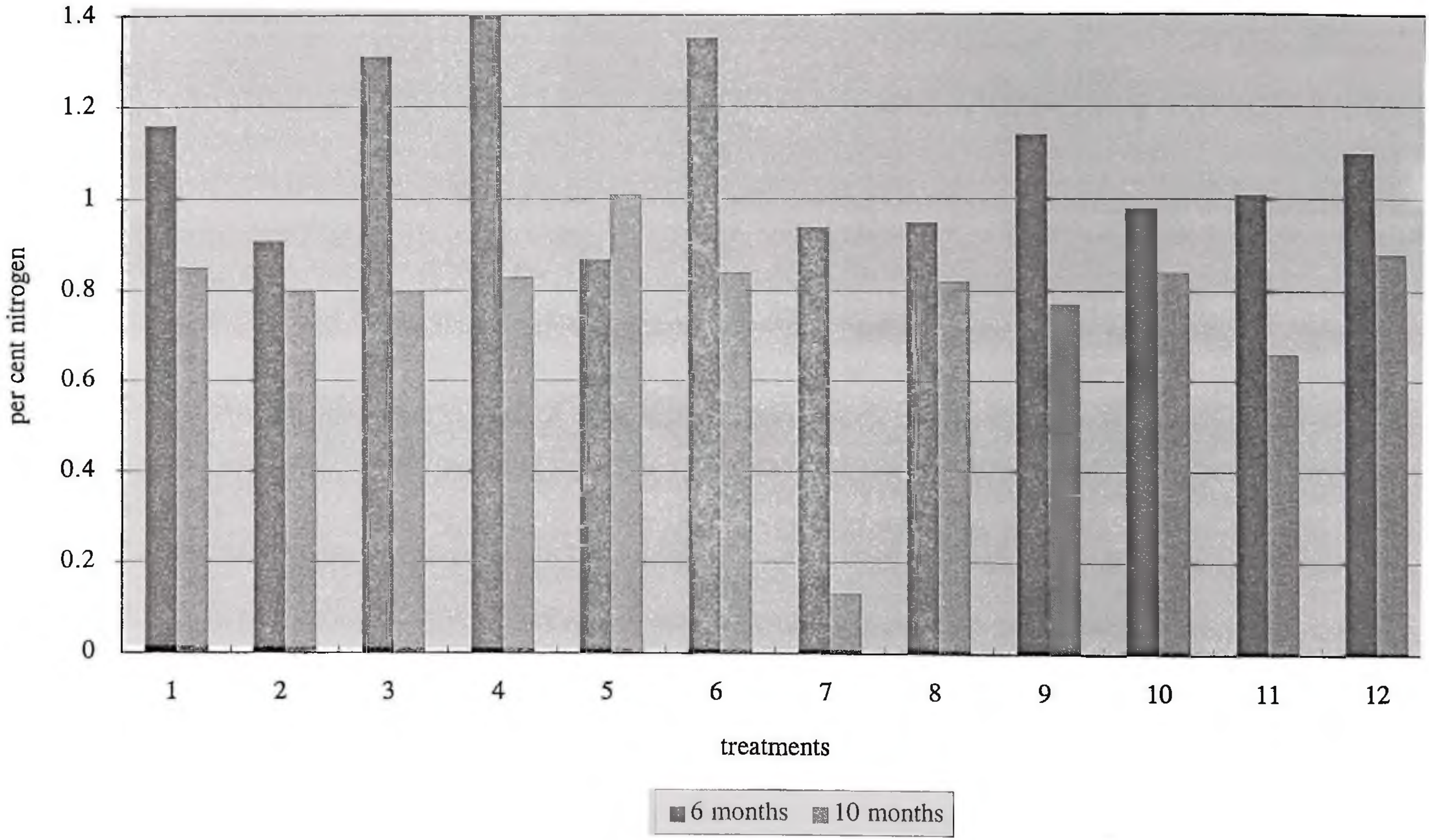
Appendix 1

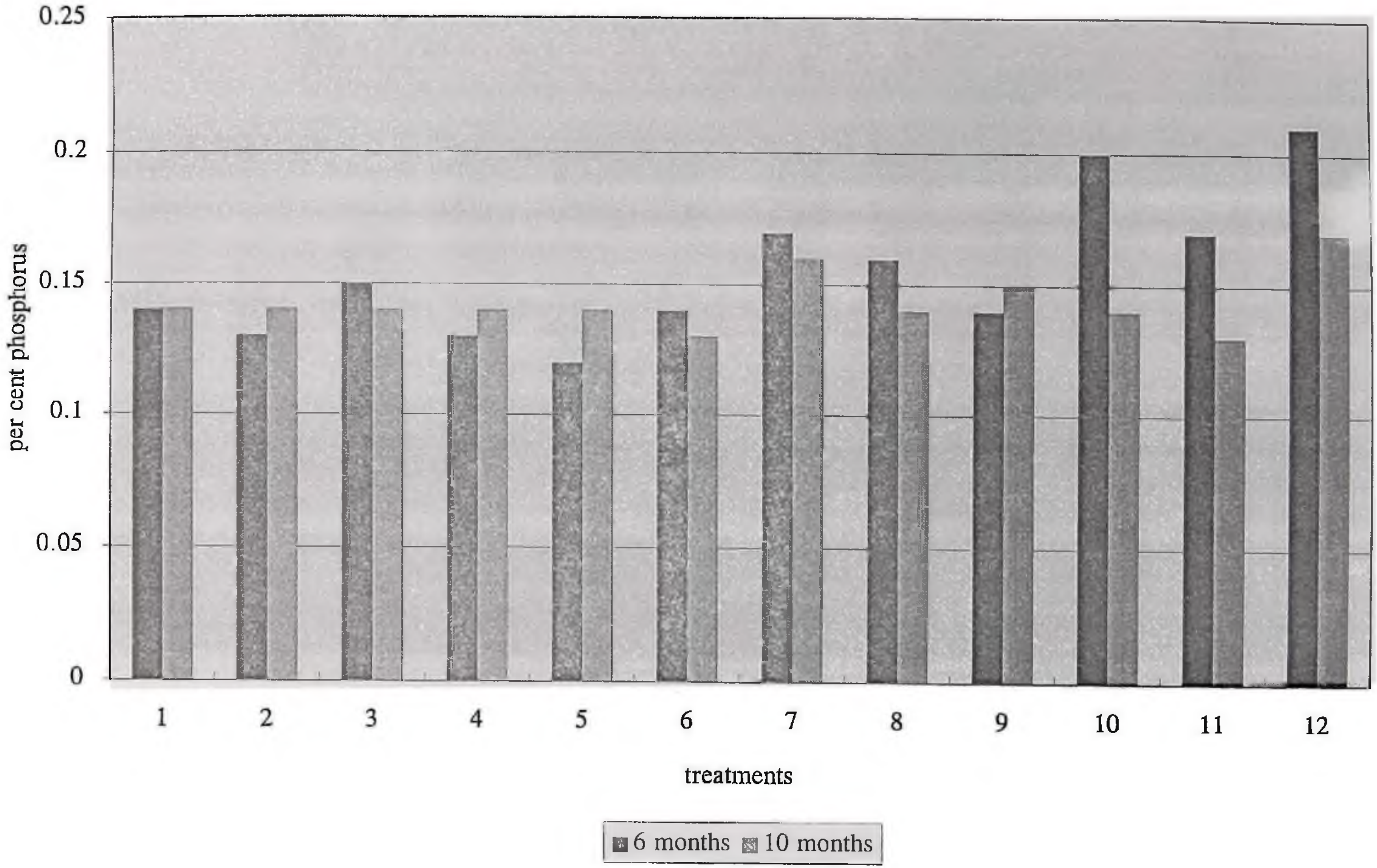
Fig. 2: Per cent nitrogen in leaves at two sampling times at Pokuase.



Treatments 1 - 6 = N/K fertilizer ratios + P(0 kg/ha), treatments 7 - 12 = N/K fertilizer ratios = P(50 kg/ha).

Appendix 1

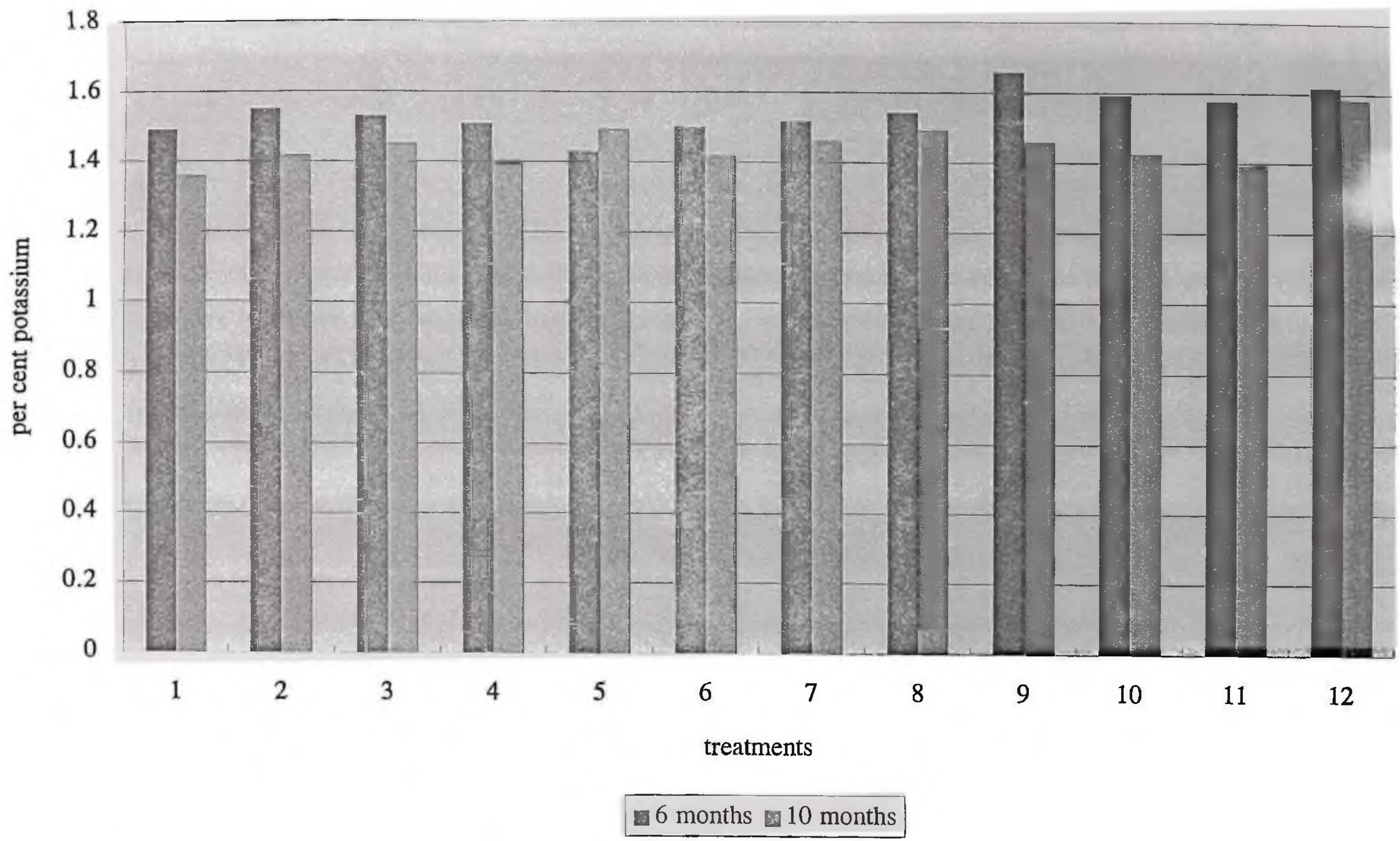
Fig. 3: Per cent phosphorus in leave s at two sampling times at Pokuase.



Treatments 1 - 6 = N/K fertilizer ratios + P(0 kg/ha), treatments 7 - 12 = N/K fertilizer ratios + P(50 kg/ha).

ppendix 1

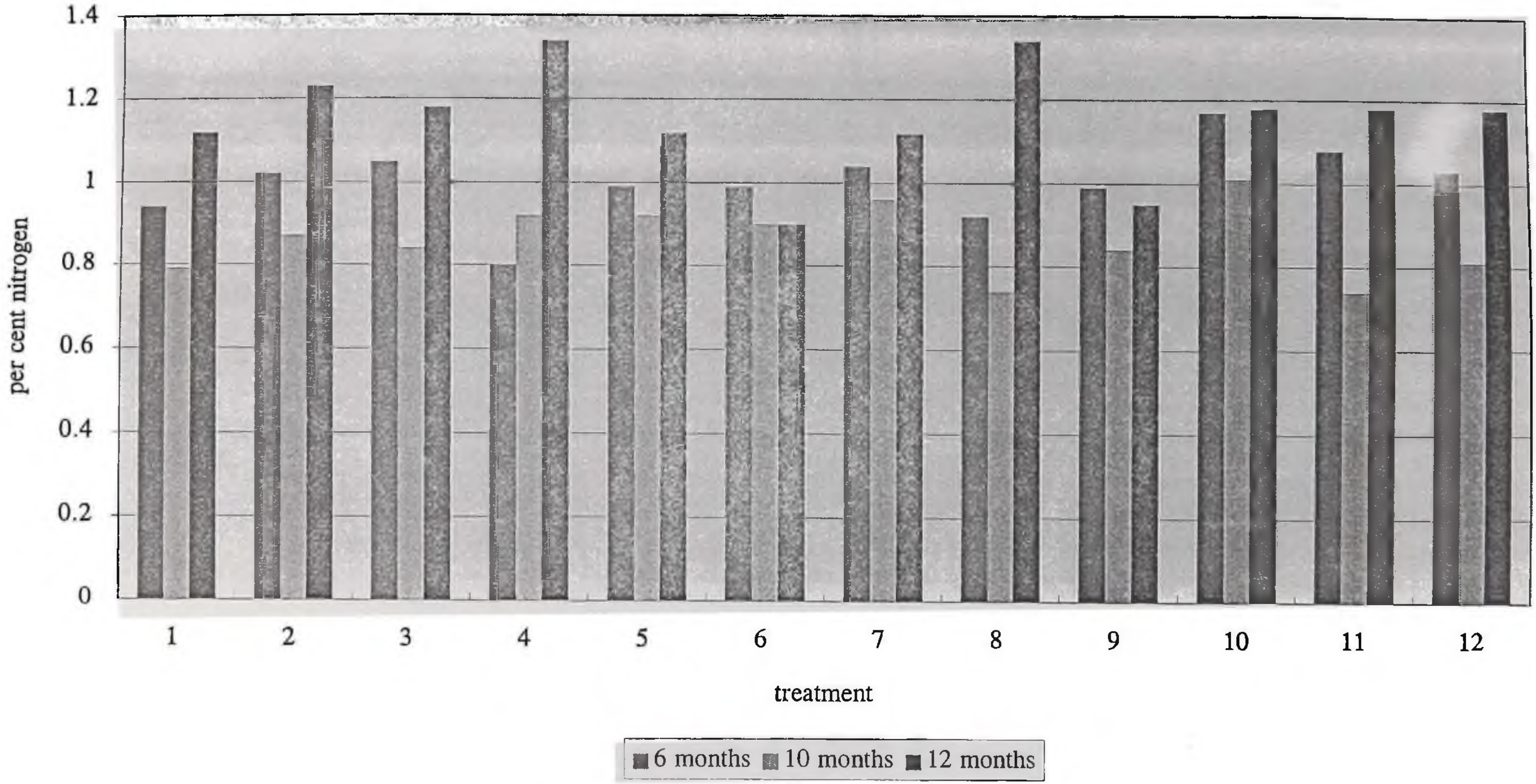
Fig. 4: Per cent potassium in leaves at two sampling times at Pokuase



Treatments 1 - 6 = N/K fertilizer ratios + P(0 kg/ha), treatments 7 - 12 = N/K fertilizer ratios + P(50 kg/ha).

Appendix 1

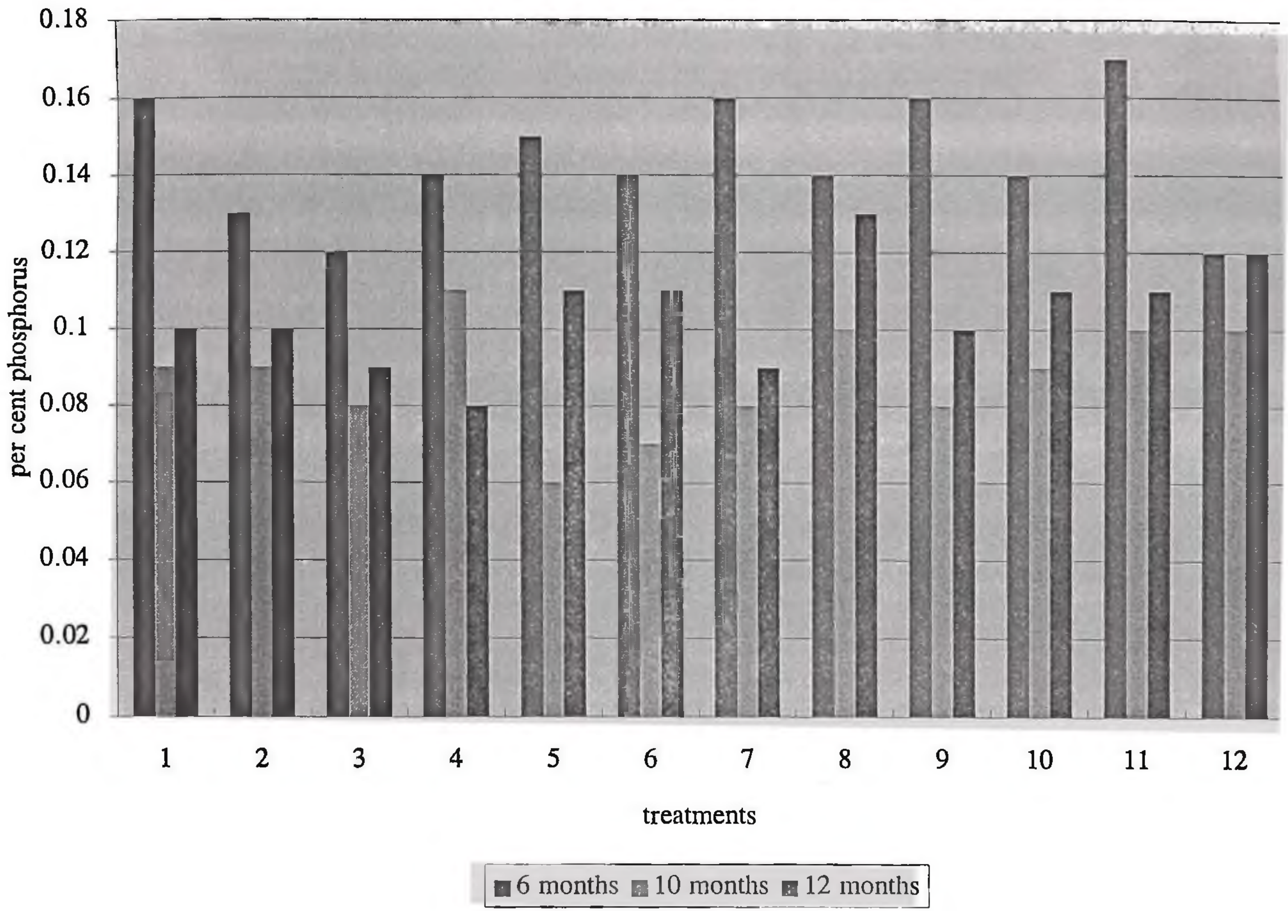
Fig. 5: Per cent nitrogen in leaf at the three sampling times at Parrico



Treatments 1 - 6 = N/K fertilizer ratios + P(0 kg/ha), treatments 7 - 12 = N/K fertilizer ratios + P(50 kg/ha)

Appendix I

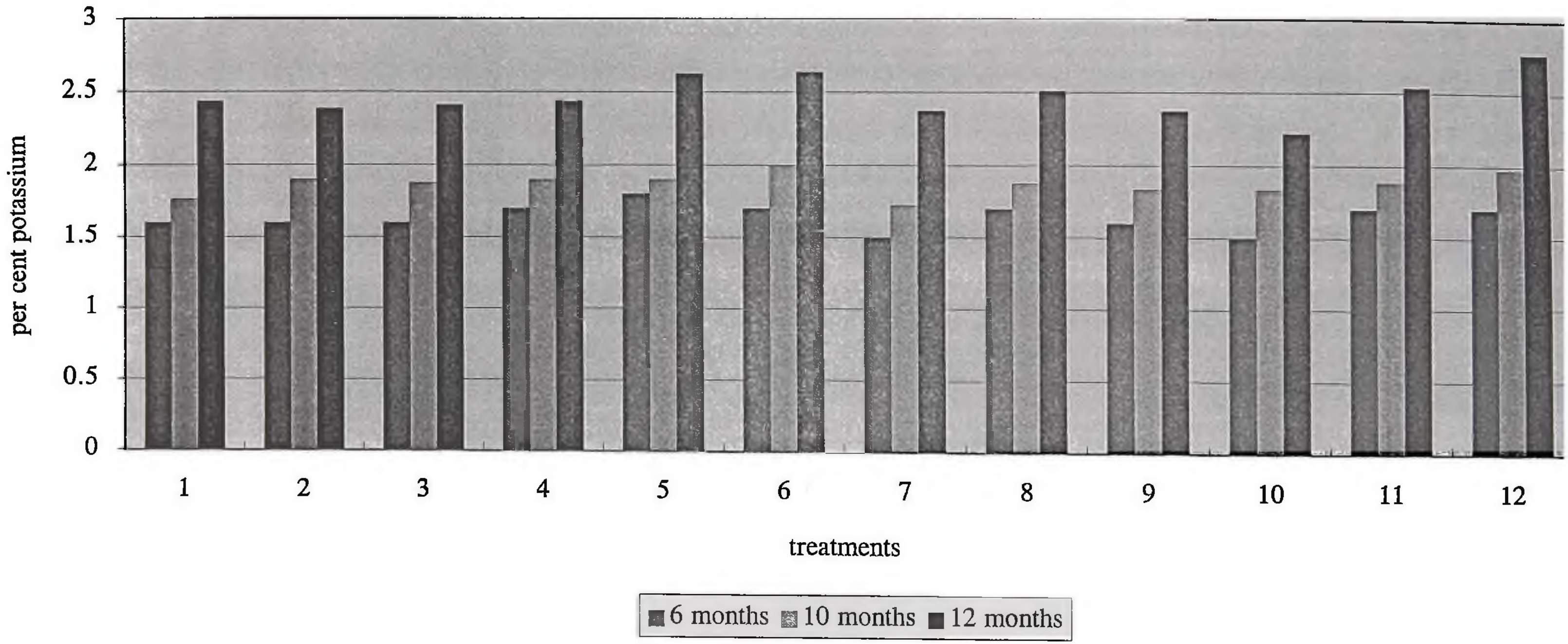
Fig. 6: Per cent phosphorus in leaves at two sampling times at Parrico



Treatments 1 - 6 = N/K fertilizer ratios + P(0 kg/ha), treatments 7 - 12 = N/K fertilizer ratios + P(50 kg/ha).

Appendix 1

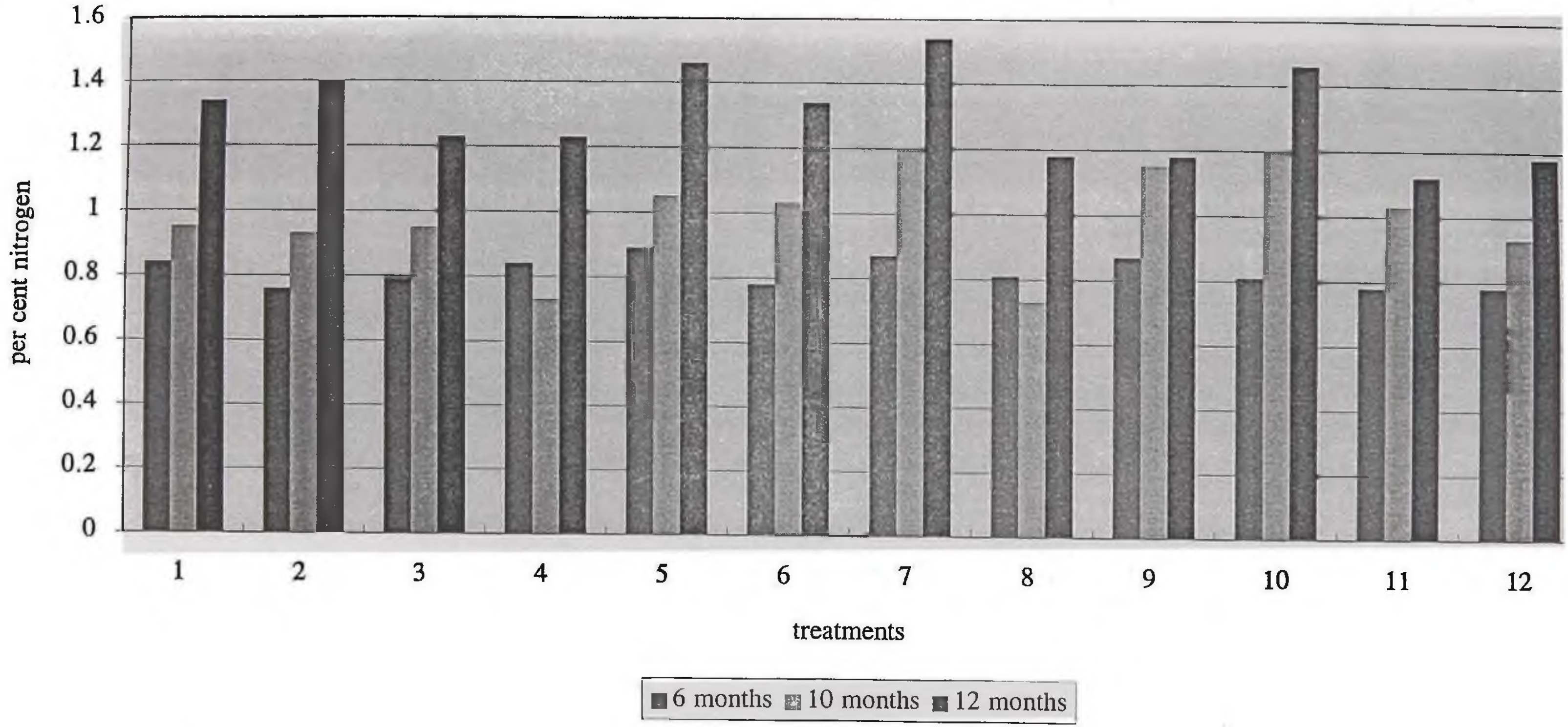
Fig. 7: Per cent potassium in leaves at three sampling times at Parrico.



Treatments 1 - 6 = N/K fertilizer ratios + P(0 kg/ha), treatments 7 - 12 = N/K fertlizer ratios + P(50 kg/ha).

Appendix 1

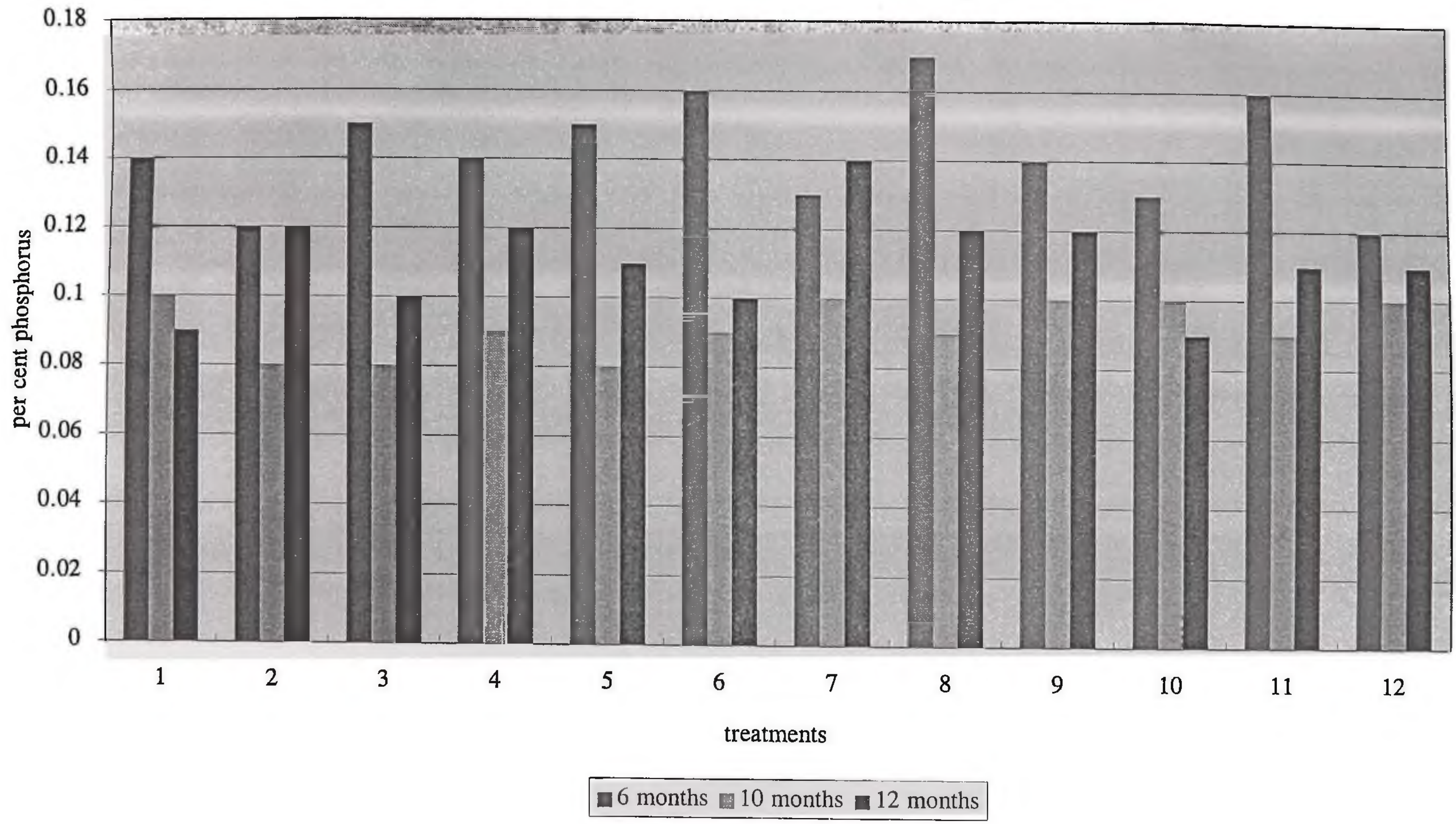
Fig. 8: Per cent nitrogen in leaf at three sampling times at Silwood.



Treatments 1 - 6 = N/K fertilizer ratios + P(0 kg/ha), treatments 7 - 12 = N/K fertilizer ratios + P(50 kg/ha)

Appendix 1

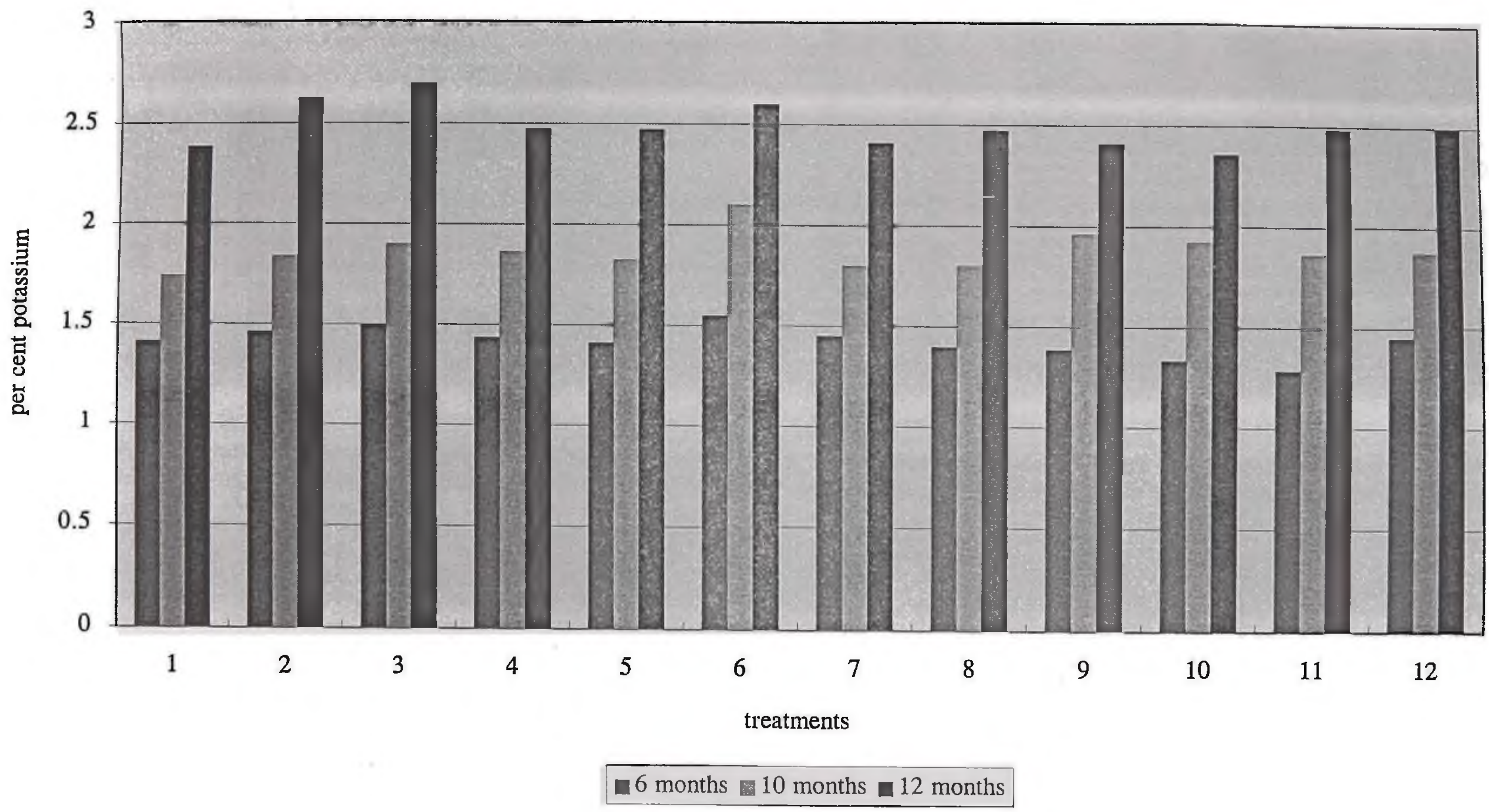
Fig. 9: Per cent phosphorus in leaf at three sampling times at Silwood



Treatments 1 - 6 = N/K fertilizer ratios + P(0 kg/ha), treatments 7 - 12 = N/K fertilizer ratios + P(50 kg/ha)

Appendix 1

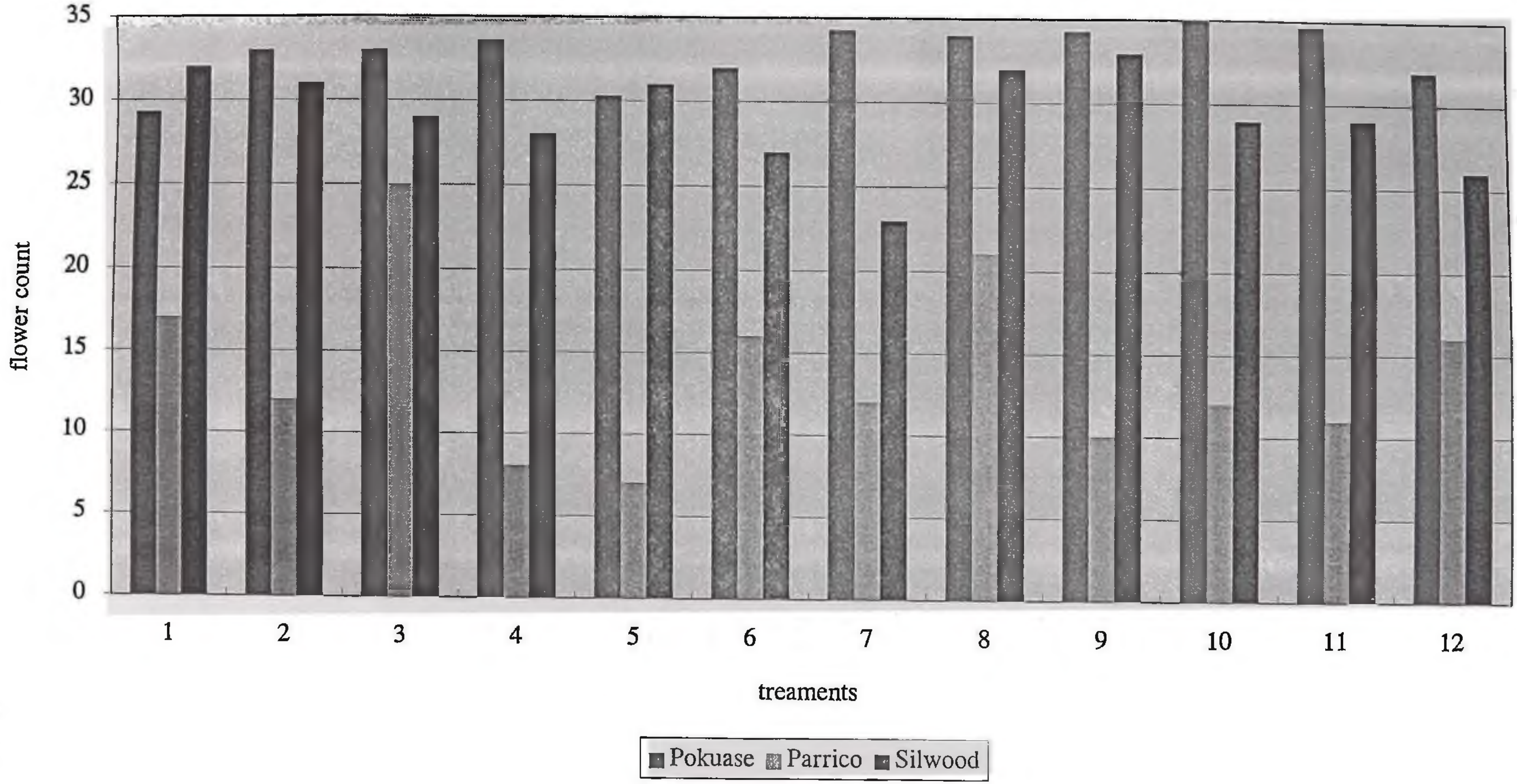
Fig. 10: **Per cent potassium in leaves at three sampling times from Silwood**



Treatments 1 - 6 = N/K fertilizer ratios + P(0 kg/ha), treatments 7 - 12 = N/K fertilizer ratios + P(50 kg/ha)

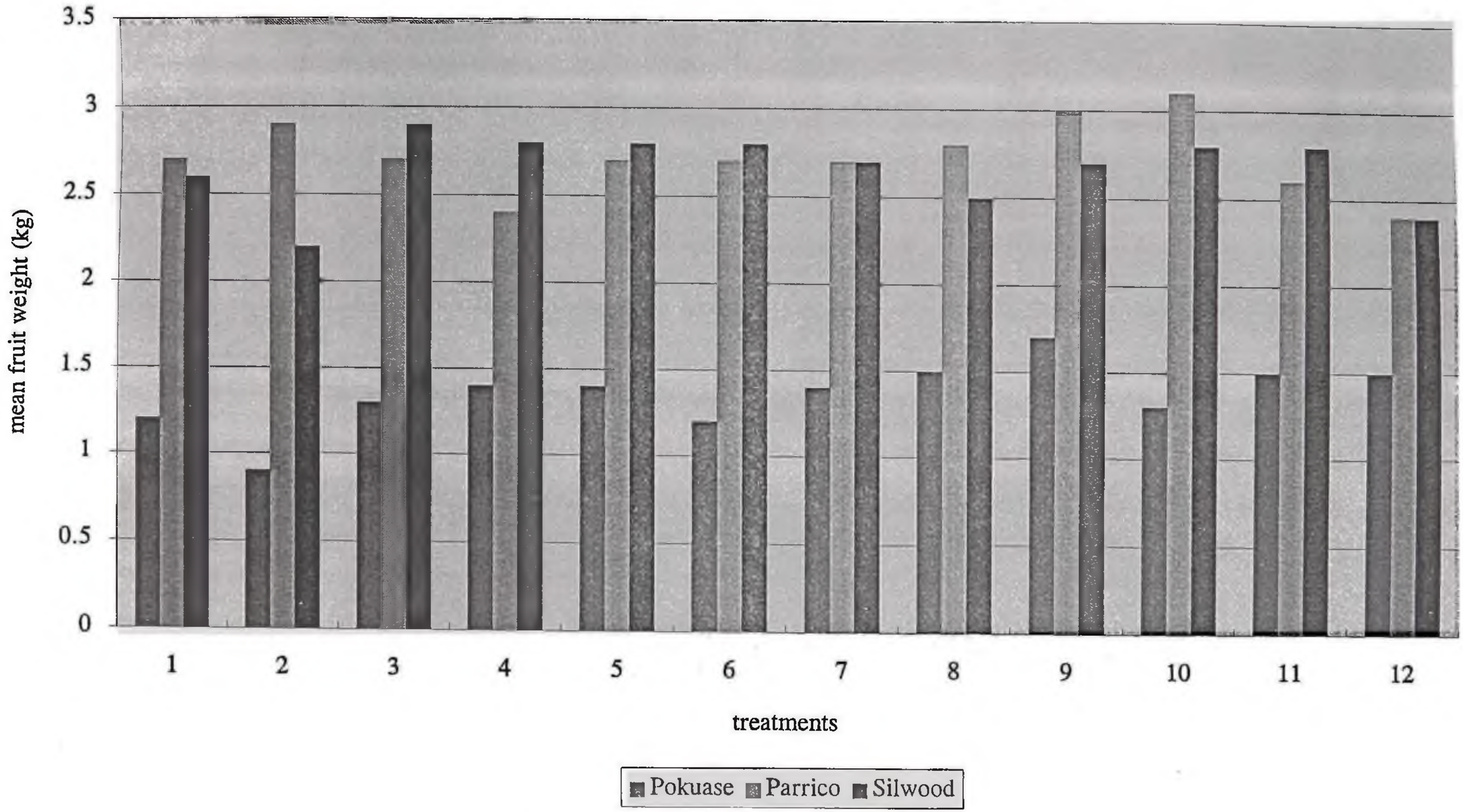
Appendix 1

Fig. 11: Flower count from the three sites at 12 months.



Treatments 1 - 6 = N/K fertilizer ratios + P(0 kg/ha), treatments 7 - 12 = N/K fertilizer ratios + P(50 kg/ha)

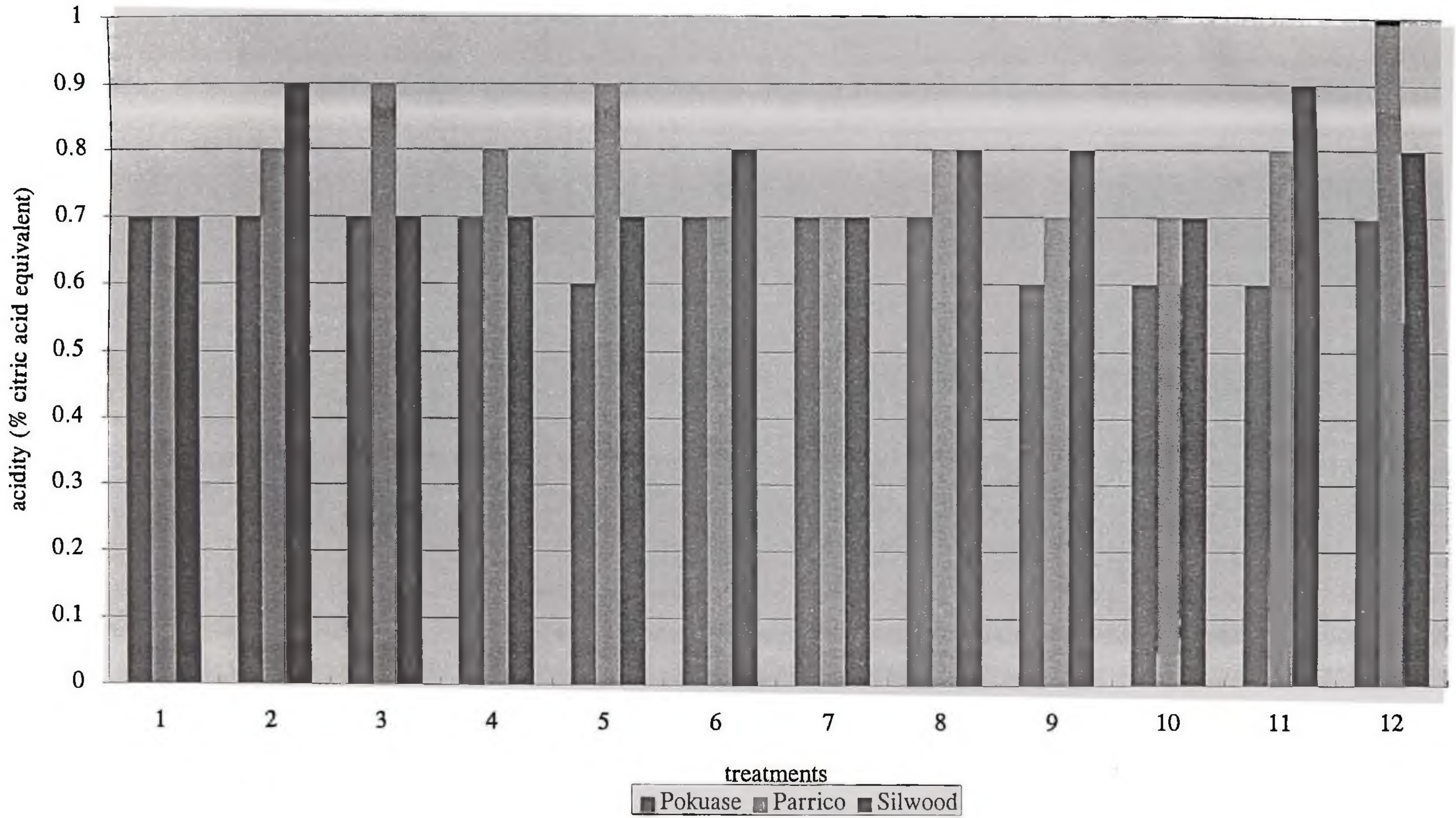
Fig. 12: Mean fruit weight (kg) from the three sites.



Treatments 1 - 6 = N/K fertilizer ratios + P(0 kg/ha), treatments 7 - 12 =N/K fertilizer ratios + P(50 kg/ha)

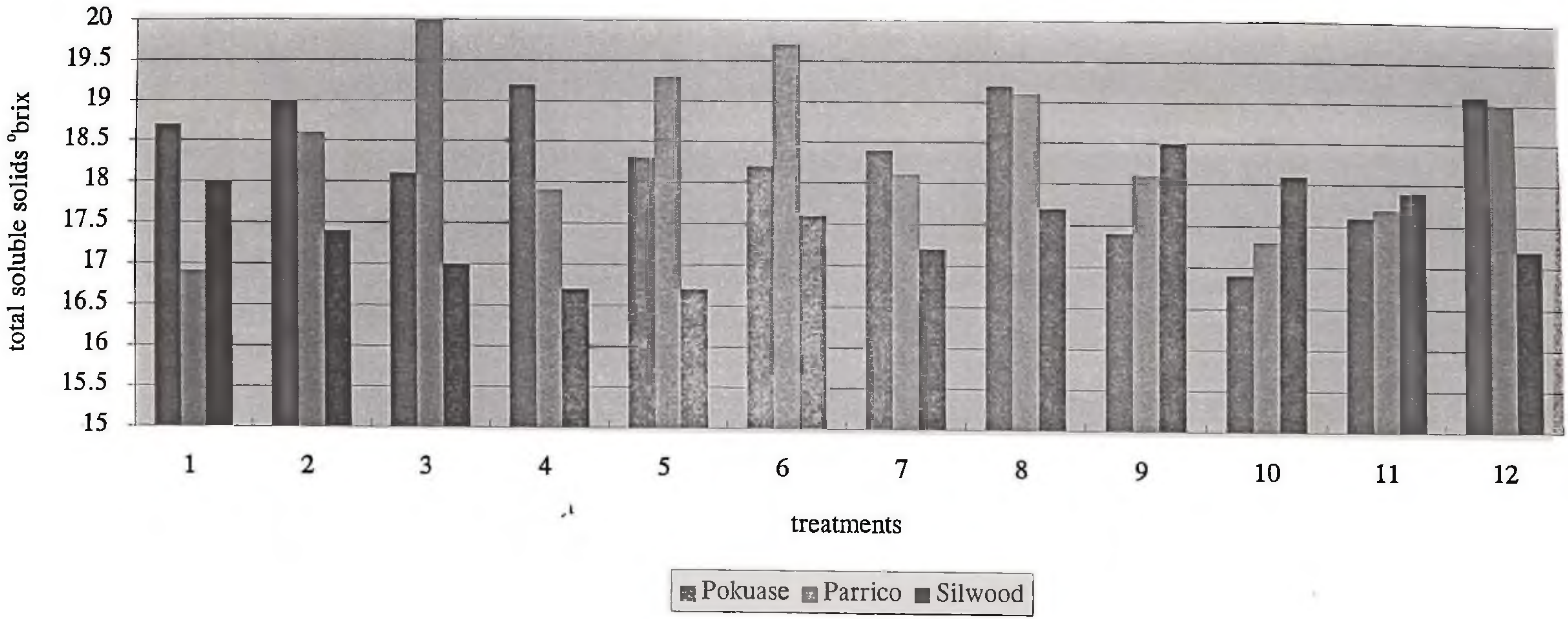
Appendix 1

Fig. 13: Acid content (%citric acid equivalent) of fruits from the three sites



Treatments 1 - 6 = N/K fertilizer ratios + P(0 kg/ha), treatments 7 - 12 = N/K fertilizer ratios + P(50 kg/ha).

Fig. 14: Sugar (total soluble solids, ^{o}brix) content of fruits from the three sites



Treatments 1 - 6 = N/K fertilizer ratios + P(0 kg/ha), treatments 7 - 12 = N/K fertilizer ratios + P(50 kg/ha).