EFFECT OF SHADE ON GROWTH AND FRUITING IN PINEAPPLE

BY

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THESIS

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1979

DECLARATION

I hereby declare that this thesis entitled "Effect of shade on growth and fruiting in pineapple" is a record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara,
10.8.1979.

([illegible])

CERTIFICATE

Certified that this thesis is a record of research work done independently by Kumari T. Radha, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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CONTENTS

			Page
I.	INTRODUCTION	...	1
II.	REVIEW OF LITERATURE	...	3
III.	MATERIALS AND METHODS	...	22
IV.	RESULTS	...	35
V.	DISCUSSION	...	67
VI.	SUMMARY	...	78

REFERENCES

APPENDICES

ABSTRACT

LIST OF TABLES

1. Effect of shading on number of leaves per plant and mean 'D' leaf area.

2. Effect of shading on fresh and dry weights of 'D' leaf.

3. Effect of shading on percentage dry weight of 'D' leaf.

4. Effect of shading on flowering.

5. Effect of shading on the time taken for fruit maturity.

6. Effect of shading on fruit development

7. Effect of shading on yield per hectare.

8a. Effect of shading on fruit characters.

8b. Effect of shading on fruit characters.

9. Effect of shading on fruit quality.

10. Effect of shading on nitrogen content of leaves.

11. Effect of shading on phosphorus content of leaves.

12. Effect of shading on potassium content of leaves.

13. Effect of shading on calcium content of leaves.

14. Effect of shading on magnesium content of leaves.

15. Effect of shading on chlorophyll 'a', 'b' and total contents of leaves.

16. Effect of shading on sucker production and vegetative characters of suckers.

17. Effect of shading on flowering of Ethrel treated plants.

18. Effect of shading on the time taken for fruit maturity of Ethrel treated plants.

LIST OF FIGURES

1. Lay out.

2. Effect of shading on percentage of flowering.

3. Effect of shading on fruit development.

4. Effect of shading on fruit characters.

5. Effect of shading on nutrient status of leaves.

LIST OF PLATES

I. A general view of the field.

II. Variation in fruit size due to shade treatments.

III. Variation in crown size due to shade treatments

IV. Variation in the size of suckers due to shade treatments.

LIST OF APPENDICES

I. Weather data for the period from August, 1976 to July, 1978.

II. Analysis of variance for effect of shading on vegetative characters (six months after planting).

III. Analysis of variance for effect of shading on vegetative characters (one year after planting).

IV. Analysis of variance for effect of shading on vegetative characters (at flowering).

V. Analysis of variance for effect of shading on flowering.

VI. Analysis of variance for effect of shading on time taken for fruit maturity and yield per hectare.

VII. Analysis of variance for effect of shading on fruit characters.

VIII. Analysis of variance for effect of shading on crown characters.

IX. Analysis of variance for effect of shading on fruit quality.

X. Analysis of variance for effect of shading on nutrient status of leaves (six months after planting).

XI. Analysis of variance for effect of shading on nutrient status of leaves (one year after planting).

XII. Analysis of variance for effect of shading on nutrient status of leaves (at flowering).

XIII. Analysis of variance for effect of shading on chlorophyll 'a', 'b' and total contents of leaves.

XIV. Analysis of variance for effect of shading on sucker production and vegetative characters of suckers.

XV. Analysis of variance for effect of shading on flowering of Ethrel treated plants.

XVI. 't' test for comparing the percentage of flowering in Ethrel treated and non treated plants, under different intensities of shade.

INTRODUCTION

INTRODUCTION

Pineapple (*Ananas comosus* L. Merr.) is considered to be one of the most important fruits of the world. In India commercial cultivation of this fruit crop is limited to an area of 12,500 hectares (Chadha *et al.*, 1973), and is largely confined to Assam and Kerala. Large scale cultivation of pineapple in Kerala is mainly as pure crop, although its small scale growing as an intercrop existed in the homesteads from very early times.

With the present trend of growing tree crops like coconut wherever possible, further reduction in the land available for monocropping of pineapple could be anticipated. Commercial cultivation of pineapple as an intercrop in coconut gardens is perhaps the possible solution in order to maintain the supremacy of the State in pineapple production.

Although pineapple is recommended as an intercrop in coconut gardens or in the homesteads, no experiments have been so far conducted in intercropped pineapples to make these recommendations scientific. The present recommendations on crop management have limited application for pineapples grown as an intercrop. Experiments have to be planned to evolve suitable crop management techniques for pineapple grown under shaded or partially shaded conditions. The ultimate success of such experiments depends upon a full understanding of the various aspects of shade tolerance of this crop.

It is with the above objective the present study was initiated in the College of Horticulture, Kerala Agricultural University. The commercially accepted variety 'Kew' grown in large scale in the State was selected for the study. Controlled intensities of shade were provided using coconut fronds on erected pandals mainly with an idea of simulating conditions of shade to the extent possible that prevailed in coconut plantations or in the homesteads. Lower intensities of shade were included to strike the possible shade tolerance limit of pineapple.

The various aspects studied in the present investigation included growth, flowering, fruit development, production, quality of fruits and uptake of major nutrients. The results obtained in the present study is expected to provide basic information on shade tolerance and growth behaviour of pineapple under shade in addition to emphasising the need for intensifying crop management studies on pineapple under shaded conditions.

REVIEW OF LITERATURE

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As early as in 1918, Boysen Jensen as quoted by aeki (1963), elucidated the importance of light factor in plant communities in relation to dry matter production. Acute interest in light relations in plant communities however, developed only during the last two decades. The humidity of the atmosphere and the amount of cloudy weather are the most important factors causing variation in intensity of light. Altitude of the region is also another factor causing variation in light intensity. Shirley (1931) reported that the total radiation received on a cloudy day might be as low as four per cent of that received during the same season in a particular station during a day of full sunshine.

Black and Edelman (1971) brought out the effect of light intensity on plant growth. The plants growing in darkness were spindly with greatly elongated internodes, small leaves and a hooked apical bud having a more chlorotic colour due to reduction in chlorophyll. In contrast to these features, the light grown plants were green with sturdy, shorter internodes, expanded leaves and upright apex. Intensities of light in between the two above mentioned extremes, viz., open and darkness, also have a great influence on plant growth and development.

Comparatively very little work has been done on the effect of shading on fruit crops and practically no detailed work has been done in pineapple. The various aspects of light and shade effects on plants with special reference to fruit crops are reviewed hereunder.

1. EFFECT ON VEGETATIVE CHARACTERS

Rolfs (1903) conducted shading experiments on pineapple and citrus. He reported that in pineapple longer and more deeply coloured leaves were produced under shade, but the number of leaves produced per plant did not vary in shade and in open. He also noticed the increased occurrence of thorny leaves in plants grown in the open and deposition of a red colouring matter in them which was totally absent under shade. Citrus plants grown under 50 per cent shade, developed thinner leaves with a greater leaf area but with considerably reduced total leaf area per plant.

Duggar (1903) studied and reported the general effects of shading on plants. Plants under shaded conditions exhibited increased growth of the main axis, reduced number of branches, lessened development of woody fibre and deficiency in sugars and various carbohydrates. He also found that acidity increased with shading, provided the plants had abundant supply of carbohydrates. Clark (1905) observed that for leaf development, low intensity of light was most favourable and intense light caused decreased leaf growth resulting in smaller and thicker leaves. Lazenby (1906) noticed increased leaf area in the case of salad crops such as tomato, cabbage and lettuce under shaded conditions. Gourley (1920) reported that in apples, shading resulted in the production of loosened mesophyll tissues and thinner epidermal cells in leaves and in increased leaf area. Peaches under shade produced less number of branches which were willowy and slender. Gourley and Nightingale (1921) reported that apple leaves averaged about 224 per cent greater in area when grown under 15 per cent light intensity than those developed in full sunshine.

Kraybill (1922) observed higher contents of moisture and nitrogen in shaded apple leaves. Vinson (1923) brought out the effects of shading on a number of horticultural plants such as apple, peaches, cherry, currant, strawberry, tomato, radish, potato and geranium. Slender stem, greater length of internodes, leaves with larger area and smaller cross sections, increased moisture content and higher ratio of nitrogen to carbohydrates were all reported by him as results of shading plants. Johonnson (1926) as quoted by Gardner et al.,(1952) stated that light was the most important environmental factor modifying the daily opening and closure of stomata. According to Weaver and Clements (1929) partial shade was useful to increase the succulence and delicacy of plant structures. Crocker (1949) stated that light quality and not the intensity decided the morphological characters of plants. However, according to Thomson and Miller (1963) light intensity had influence on cell enlargement and differentiation and thus influenced height, growth, leaf size and the structure of leaves and stems of plants.

Beinhart (1963) studied the effects of temperature and light intensity on the growth of clover in growth chambers. His conclusions were that, increased light intensity resulted in greater growth, increased branching and in turn greater leaf area production. Light intensity had no influence on the mean number of leaves produced per plant. Edmond et al., (1964) noticed the production of thinner leaves by shaded apple trees and they concluded that the thickness of leaves in open condition was due to the increased production of palisade tissues in the leaves. Einert and Box (1967) noticed greater stem elongation under 50 and 75 per cent intensities of light in *Lilium longiflorum*.

Holmgren (1968) reported that higher intensities of light during the growth of plants generally increased the stomatal frequency, but there were no significant changes either in the length of the stomatal pore or in the size of the guard cells. Bjorkman et al., (1972); Goodchild et al., (1972) and Charles-Edwards and Ludwig (1975) also reported similar effects of shading on the stomatal characters.

Tibbitts and Rao (1968) found that tipburn of leaves in lettuce plants was severe under high light intensity conditions. According to them, high intensity of light increased photosynthesis, growth rate and dry matter accumulation leading to the rupture of the laticifers. Wassink (1969) found that in Iris, the leaves were altered in length and breadth as the intensity of light rose but the surface area was little affected. Anatomical studies of shaded leaves showed that the growth of the vascular bundles was less influenced by the intensity of light. Jackson and Beakbane (1970) reported that in Coxs' Orange Pippin apple, leaf thickness was closely correlated with the level of illumination under which the leaf was growing.

Miroi et al., (1970) explained the effects of different intensities of light on Aphelandra squarrosa. Taller plants were produced under 30, 16 and 10 per cent of full sunlight and the stems were thinnest at 5 per cent. The weight of leaf was highest at 30 and 16 per cent light and the largest leaf area was associated with 16 per cent light intensity. Leaves were found to last longer on shaded plants and they were greenish in colour and smooth surfaced in contrast to the rough, greenish yellow coloured leaves in unshaded plants. In deeply shaded plants the root system was relatively small in relation to the proportion of leaf. Khossein (1970) noticed reduction in the leaf pigment content and depression in growth at high intensity of light in the case of bean plants. Kaname and Yagi (1970) showed that in cucumber, shading upto 50 or 73 per cent by black cloth did not affect stem length, leaf size and number of leaves, but reduced stem diameter, leaf weight and leaf dry matter production. Shading also depressed the number of lateral shoots. Webster and Crowe (1971) noticed increased length to diameter ratios of stems and decreased stem cavity depths in the case of shaded McIntosh apple. Frets and Durham (1971) reported that American Holly plants (_Ilex opaca_) exhibited higher amounts of potassium and magnesium in leaf tissues when the plants were grown at 92 per cent shade but the stem diameter got reduced under shade. Leaf size of plants under 50 and 92 per cent shades was found to increase. Guers (1971) reported that in cocoa, leaves exposed to direct sunlight were smaller, thicker and contained less moisture and nitrogen than shaded leaves.

Hilis and Stanko (1972) found that in Bigonia and ornamental cabbage, the red colour of the leaves was reduced by light shading i.e., 60-70 per cent full sunlight. Cripps (1972) noticed reduced root growth, root/shoot ratio and leaf weight per unit area in shaded Granny Smith apples. He also found that the weight of shoots increased slightly under relatively light shading viz., upto 30 per cent. Reduction in the accumulation of starch especially in the underground parts was another effect of shading. Cantliffe (1972) found that in spinach, the concentration of potassium in the tissues increased as reduction in the light intensity occurred. In the case of American Holly plants, Fretz and Dunham (1972) reported that shading resulted in a significant increase in leaf area and green colour of the leaves. Rodriguez et al., (1973) noticed that shade levels had little effect on the leaf nutrient content of Dracaena plants, except that high shade intensity increased potassium and magnesium especially in young leaves.

Streitberg and Hoffmann (1973) studied the effect of reduced light intensity on apple trees, by covering them with nets and they observed longer internodes and increased total shoot length under reduced intensities of light. In a 30 year old Trinitario cocoa plantation, the flushing intensity, leaf number and total foliar surface per tree were greater in unshaded trees than in those under light or moderate shade. Cambial activity measured as girth increment was also greater in unshaded trees (Boyer 1974).

Anan and Nakgawa (1974) analysed the shoots from shaded and unshaded plants in tea and they observed that total nitrogen, amino acids and caffeine of newly shaded shoots increased at first and later decreased, whereas that of shoots from unshaded plants decreased during the whole period. The aspartic acid content of shoots of shaded plants remained unchanged but fell in unshaded plants. Free reducing sugar content in shaded shoots remained unchanged but that in shoots from unshaded plants rose gradually.

Differential response of apple varieties to decreased light intensity conditions was noticed by Streitberg (1975). Barden (1977) reported that Delicious apple trees exhibited suppressed shoot growth and increased dry weight under 60 per cent shade provided by saran cloth or slats. But shading was not found to influence the leaf area of plants in this experiment. Jackson and Palmer (1977) studied the effect of shading on Coxs' Orange Pippin apple and found that shading decreased the number and weight of new shoots, the fresh weight per unit length of shoot, girth increment, leaf thickness and weight per unit area. He also noticed increased concentrations of potassium and magnesium in the leaves of shaded plants. Boardman (1977) described general effects of shading on plants. According to him, leaves of shaded plants were thinner showing poor development of palisade tissues and spongy mesophyll cells.

2. EFFECT ON CHLOROPHYLL CONTENT, PHOTOSYNTHESIS AND DRY MATTER ACCUMULATION

Generally, certain optimum intensity of light was found to be necessary for chlorophyll production in plants (Clark, 1905). He found that direct sunlight of high intensity was resulting in destruction of chlorophyll and this effect was noticed clearly in strawberry plants during summer months in Arizona. Shirley (1929) as quoted by Gardner et al., (1952), reported that in general the concentration of chlorophyll per unit area or weight of leaf increased with decreasing light intensities until the intensity was so low that it hazarded survival of the plants. Priestly (1929) stated that the chloroplasts in leaves would undergo changes in position according to the differences in light intensity. He pointed out that in leaves of plants grown under lower light intensities, the plastids were limited in number and they were arranged at right angles to the light rays and were larger in size thus increasing the area for light absorption. Smith et al., (1931) found that in tomato, fruits ripening in total darkness did not develop any chlorophyll. Increased chlorophyll contents in the leaves of shaded plants were reported by Evans and

Murray (1951) and Guers (1971) in cocoa; Ramaswamy (1960) and Venkataramani (1961) in tea; Misra *et al.*, (1968) in bougainvillea; Frydrych (1970) in lettuce; Cappellini and Monastra (1971) in peaches; Shimizu and Torikata (1972) in Satsuma orange and Tanslew (1976) in apple. Bjorkman and Holmgren (1963) reported that leaves of plants grown at lower light intensities contained more chlorophyll per unit weight or per unit volume of leaf, but the chlorophyll content per unit area of leaf surface was very often lower than that of open grown leaves.

Fewer number of chloroplasts which were larger in size, containing more chlorophyll were noticed in leaf sections of shade plants by Bjorkman *et al.*, (1972). Ikeno (1974) found that shading resulted in thicker grana in chloroplasts of apple leaves. Tsankov *et al.*, (1976) observed the occurrence of less number of chloroplasts but at the same time larger in size in shaded leaves of grapes.

Shading either partial or complete was found to reduce the CO_2 assimilation and thereby the available constructive material for plants (Duggar, 1903). Shirley (1936) as quoted by Gardner *et al.*, (1952), reported that generally with increasing light intensities, there would be an increase in the per cent dry matter in trees. The difference in photosynthetic rate was suggested as an explanation of differences in the tolerance of different species for shade and light (Gardner *et al.*, 1952). Kursanov (1956) stated that the direct products of photosynthesis were dependent on illumination, age and nutrition of the plants.

Nelson (1963) observed in *Pinus strobus* that low light intensity during the translocation period had little or no effect on translocation. He ultimately concluded that light intensity had no influence on the movement of materials through the stem or on activity of the roots but rather on the physiological state of the shoots. Gastra (1963) found a linear relationship between photosynthesis and light intensity at low intensities. Edmond *et al.*, (1964) reported that in apple, the rate of photosynthesis increased with increasing light intensity upto full sunlight. Misra *et al.*, (1968) observed increased dry matter production in the unshaded leaves of bougainvillea plants.

Wassink (1969) compared the photosynthetic efficiency of Iris plants grown at 12 per cent and 100 per cent daylight. He observed that the photosynthetic efficiency decreased with diminishing light intensity. He also noticed that an eight fold increase (12 to 100 per cent) in light intensity only resulted in trebled dry weight of leaves. Misko (1970) reported that in apple, low light intensity resulted in reduced photosynthetic rates. In kohl-rabi plants also similar was the case as reported by Frydrych (1970). In contrast to these reports, Logan (1970) observed an increased rate of photosynthesis under conditions of low light intensity in the shaded leaves of yellow birch plants (*Betula alleghaniensis*).

Karnatz (1971) reported that in black current seedlings, higher light intensity resulted in dry matter increases of 40 per cent in leaves, 107 per cent in stems and 164 per cent in roots. However, in coffee seedlings the best growth in terms of dry matter production was obtained with 50 per cent light (Silveira and Maestri, 1973). Barden (1977) reported that in Delicious apple, net photosynthesis of shaded leaves was only 70 per cent of that of unshaded leaves. Dark respiration rates were also higher in unshaded than in shaded leaves.

3. EFFECT OF SHADING ON FLOWERING

In the process of flower bud initiation and differentiation, the length of the light period (photoperiod) plays the most important role, rather than the intensity of light. Clark (1905) stated that flower bud formation was a process which required relatively higher intensities of light. However, earlier reports by Duggar (1903) pointed out that flowers might develop on plants exposed to partial light also, but generally in such case it would be delayed considerably. Gourley (1920) observed that shaded geranium, nasturtium and tomato plants put forth only few blossoms compared to those in the open. Kraybill (1922) reported that in apple and peaches, shading resulted in decreased fruit bud formation and he associated this with an increase in moisture and total nitrogen and a decrease in free reducing substances, sucrose and starch. Vinson (1923) observed that fruiting in plants like apple, peaches, cherry, currant, strawberry, tomato, radish, potato and geranium averaged uniformly less under shaded conditions except in raspberry. Weaver and Clements (1929) pointed out that a half shade was employed in forcing rhubarb and in pineapple culture, especially in Florida.

Einert and Box (1967) reported that light intensity of 75 and 50 per cent during the forcing period had no effect on flower bud abortion, bloom size or forcing time of Lilium longiflorum. However, 50 per cent light intensity resulted in decreased number of flower buds and 75 per cent had no effect on initiation of flower buds. Buttrose (1969a) observed that in grapes, an increase in light intensity resulted in an increase in both the number and the size of fruiting primordia. Hiroi et al., (1970) reported that in Aphelandra squarrosa plants, flower bud formation was dependent on light intensity and did not occur on the more shaded plants. Guyot and Py (1970) stated that the presence or absence of light had no effect on the flowering response of Ethrel in pineapple. Kaname and Yagi (1970) observed that in cucumber 50 and 75 per cent shading lowered the proportion of female flowers. Pears and Peaches when shaded by nets to provide 25 and 75 per cent light produced considerably lower number of flowers only (Cappellini and Monastra, 1971). However, in _Ilex opaca_, flower production was reduced only under very heavy shading (92 per cent) as reported by Frets and Dunham (1971). Boula _et al_., (1973) provided three different levels of shading viz., 25, 50 and 75 per cent for anthuriums. The greatest number of flowers were produced with the least shading, but flower quality was better under heavy shading. Buttrose (1974) observed reduced number of flower buds initiated in shaded grapes and other horticultural plants like apple, peaches, pear apricot, blue berry, cocoa and coffee. However, Boyer (1974) reported that in cocoa, the number of flowers per tree was 60 to 70 per cent more in moderately shaded trees than in unshaded ones.

Streitberg (1975) stated that in apple, the effect due to reduction in light intensity even upto 26 per cent on flowering, fruit growth and yield was not so great.

Low light intensity reduced flowering in Carola variety, but at the same time in cv. Elektra increased flowering was noticed. Dikan (1976) reported that solar radiation directly affected the initiation and differentiation of floral parts in grape vines. Jackson and Palmer (1977) also observed reduced flower bud formation in apple by shading.

4. EFFECT OF SHADING ON YIELD AND QUALITY OF PRODUCE

Shading experiments conducted on pineapples and citrus by Rolfs (1903) revealed that generally, shading was favourable for pineapple and was unfavourable for citrus. Pineapple produced 25 per cent increased yield under shade whereas in citrus, yield was reduced considerably but the quality was the finest under shade. Duggar (1903) pointed out that partial shading was one of the factors favouring improved texture and quality of the produce. Clark (1905) reported that the sugar content in plants was dependent on the intensity of illumination and he observed that in beets and sorghum, development of sugar was in proportion to the intensity of illumination. Lasenby (1906) reported that the period for seed production was very much hastened in certain salad crops such as lettuce, cabbage and tomato under shade and also bulbous plants went to seed very much earlier under shade than in open. Overholser (1917) observed that in fruit crops like apples, pears, peaches and apricots exclusion of light from fruits resulted in the complete absence of colour development. Caldwell (1925) as quoted by Gardner et al., (1952) reported that in grapes the amount of sunshine received during the growing season was very important in determining the sugar, acid and the astringent contents of the berries.

Smith et al., (1931) observed that bagged peach fruits developed a higher carotenoid content than the unbagged. In tomato, the carotenoid content was higher in the unbagged fruits of red fleshed varieties, but reverse was the condition in the case of yellow fleshed varieties. In all the varieties tried except one, a higher pH in the case of bagged fruits than the unbagged ones was noticed.

High intensity of light favoured high quality and large size in fruits like apple (Weaver and Clements, 1929). High intensity of light had also been cited as favouring fruit and seed production in a number of forest tree species (Shirley, 1932). Harding et al., (1938) observed higher ascorbic acid contents in orange fruits which were well exposed to sunlight than those were shaded. Surface scalding of the fruits of apple, pear and gooseberry had been reported as due to high light intensity by Thut and Loomis (1944). Gardner et al., (1952) stated that fruit setting in the Delicious apple was closely correlated with the gram-calories of radiant energy received during a period of two to three weeks immediately following blossoming. Hayes (1957) suggested that a half shaded condition might be useful and favourable for successful pineapple culture. Collins (1960) explained that in pineapple a very low percentage of sunlight would retard the plant growth and result in small fruits of poor quality, particularly lacking in sugars.

Edmond et al., (1964) conducted shading experiments in tomatoes, providing shade by nylon and muslin clothes. Maximum yield was obtained from plants receiving only 45 per cent of full sunlight and they explained the reasons for low yield under increased light in three ways viz., (1) concerning with the chlorophyll content (2) concerning with the water supply or (3) concerning with enzyme activity.

Kolesnikov (1964) reported that in fruits such as apple, peaches and pears high intensity of light favoured high quality. He observed a 20 to 65 per cent reduction in the yield of interplanted orchard crops such as soft fruits and vegetables due to insufficient lighting in the shade of the trees. Al-rawi (1969) brought out the effects of light intensity on the quality of apple fruits and found that the anthocyanin content of the fruit was correlated positively and the chlorophyll and acid contents negatively with lighting during the vegetative period. Better illuminated fruits contained more soluble solids also. Khossein (1970) reported that in beans, the plant productivity was higher in plants grown in open than those under diffused light. Cartechini and Tombesi (1970) found that in grapes reduction of light intensity by 10 per cent considerably lowered the sugar content of berries. Shading the bunches only, without shading the leaves lessened colour production of berries but not influenced the sugar content of berries.

Maname and Yagi (1970) observed delayed and significantly reduced yields in cucumber when shaded. Chujo (1971) reported that in persimmon the proper red colour development of fruits required only 25 - 30 per cent of normal daylight and lycopene was the most affected pigment by light intensity. Sistrunk and Moore (1971) reported reduced amounts of ascorbic acid, soluble solids, total solids and citric acid in strawberry under shaded conditions. Shading also lowered the pH and reduced the redness of fruits in strawberry. In Coxs' Orange Pippin variety of apple shaded fruits were smaller in size and possessed a decreased ratio of Ca to K (Jackson et al., 1971). Fretz and Dunham (1971) provided 50 per cent and 92 per cent shades to American Holly plants and found that soluble D-fructose, α.D-glucose, β.D-glucose and sucrose levels were not affected by shading but at the same time D-galactose increased in shaded plants. Webster and Crowe (1971) observed an increased length to diameter ratio in shaded apple fruits. In sweet cherry fruits covered with aluminium foil bags, the soluble solids content was found to be much less than that of exposed fruits (Hyugo and Intrieri, 1972).

Boyer (1974) stated that in cocoa, the fruit set was related positively to rainfall and negatively to temperature and radiation. Johnson and Peterson (1974) observed that in pineapple top quality fruits were produced under conditions of abundant sunshine. Iyer *et al.*, (1976) noticed that exposed fruits of mango possessed increased fruit weight, higher percentage of edible matter, higher [illegible] and better ratios of glucose to fructose and sugar to acid contents.

Dikan (1976) provided artificial shades for the buds of grape and found that shading depressed fruitfulness. Reduced fruit size and fruit-let retention were resulted by shading in apple (Jackson and Palmer, 1977). Jackson *et al.*, (1977) reported that shading reduced fruit size, colour and the degree of skin cracking in apple. Fruits grown under shade had less dry matter and starch per unit fresh weight and lower rates of ethylene and CO_2 production per unit weight at harvest. Shading was found to have no effect on the concentration of N, P, K, Ca and Mg in the fruits. Kliewer (1977) observed decreased soluble solids and anthocyanin contents in Emperor grapes by shading upto 15 per cent. However, brix values were not found to be influenced by the intensity of shade.

MATERIALS AND METHODS

MATERIALS AND METHODS

The investigations were carried out in the College of Horticulture, Vellanikkara, during the years 1976-'79 to study the growth and fruiting behaviour of pineapple variety 'Kew' under different intensities of shade.

Uniform suckers with 14 to 20 leaves were used for planting in August 1976. The shading was given after the suckers were established, in October 1976. The trial was laid out in randomised block design with four treatments and five replications. Each treatment consisted of two hundred plants with 40 plants per replication, planted in two trenches of two rows each with a spacing of 90 cm between trenches, 60 cm between rows and 30 cm within the row. All the plants received uniform cultural and manurial practices throughout the course of the study as per the recommendations of Kerala Agricultural University. The duration of the plant crop on which the observations were made was 21 months i.e., from August 1976 to April-May 1978.

The treatments were as follows:

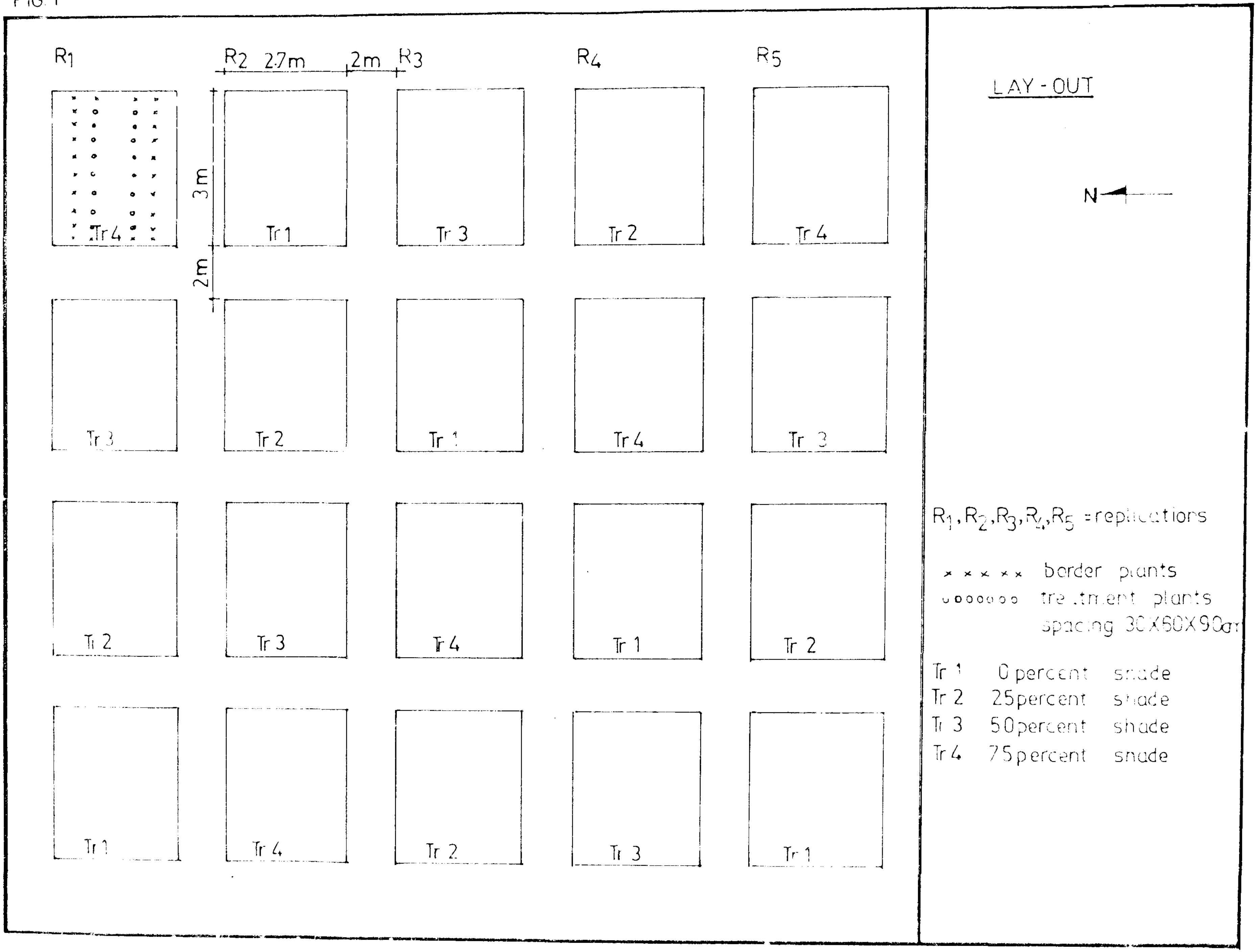
Treatment 1	0 per cent shade (open)
Treatment 2	25 per cent shade
Treatment 3	50 per cent shade and
Treatment 4	75 per cent shade

Artificial shading to the desired level was obtained by placing coconut leaves on erected pandals. Pandals were individually erected for each treatment plot by fixing wooden reapers on posts. Sufficient space was provided between the treatments so that mutual shading of plants was minimised to the extent possible. The rows were in east-west direction in all the plots. Coconut leaves were used as shading material to simulate more or less the conditions that existed in coconut plantations. An 'Aplab' Lux meter was used for adjusting the light intensities. Frequent checks were made throughout the course of the experiment to maintain the shade intensities as per the design of the experiment. The trial was intended not to study the performance of pineapple under different well defined ranges of light intensities but to evaluate the growth and fruiting habits under different shade conditions that might prevail in a multiple cropping system.

Field observations consisted of the vegetative, flowering and fruiting characters of the plants. The details of the observations and the time intervals at which they were made are given elsewhere.

Eighty plants from each treatment consisted the sample for recording the morphological and fruit characters.

FIG. 1



R1
R2
2.7m
2m
R3
R4
R5
LAY-OUT
3m
2m
N
Tr 4
Tr 1
Tr 3
Tr 2
Tr 4
Tr 3
Tr 2
Tr 1
Tr 4
Tr 3
Tr 2
Tr 3
Tr 4
Tr 1
Tr 2
Tr 1
Tr 4
Tr 2
Tr 3
Tr 1
R1, R2, R3, R4, R5 = replications
border plants
treatment plants
spacing 30X60X90cm
Tr 1 0 percent shade
Tr 2 25 percent shade
Tr 3 50 percent shade
Tr 4 75 percent shade

The plants selected for recording observations in a treatment were from the inside rows. The outside rows were kept as border plants (Fig 1 and Plate I).

The following observations were recorded.

1. VEGETATIVE CHARACTERS

The observations on vegetative characters of the suckers were recorded at three intervals viz., six months after planting, one year after planting and at the time of flowering.

1.1 Leaf number

The number of leaves produced per plant was recorded at the three stages of growth mentioned earlier.

1.2 'D' leaf area

The length and breadth of 'D' leaf i.e., 5th leaf from the top of the plant were taken and 'D' leaf area was worked out using the formula, length x breadth x 0.725 (Balakrishnan *et al*., 1978)

1.3 Percentage dry weight of 'D' leaf

The 'D' leaves from plants marked in different treatments were pulled out at three stages of growth mentioned earlier, and their fresh and dry weights recorded individually. The dry weights were obtained by keeping the 'D' leaves in an air oven at 80°C till constant weights were obtained. From the fresh and dry weights, percentage dry weight of 'D' leaf was worked out.

2. FLOWERING CHARACTERS

2.1 Number of days taken for flowering

The date of emergence of inflorescence was recorded when the inflorescence just emerged out of the heart of the plant and number of days taken from planting to the emergence of inflorescence under each treatment was worked out.

2.2 Percentage of flowering

The percentage of flowering was recorded at weekly intervals commencing from the emergence of the first inflorescence until flower emergence in the treatments was completed for the particular season.

3. FRUIT CHARACTERS

3.1 Time taken for maturity of fruit

The time taken for fruit maturity in terms of the number of days from the emergence of inflorescence to harvest was recorded for each treatment. The harvesting of fruits was done when basal 1/3 portion of them turned yellowish in colour.

3.2 Fruit development

To study the fruit development under different treatments, ten inflorescences from each treatment were separately tagged. The length of fruit and the girth at the middle were recorded at fortnightly intervals till the values became constant. The measurement of fruits started on 45th day after flowering.

3.3 Fruit weight

The fruit weight with and without crown was recorded immediately after harvest.

3.4 Fruit length and breadth

The length of the fruit and the breadth at the middle were recorded for every treatment.

3.5 Crown weight and crown leaf number

The crowns detached from the fruits were weighed separately. The number of leaves on the crowns was counted for each treatment.

3.6 Canning ratio

Canning ratio was worked out by dividing the length of fruit by the breadth at the middle portion (Pantastico, 1975).

3.7 Peel weight

The fruits were peeled carefully and the weight of peel was recorded for each treatment.

3.8 Pulp weight

After removing the peel and the central core of the fruit, the weight of the pulp was recorded for each treatment.

3.9 Peel/pulp ratio

This ratio was worked out by dividing the weight of the peel by the weight of pulp per fruit for each treatment.

3.10 Weight of core

The weight of the core per fruit was recorded for each treatment.

4. QUALITATIVE ANALYSIS

The fruits were analysed for total soluble solids, acidity, ascorbic acid, reducing sugars, nonreducing sugars, total sugars and sugar/acid ratio. The methods in detail are given under section 8.

5. LEAF ANALYSIS

The nutrient status of the leaves was estimated at three intervals viz., six months after planting, one year after planting and at the time of flowering.

The chemical analysis for the determination of N, P, K, Ca and Mg was carried out.

During the summer months (February-April), a striking difference was noticed in the intensity of green colour of leaves between shaded and unshaded plants. Therefore leaf samples were collected during March 1979 and analysed for chlorophyll content. Chlorophyll 'a', 'b' and total were estimated.

The methods in detail are given under Section 9.

6. SUCKER PRODUCTION

6.1 Number of suckers per plant

Number of suckers produced per plant was recorded for each treatment after the fruits were harvested, in July.

6.2 Height of suckers

The height of suckers produced under each treatment was measured, when they were three months old.

6.3 Number of leaves per sucker

The number of leaves produced by each sucker was recorded after three months of their production for each treatment.

6.4 'D' leaf area of suckers

The length and breadth of 'D' leaf of suckers were recorded and the leaf area was worked out as per procedure indicated earlier.

6.5 Percentage dry weight of 'D' leaf of suckers

The fresh and dry weights of 'D' leaf of suckers were recorded as done in the case of mother plants and the percentage dry weight of 'D' leaf was worked out.

7. INDUCTION OF FLOWERING BY ETHREL UNDER DIFFERENT INTENSITIES OF SHADE

In order to find out the effect of Ethrel, a flower inducing agent commonly used in pineapple, under different intensities of shade, application of this growth regulator was made on 50 plants under each treatment, when the suckers were seventeen months old. The suckers at this stage possessed 25 to 30 leaves. The concentration of Ethrel used was 500 ppm applied at the rate of 50 ml per plant by pouring into the heart of the plant.

The observations recorded consisted of the number of days taken for flowering, percentage of flowering and the time taken for maturity of fruits.

8. METHODS OF QUALITATIVE ANALYSIS OF FRUITS

The fruits for qualitative analysis were harvested when they were fully mature as indicated by the yellowish colour that developed at the basal 1/3 portion. Four fruits from each replication were collected for analysis. Samples were taken from each fruit from three portions viz., top, middle and bottom and these samples were then pooled and macerated in a warring blender. Triplicate samples from this were used for different analysis.

8.1 Total soluble solids

Total soluble solids were found out by a pocket refractometer and were expressed as percentage.

8.2 Acidity

Ten g of the macerated sample was digested with boiling water and made up to a known volume. An aliquot of the filtered solution was titrated against 0.1 N sodium hydroxide using phenolphthalein as indicator. The acidity was expressed as percentage of citric acid (A. O. A. C., 1960).

8.3 Ascorbic acid

A known quantity of the pooled sample of the fruit was macerated in a mortar by adding small quantities of two per cent oxalic acid and then filtered and made up to a known volume. An aliquot of the extract was taken to which an equal volume of two per cent oxalic acid was added. The content was titrated against a standardised solution of 2, 6 - dichlorophenol indophenol dye. The ascorbic acid content of the juice was then calculated and expressed as mg/100 g of the pulp (A.O.A.C., 1960).

8.4 Reducing sugars

The reducing sugars of the sample were determined as per the method described by A. O. A. C. (1960)

To a known quantity of macerated pulp, distilled water was added. The solution after thorough mixing was clarified with neutral lead acetate and deleaded with sodium oxalate and made up to known volume. The solution was then filtered and an aliquot of this solution was titrated against a mixture of Fehling's A and B solutions, using methylene blue as indicator. The reducing sugar was expressed as percentage.

8.5 Total sugars

Total sugars were determined as per the method described by A. O. A. C. (1960). Five ml of concentrated hydrochloric acid was added to a known volume of clarified solution and the same was kept overnight. The solution was then neutralised by adding sodium hydroxide and titrated against a mixture of Fehling's A and B solutions.

8.6 Non-reducing sugars

Non-reducing sugars were obtained by the method of difference between reducing sugars and total sugars estimated.

8.7 Sugar/acid ratio

The sugar/acid ratio was worked out from the percentages of sugar and acid obtained.

9. METHODS OF LEAF ANALYSIS

In order to find out the nutrient constituents of leaf, analysis were carried out for N, P, K, Ca and Mg. For analysis the basal non chlorophyllous section (Godfrey, 1970) of the 'D' leaf was taken. The samples were dried and powdered in a Wiley Mill and stored in stoppered bottles till use.

.1 Nitrogen

A sample of 0.1 g of the powdered material was digested in concentrated sulphuric acid and nitrogen content was estimated by microkjeldahl's method (A. O. A. C. 1960).

.2 Phosphorus

One g of the ground sample was digested in 1:2:9 concentrated perchloric acid: sulphuric acid: nitric acid mixture and made up to a volume of 100 ml with distilled water and filtered. Phosphorus in 10 ml of this extract was determined colorimetrically using vanadomolybdophosphoric yellow colour method (Jackson, 1958).

.3 Potassium

Potassium in an aliquot of the triple acid extract of the sample was determined using a flame photometer (Jackson, 1958).

.4 Calcium

Calcium in an aliquot of the triple acid extract of the sample was determined by versenate titration method after the removal of interfering ions, as described by Jackson, 1958.

9.5 Magnesium

The content of magnesium was estimated by subtracting the content of calcium from the content of calcium plus magnesium estimated by versenate titration method (Jackson, 1958).

9.6 Chlorophyll

Chlorophyll 'a', 'b' and total of the leaf samples were estimated by the spectrophotometric method as adopted by Ranganna (1977).

A representative sample of the fresh 'D' leaf was taken from the different portions of the fresh leaf by taking leaf punches. To a 5 g sample, a small amount of calcium carbonate was added. The tissue was extracted with acetone (85 per cent) in a mortar using purified quartz sand. The supernatant liquid was decanted and the extraction was repeated till the residue became colourless. The extract was filtered and made up to 100 ml in a volumetric flask.

Fifty ml of ether was taken in a separating funnel and 50 ml of acetone extract was pipetted into the ether. Water was added from the sides of the separating funnel till the water layer was apparently free of all the fat soluble pigments. The water layer was drained off and the ether layer was again washed with distilled water for 5 to 10 times. The ether extract was then transferred to a 100 ml volumetric flask and made up to the volume with ether and mixed.

The solution was then taken in an amber coloured reagent bottle and 3 g of anhydrous sodium sulphate was added to the solution. An aliquot of the clear solution was then pipetted out and used for reading the optical density in a spectrophotometer. The optical density was read at two different wavelengths viz., 642.5 mμ and 660 mμ and the contents of chlorphyll 'a', 'b' and total were estimated and expressed as percentage.

10. STATISTICAL ANALYSIS

The data on different characters studied were subjected to statistical analysis, following the methods of Snedacor and Cochran (1967). The mean values were worked out for different parameters. All the characters of different treatments were analysed by the analysis of variance technique. Critical differences were calculated for the comparison of treatments.

In order to compare the flowering percentages obtained among the Ethrel treated and nontreated plants under different shade treatments, 't' test was done.

RESULTS

RESULTS

1. VEGETATIVE CHARACTERS

The mean leaf number per plant, 'D' leaf area, fresh and dry weight of 'D' leaf and the percentage dry weight of 'D' leaf at three stages of growth, viz., six months after planting, one year after planting and at the time of flowering are presented in Tables 1, 2 and 3.

1.1 Mean number of leaves per plant

The treatments did not show any significant difference in respect of number of leaves per plant, at all the three stages.

1.2 'D' leaf area

During the first stage of observation, Treatment 1 (0 per cent shade) resulted in significantly smaller 'D' leaf area production than the other three treatments which were on par. The difference in 'D' leaf area was more perceptible in the later stages, Treatment 4 (75 per cent shade) and Treatment 3 (50 per cent shade) recording significantly higher values than Treatment 2 (25 per cent shade) and Treatment 1 (0 per cent shade).

1.3 Fresh and dry weight of 'D' leaf

With respect to the fresh weight of 'D' leaf, it was found that although Treatments 3 and 2 resulted in greater values during the first stage of growth than Treatments 1 and 4, during the second stage of observation,

Table 1. Effect of shading on number of leaves per plant and mean 'D' leaf area.

Treatments	Mean leaf number/plant			Mean 'D' leaf area (sq.cm)		
	a	b	c	a	b	c
1. 0 per cent shade	17.72	26.42	29.99	151.18	321.32	339.5
2. 25 per cent shade	19.52	26.57	31.09	216.68	350.45	374.01
3. 50 per cent shade	20.25	28.35	29.10	225.88	360.82	393.09
4. 75 per cent shade	19.54	26.25	29.44	210.36	379.59	404.06
C.D (5%)	NS	NS	NS	49.03	37.93	16.79
S.Em	0.69	0.84	1.52	15.97	12.36	5.47

a - six months after planting
b - one year after planting
c - at flowering

Table 2. Effect of shading on fresh and dry weights of 'D' leaf

Treatments	Fresh weight of 'D' leaf (g)			Dry weight of 'D' leaf (g)		
	a	b	c	a	b	c
1. 0 per cent shade	21.56	41.52	43.85	2.62	5.86	6.34
2. 25 per cent shade	28.63	44.41	47.63	3.26	6.47	6.62
3. 50 per cent shade	28.77	42.97	47.95	3.34	6.00	6.19
4. 75 per cent shade	24.14	47.36	51.45	2.92	6.01	6.52
C.D (5%)	5.76	NS	3.79	0.52	NS	NS
S. Em	1.88	2.29	1.23	0.17	0.32	0.20

a - six months after planting
b - one year after planting
c - at flowering

there was no significant difference between the treatments. However, at the time of flowering there existed significant variation among the treatments in respect of fresh weight of 'D' leaf. At this stage, Treatments 4 and 3 recorded higher values than Treatments 2 and 1.

The dry weight of 'D' leaf was higher in Treatment 3 and Treatment 2 during the early stage of growth which however levelled off in the later stages.

1.4 Percentage dry weight of 'D' leaf

The treatments did not exhibit any significant difference among themselves in respect of the percentage dry weight of 'D' leaf during the early stages of growth but at the time of flowering, Treatment 1 was significantly superior to the other treatments, the mean value recorded being 14.5 g compared to 13.96 g, 12.93 g and 12.68 g in Treatments 2, 3 and 4 respectively.

1.5 Colour of leaves

During summer months (February-April) perceptible difference could be noticed in the colour of leaves of the plants grown in open and shade conditions. The leaves of plants under shade were darker in green colour compared to the leaves of the plants grown under open conditions.

2. EFFECT OF SHADING ON FLOWERING

The data on the days taken for flowering and the percentage of flowering are presented in Table 4.

Table 3. Effect of shading on percentage dry weight of 'D' leaf

Treatments	Percentage dry weight of 'D' leaf		
	a	b	c
1. 0 per cent shade	12.13 (20.35)	14.21 (22.10)	14.5 (22.39)
2. 25 per cent shade	11.43 (19.77)	14.74 (22.53)	13.96 (21.93)
3. 50 per cent shade	11.67 (19.95)	13.95 (21.93)	12.93 (21.08)
4. 75 per cent shade	12.32 (20.46)	12.67 (20.84)	12.68 (20.87)
C.D (5%)	NS	NS	1.07
S. Em	0.56	0.55	0.35

a - six months after planting
b - one year after planting
c - at flowering

Note: The figures in parenthesis indicate the means for angular transformed data and the C.D and S.Em are for the transformed data.

2.1 Days taken from planting to flowering

The data showed that pineapple plants under shade flowered earlier than plants under open conditions. In the open, the plants required 565.6 days to flower which was significantly higher than the time taken to flower by plants under shade. The earliest flowering was noted in Treatment 3 (523.1 days) but was on par with Treatments 2 and 4 (527.9 days).

2.2 Percentage of flowering

There was significant increase in percentage of flowering under shade in all the five stages of observations.

During the first week, the percentage of flowering under different intensities of shade ranged from 50 to 76, the maximum being in Treatment 3. In Treatment 1, only six per cent of the plants flowered during the first week. During the other periods of observation also, similar trend was noticed. At the final stage, the percentage of flowering in open was only 24, which was significantly inferior to all the other treatments. Maximum percentage of flowering was in Treatment 3 (83), followed by Treatments 2 (75) and 4 (59.5) (Fig 2).

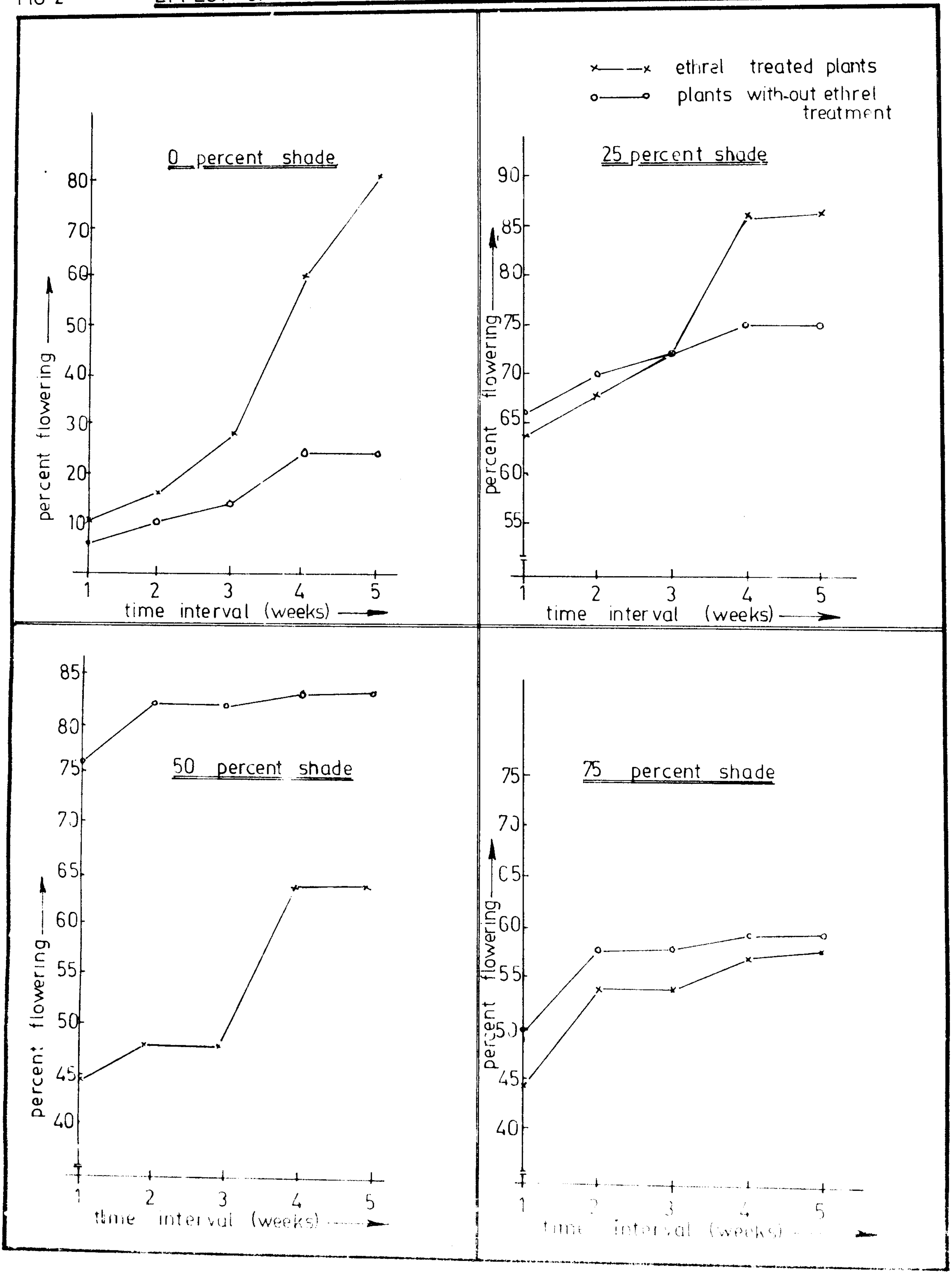
3. EFFECT OF SHADING ON FRUITING BEHAVIOUR

Data on the various aspects of fruiting characters under different intensities of shade are presented in Tables 5, 6, 7, 8a and 8b.

Table 4. Effect of shading on flowering

Treatments	Mean number of days from planting to flowering	Flowering percentage at weekly intervals				
		I week	II week	III week	IV week	V week
1. 0 per cent shade	565.6	6.00	10.00	14.00	24.00	24.00
2. 25 per cent shade	527.9	66.00	70.00	72.00	75.00	75.00
3. 50 per cent shade	523.1	76.00	82.00	82.00	83.00	83.00
4. 75 per cent shade	527.9	50.00	58.00	58.00	59.50	59.5
C.D (5%)	5.14					1.24
S.Em	1.67					0.40

FIG 2 EFFECT OF SHADING ON PERCENTAGE OF FLOWERING



3.1 Time taken for fruit maturity

In this respect the effect due to treatments was significant. In Treatment 1, the time taken for fruit maturity was 138.8 days which was significantly higher than the other treatments. Treatments 2, 3 and 4 were on par.

3.2 Fruit development

The development of fruits in terms of increase in the length and circumference are presented in Table 6 along with the incremental percentage increase.

On a general analysis of the data on fruit development, it was found that the pattern of development in terms of length and circumference of the fruits was not altered due to treatments. However, differential growth response was perceptible. The length and circumference of the fruit showed an increase in the case of fruits grown in the open especially between 75 and 90 days after flowering. But towards the maturity stage the difference became negligible, all the treatments recording similar values (Fig 3).

3.3 Yield per hectare

Data on per hectare yield calculated for a population density of 43,060 plants indicated that without growth regulator treatment, maximum tonnage of fruits was obtained from Treatment 3 and the minimum from Treatment 1, the results

Table 5. Effect of shading on the time taken for fruit maturity

Treatments	Number of days taken from flowering to fruit maturity
1. 0 per cent shade	138.8
2. 25 per cent shade	123.8
3. 50 per cent shade	123.9
4. 75 per cent shade	123.7
C.D (5%)	1.92
S.Em	0.63

Table 6. Effect of shading on fruit development

Treatments	Days after flowering													
	45		60		75		90		105		120		135	
	L	C	L	C	L	C	L	C	L	C	L	C	L	C
1.	13.0	24.5	14.75 (13.46)	29.0 (18.37)	16.2 (9.83)	32.25 (11.21)	17.60 (8.64)	35.4 (9.77)	18.80 (6.82)	37.2 (5.08)	19.7 (4.79)	38.75 (4.17)	19.7 (0)	38.75 (0)
2.	11.0	28.5	12.80 (16.36)	31.3 (9.82)	14.4 (12.5)	33.5 (7.03)	15.75 (9.38)	35.4 (5.67)	17.0 (7.94)	37.0 (4.52)	18.0 (5.88)	38.5 (4.05)	18.0 (0)	38.5 (0)
3.	11.0	26.0	12.5 (13.64)	30.0 (15.38)	13.9 (11.2)	33.25 (10.83)	15.0 (7.91)	34.7 (4.36)	16.0 (6.67)	36.5 (5.19)	16.75 (4.69)	38.0 (4.11)	16.75 (0)	38.0 (0)
4.	12.0	28.0	13.25 (10.42)	30.5 (8.93)	14.35 (8.30)	32.5 (6.56)	15.25 (6.27)	34.3 (5.54)	16.0 (4.92)	36.0 (4.96)	16.7 (4.38)	37.5 (4.17)	16.7 (0)	37.5 (0)

Note: The figures in parenthesis indicate the incremental percentage increase at each time interval

L - length of fruit (cm)
C - circumference of fruit (cm)

Fig. 3 EFFECT OF SHADING ON FRUIT DEVELOPMENT

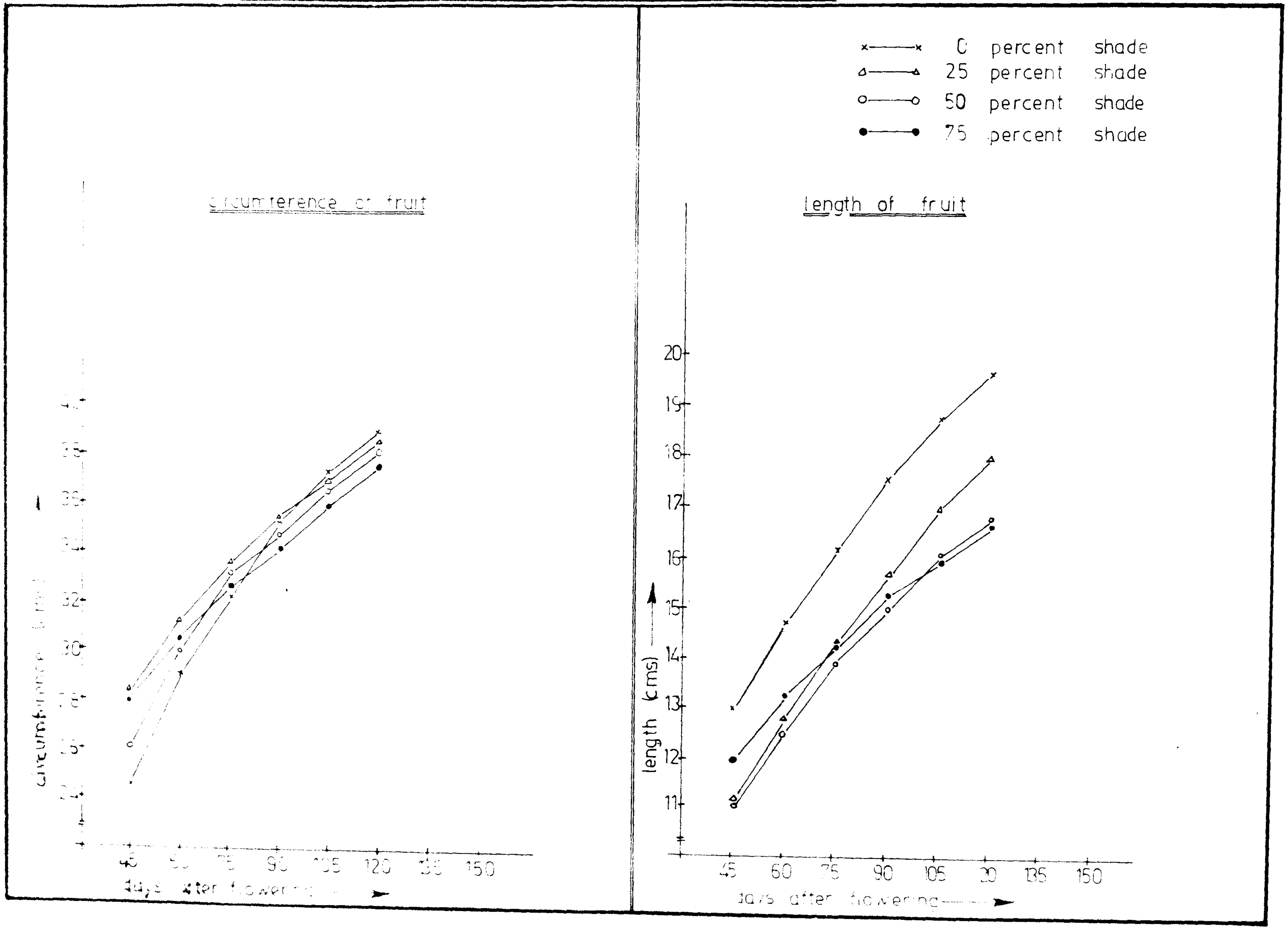


Table 7. Effect of shading on yield per hectare

Treatments	Per hectare yield from non ethrel treated plants (tons)
1. 0 per cent shade	18.2
2. 25 per cent shade	52.71
3. 50 per cent shade	55.55
4. 75 per cent shade	42.87
C.D (5%)	3.66
S. Em	1.19

being statistically significant.

3.4 Fruit characters

Data on weight, length and breadth of fruits, crown characters, canning ratio, peel, core and pulp weight and peel/pulp ratio are presented in Tables 8a and 8b and depicted in Fig 4.

3.4.1 Fruit weight

The treatments did not exhibit any significant difference among themselves with respect to the weight of fruit with crown. But there was significant difference when fruit weight without crown was taken into account. Maximum fruit weight without crown (1.46 kg) was recorded by Treatment 1. The fruit weight without crown under different intensities of shade ranged from 1.16 kg to 1.21 kg, the difference being not significant.

3.4.2 Length and breadth of fruit

Similar trend as in the case of fruit weight without crown was noticed in respect of the length of the fruits, fruits grown under open conditions recording the maximum average fruit length of 22.2 cm which was significantly superior to all the other treatments. Treatments 2, 3 and 4 were on par (Plate II).

On the other hand, the breadth of the fruits did not show any significance due to treatments.

3.4.3 Crown chracters

The lowest crown weight was recorded by Treatment 1, the value being 277.79 g. The maximum crown weight was recorded by Treatment 4 (512.89 g) and Treatments 2 and 3 were on par.

The weight of crown in terms of percentage of fruit weight also showed a similar trend as was noticed in the case of crown weight. In Treatment 4, 30.65 per cent of the fruit weight was constituted by crown alone while it was only 15.72 per cent in the case of fruits grown in open. Treatments 2 and 3 were on par, but in these cases also 27.14 to 27.68 per cent of the fruit weight was due to crown weight (Fig 4).

The number of leaves on the crown was also high as the shading intensities increased. Maximum crown leaf number (124.78) was recorded by Treatment 4 and the least by Treatment 1 (73.7). The treatments 2 and 3 were on par in this respect also (Plate III).

3.4.4 Canning ratio

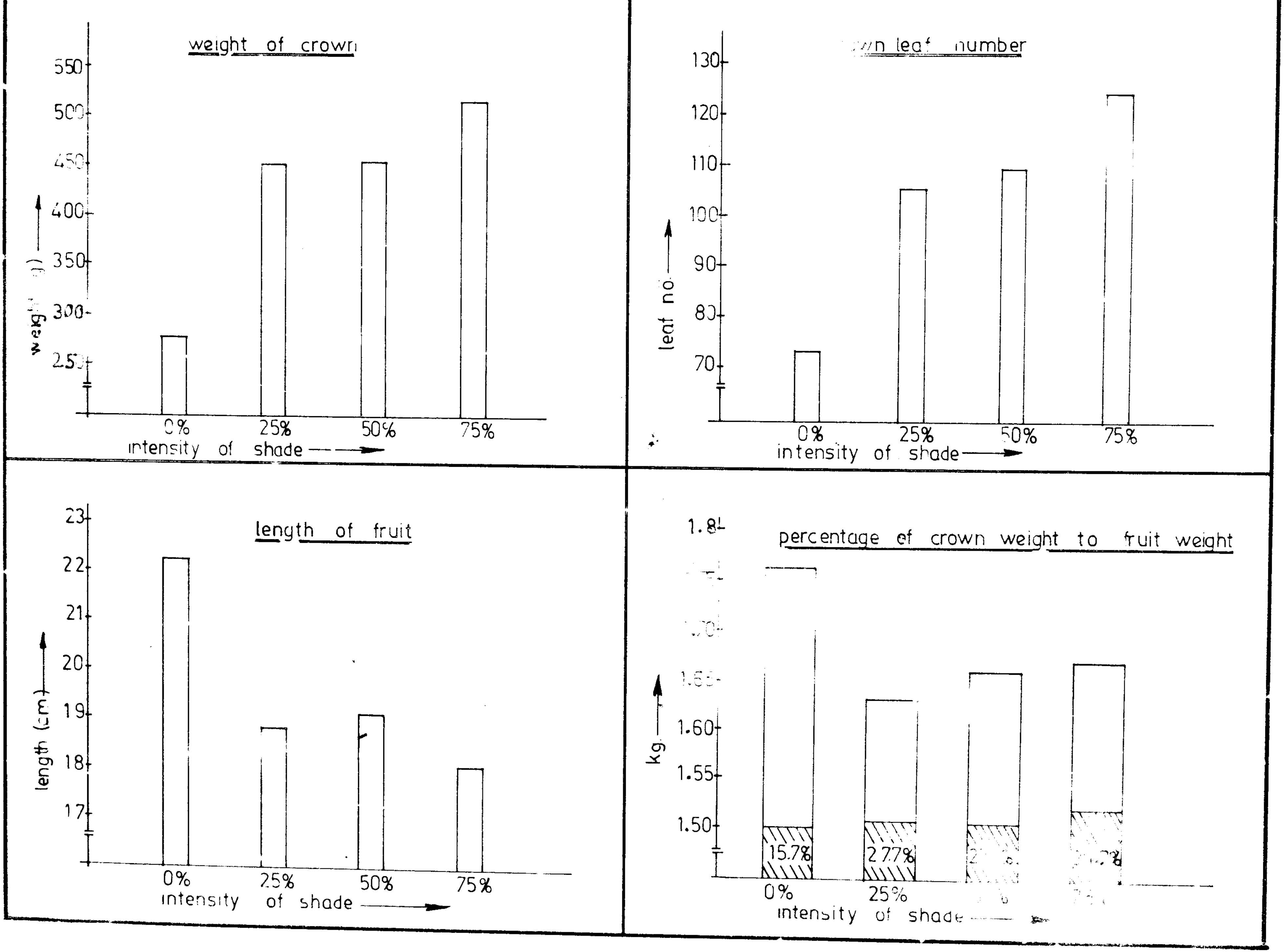
Highest canning ratio of 1.71 was recorded by Treatment 1 which was significantly superior to other treatments. Treatments 2, 3 and 4 were on par.

3.4.5 Weight of peel, core and pulp

Treatments 1, 3 and 4 were statistically on par with

Table 8a. Effect of shading on fruit characters

Treatments	Fruit weight with crown (kg)	Fruit weight without crown (kg)	Length of fruit (cm)	Breadth of fruit (cm)	Weight of crown (g)	Crown weight as percentage of fruit weight	Crown leaf number	Canning Ratio (L/B)
1. 0 per cent shade	1.76	1.48	22.2	12.95	277.79	15.72	73.70	1.71
2. 25 per cent shade	1.63	1.18	18.8	12.86	450.75	27.68	105.34	1.46
3. 50 per cent shade	1.66	1.21	19.01	12.65	451.51	27.14	109.04	1.48
4. 75 per cent shade	1.67	1.16	18.01	12.17	512.89	30.65	124.78	1.47
C.D. (5%)	NS	0.09	1.90	NS	31.13	2.86	5.67	0.2
SEm	0.03	0.03	0.62	0.26	10.14	0.93	1.85	0.07



weight of crown
550
500
450
400
350
300
weight (g)
0%
25%
50%
75%
intensity of shade
leaf number
130
120
110
100
90
80
70
leaf no.
0%
25%
50%
75%
intensity of shade
length of fruit
23
22
21
20
19
18
17
length (cm)
0%
25%
50%
75%
intensity of shade
percentage of crown weight to fruit weight
1.8
1.60
1.55
1.50
kg
15.7%
27.7%
0%
25%
intensity of shade

Table 8b. Effect of shading on fruit characters

Treatments	Weight of peel (g)	Weight of core (g)	Weight of pulp (g)	Peel/pulp ratio
1. 0 per cent shade	311.35	171.33	1162.0	0.27
2. 25 per cent shade	382.22	220.68	866.1	0.44
3. 50 per cent shade	284.66	148.00	714.5	0.40
4. 75 per cent shade	267.42	141.20	698.3	0.38
C.D (5%)	59.99	56.33	166.70	0.07
SEm	19.54	18.35	54.30	0.02

respect to weight of peel but Treatment 2 was significantly superior to other treatments. In the case of the weight of core also the trend was the same.

Treatment 1 was significantly superior to the other treatments in terms of the weight of pulp per fruit. Treatment 2 was superior to Treatments 3 and 4 which were on par.

3.4.6 Peel/pulp ratio

Treatment 1 showed the least peel/pulp ratio, the value being 0.27 and the other three treatments were not significantly different.

4. FRUIT QUALITY

The total soluble solids, acidity, ascorbic acid content, reducing, non reducing and total sugars and sugar/acid ratio of fruits of different treatments are presented in Table 9.

4.1 Total soluble solids

The data indicated that there was no significant difference between the treatments in the case of total soluble solids of fruits.

4.2 Acidity

The treatments exhibited significant difference among themselves with respect to the percentage of acidity of fruits. The maximum value (1.17 per cent) was obtained in Treatment 4 followed by Treatment 3 (0.86 per cent). The acidity percentages in Treatment 2 and Treatment 1 remained on par.

4.3 Reducing sugars

The treatments differed significantly in respect of reducing sugar content. The maximum value was recorded by Treatment 1 (4.78 per cent) which was on par with Treatment 2 (4.41 per cent). Treatments 3 and 4 did not show significant difference between themselves in terms of reducing sugar content.

4.4 Non-reducing sugars

In this case the trend was the same as in the case of reducing sugar content.

4.5 Total sugars

The highest total sugar content was recorded by Treatment 1 followed by Treatments 2, 3 and 4, indicating thereby that the total sugar content decreased as the intensity of shade increased.

4.6 Sugar/Acid ratio

The trend was the same as in the case of the total sugar content. The maximum value was recorded in Treatment 1 (19.96) followed by Treatments 2 (16.94), 3 (12.84) and 4 (9.03).

Table 9. Effect of shading on fruit quality

Treatments	Total soluble solids (%)	Acidity (%)	Reducing sugars (%)	Non reducing sugars (%)	Total sugars (%)	Sugar/ acid ratio	Ascorbic acid (mg/100 g)
1. 0 per cent shade	15.30	0.65	4.78	8.31	12.92	19.96	12.8
2. 25 per cent shade	15.55	0.72	4.41	8.05	12.12	16.94	11.17
3. 50 per cent shade	15.85	0.86	3.79	7.26	11.05	12.84	11.09
4. 75 per cent shade	16.06	1.17	3.38	7.08	10.46	9.03	9.79
C.D (5%)	NS	0.07	0.44	0.44	0.37	0.92	0.65
S.Em	0.28	0.02	0.14	0.14	0.12	0.30	0.21

4.7 Ascorbic acid

Treatment 1 recorded the maximum ascorbic acid content (12.8 mg/100 g fruit) and the minimum value was exhibited by Treatment 4 (9.79 mg/100 g). Treatments 2 and 3 were on par.

5. LEAF ANALYSIS

Data on the nitrogen, phosphorus, potassium, calcium and magnesium contents of leaves at three stages of growth are presented in Tables 10, 11, 12, 13 and 14.

5.1 Nitrogen content

The data indicated that during the early stages of growth, there was no significant difference in nitrogen content of 'D' leaves, due to shading treatments. However, during the later stages of growth, the nitrogen content was found to increase significantly under shaded conditions, the difference between the three intensities of shading being not significant (Fig 5).

5.2 Phosphorus content

The treatments did not show any significant difference among themselves in all the three stages of estimation in respect of phosphorus content of 'D' leaves.

5.3 Potassium content

In the case of potassium also there was no significant difference due to treatments at all the three stages of estimation.

Table 10. Effect of shading on nitrogen content of leaves

Treatments	Nitrogen content (per cent)		
	a	b	c
1. 0 per cent shade	1.75	1.88	1.91
2. 25 per cent shade	1.98	2.13	2.16
3. 50 per cent shade	1.89	2.09	2.11
4. 75 per cent shade	1.92	2.16	2.14
C.D (5%)	NS	0.13	0.13
S. Em	0.06	0.04	0.04

a - six months after planting
b - one year after planting
c - at flowering

Table 11. Effect of shading on phosphorus content of leaves

Treatments	Phosphorus content (per cent)		
	a	b	c
1. 0 per cent shade	0.066	0.076	0.079
2. 25 per cent shade	0.075	0.082	0.078
3. 50 per cent shade	0.068	0.082	0.082
4. 75 per cent shade	0.058	0.078	0.077
C.D (5%)	NS	NS	NS
S.Em	0.01	0.004	0.004

a - six months after planting
b - one year after planting
c - at flowering

Table 12. Effect of shading on potassium content of leaves

Treatments	Potassium content (per cent)		
	a	b	c
1. 0 per cent shade	3.92	5.08	4.41
2. 25 per cent shade	3.89	5.45	4.81
3. 50 per cent shade	3.71	4.99	4.63
4. 75 per cent shade	3.59	5.09	4.62
C.D (5%)	NS	NS	NS
S.Em	0.14	0.17	0.14

a - six months after planting
b - one year after planting
c - at flowering

5.4 Calcium content

There was variation in calcium content of 'D' leaves due to treatments. In all the three stages of estimation, Treatments 1 and 2 were found to possess higher calcium content than Treatments 3 and 4, the difference between Treatments 1 and 2 being not significant (Fig 5).

5.5 Magnesium content

In all the three stages of estimation, Treatment 4 recorded the highest percentage of Mg in the 'D' leaves. During the early stages, the Mg content of Treatment 1 was significantly inferior to all other treatments, Treatments 2 and 3 being on par. At the time of flowering, Treatments 1, 2 and 3 did not exhibit significant difference among themselves (Fig 5).

5.6 Chlorophyll content

Data on chlorophyll 'a', 'b' and total contents under different intensities of shade are presented in Table 15.

With respect to chlorophyll 'a' and 'b' contents, Treatment 4 was significantly superior to other treatments.

In the case of total chlorophyll content also Treatment 4 was significantly superior (0.0697 per cent) to all other treatments. Treatment 1 recorded the minimum total chlorophyll content (0.0189 per cent). Treatments 2 and 3 were on par, the total chlorophyll contents being 0.0259 per cent and 0.0254 per cent respectively.

Table 13. Effect of shading on calcium content of leaves

Treatments	Calcium content (per cent)		
	a	b	c
1. 0 per cent shade	0.56	0.44	0.48
2. 25 per cent shade	0.57	0.43	0.46
3. 50 per cent shade	0.47	0.34	0.38
4. 75 per cent shade	0.29	0.35	0.37
C.D (5%)	0.04	0.04	0.07
S. Em	0.01	0.01	0.02

a - six months after planting
b - one year after planting
c - at flowering

Table 14. Effect of shading on magnesium content of leaves

Treatments	Magnesium content (per cent)		
	a	b	c
1. 0 per cent shade	0.19	0.19	0.19
2. 25 per cent shade	0.24	0.23	0.24
3. 50 per cent shade	0.25	0.22	0.25
4. 75 per cent shade	0.29	0.27	0.29
C.D (5%)	0.02	0.02	0.07
S.Em	0.01	0.01	0.02

a - six months after planting
b - one year after planting
c - at flowering

FIG. 5 EFFECT OF SHADING ON NUTRIENT STATUS OF LEAVES

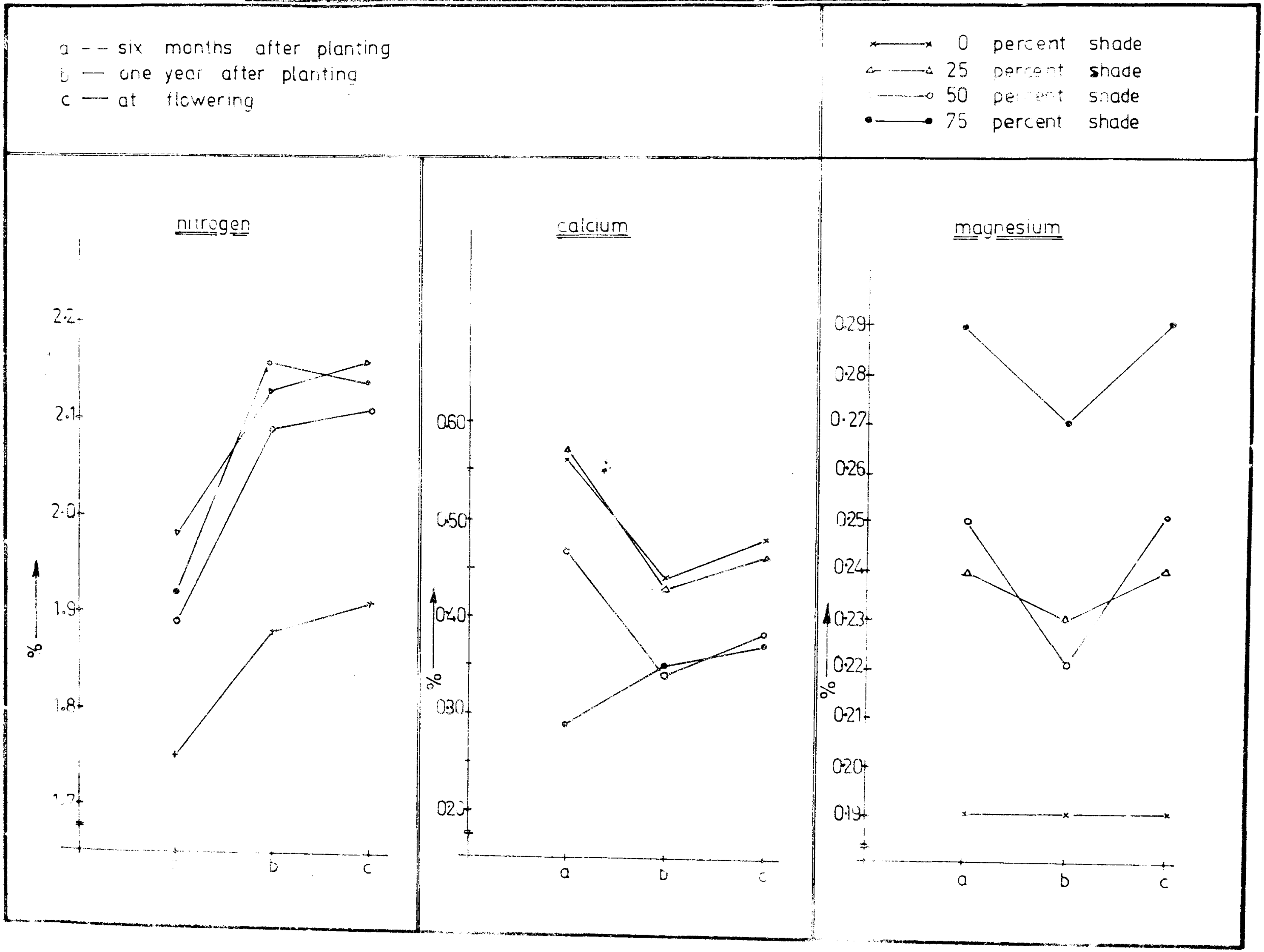


Table 15. Effect of shading on chlorophyll 'a', 'b' and total contents of leaves

Treatments	Chlorophyll 'a' (%)	Chlorophyll 'b' (%)	Total Chlorophyll (%)
1. 0 per cent shade	0.012	0.0065	0.0189
2. 25 per cent shade	0.017	0.0093	0.0259
3. 50 per cent shade	0.016	0.010	0.0254
4. 75 per cent shade	0.044	0.0262	0.0697
C.D (5%)	0.005	0.004	0.006
S.Em	0.0016	0.0013	0.0019

6. SUCKER PRODUCTION

The data recorded on sucker production and the vegetative characters of suckers are presented in Table 16.

6.1 Number of suckers per plant

The data indicated that the number of suckers produced per plant was higher in Treatment 1 (1.3) the result being significantly superior to other treatments. Treatments 2 and 3 were on par. Treatment 4 recorded the lowest value (1.08).

6.2 Height of suckers

Longest suckers were produced by Treatment 2 (87.85 cm) and the smallest by Treatment 1 (66.65 cm). Treatments 4 and 3 were on par and contributed for medium sized suckers (Plate IV).

6.3 Number of leaves per sucker

The data showed that suckers with the minimum number of leaves were produced by Treatment 1 (21.15). The highest value was recorded by plants in Treatment 2, but the difference was not significant compared to treatments 3 and 4.

6.4 'D' leaf area of sucker

Maximum 'D' leaf area of sucker was produced by Treatment 4 (110.67) which was significantly superior to

Table 16. Effect of shading on sucker production and vegetative characters of suckers

Treatments	Number of suckers per plant	Height of suckers (cm)	Number of leaves per sucker	'D' leaf area of suckers (sq.cm)	Fresh weight of 'D' leaf (g)	Dry weight of 'D' leaf (g)	Percentage dry weight of 'D' leaf
1. 0 per cent shade	1.30	66.65	21.15	94.57	13.22	1.46	11.02(19.36)
2. 25 per cent shade	1.14	67.85	29.25	96.63	14.19	1.52	10.72(19.07)
3. 50 per cent shade	1.16	74.17	27.00	97.23	14.[illegible]5	1.66	11.81(20.11)
4. 75 per cent shade	1.08	74.14	26.65	110.07	14.19	1.75	12.66(20.82)
C.D (5%)	0.04	2.94	3.79	9.37	0.47	NS	NS
S.Em	0.013	0.96	1.23	3.04	0.15	0.10	0.58

Note: Figures in parenthesis indicate the means for angular transformed data and S.Em is for the transformed data.

other treatments. Treatments 3, 2 and 1 did not show any significant difference among themselves in this respect.

6.5 Fresh weight of 'D' leaf of sucker

Treatment 1 recorded the minimum fresh weight of 'D' leaf of sucker (13.22 g) and Treatments 4, 3 and 2 were on par.

6.6 Dry weight of 'D' leaf of sucker

The treatments did not show significant difference among themselves with respect to the dry weight of 'D' leaf of sucker

6.7 Percentage dry weight of 'D' leaf

In this case also, no significant difference between treatments could be noticed.

7. FLOWERING CHARACTERS OF ETHREL TREATED PLANTS UNDER DIFFERENT INTENSITIES OF SHADE

The data on the number of days taken from planting to flowering, the percentage of flowering at weekly intervals and the time taken for fruit maturity in respect of Ethrel treated plants under different levels of shading are presented in Tables 17 and 18.

7.1 Days taken from planting to flowering

In general, under shaded situations early flowering was noticed in the case of Ethrel treated plants compared to the non-treated ones, irrespective of the intensity of shade. The plants took 528.9 to 529.84 days for flowering under all intensities of shade indicating that the effect of Ethrel application was not influenced by the intensity of shading. Under open conditions, the Ethrel treated plants came to flower only in 546.64 days which was significantly higher.

7.2 Percentage of flowering

The data indicated that the percentage of flowering was higher in the case of Ethrel treated plants under shaded conditions during the first, second and third weeks of observation compared to that of unshaded plants. However, during the later stages the percentage of flowering was minimum in Treatment 4. The highest percentage of flowering was recorded by Treatment 2 (86 per cent) followed by Treatment 1 (80 per cent).

On a general consideration of the data presented in Tables 4 and 17, it was found that maximum percentage of plants flowered in Treatment 2 (86 per cent) when treated with Ethrel. But in Treatment 3 (50 per cent shade), 83 percentage of plants flowered even without Ethrel treatment. Under 75 per cent shade, there was not much difference in the percentage of flowering between Ethrel treated and non-treated plants (58 and 59.5 per cents respectively). Thus it can be noticed that the effect of Ethrel on flowering

Table 17. Effect of shading on flowering of Ethrel treated plants

Treatments	Mean number of days from planting to flowering	Flowering percentage at weekly intervals				
		I week	II week	III week	IV week	V week
1. 0 per cent shade	546.64	10.0	16.0	28.0	60.0	80.0
2. 25 per cent shade	529.84	64.00	68.0	72.0	86.0	86.0
3. 50 per cent shade	529.06	44.0	48.0	48.0	64.0	64.0
4. 75 per cent shade	528.90	44.0	54.0	54.0	57.5	58.0
C.D.(5%)	5.21					3.05
S.Em	1.70					0.99

was more conspicuous in open than in shaded conditions. Under 25 per cent shade, appreciable difference in percentage of flowering could not be noticed due to Ethrel application. Under 50 per cent shade, Ethrel had shown rather a reducing effect on flowering, the flowering percentage being reduced from 83 to 64. Under conditions of heavy shade also (75 per cent), Ethrel not only had any advantageous effect on flowering, but also contributed for reduction in the extent of flowering of plants (Fig 2).

7.3 Time taken for fruit maturity

The data showed that under adoption of Ethrel treatment, the time taken for fruit maturity was more in treatment 1 (138.7 days). Under shaded conditions, irrespective of the intensity of shade, Ethrel treated plants took around 123 days for fruit maturity.

From a comparison between the data in Tables 5 and 16, it could be seen that under shaded conditions both Ethrel treated and non treated plants took almost the same period for fruit maturity irrespective of the intensity of shade. Similarly, in open also both the Ethrel treated and non treated plants took the same period for fruit maturity indicating thereby that Ethrel exerted no influence on the period for fruit maturity irrespective whether the plants were grown in open or in shaded conditions.

Table 18. Effect of shading on the time taken for fruit maturity of Ethrel treated plants

Treatments	Number of days taken for fruit maturity
1. 0 per cent shade	138.7
2. 25 per cent shade	123.6
3. 50 per cent shade	123.7
4. 75 per cent shade	123.9
C.D (5%)	1.2
S.Em	0.39

DISCUSSION

DISCUSSION

Light intensity is a factor which has profound influence on all phases of plant growth. This has been brought out by several workers (Gourley, 1920; Kraybill, 1922; Vinson, 1923; Edmond *et al.*, 1964 and Black and Edelman, 1971). Based on the capacity of the plants to endure shade conditions, they can be grouped as 'shade tolerant' and 'shade intolerant' (Baker, 1950). There is another group of plants called 'shade loving' which have an affinity towards shaded conditions.

Pineapple although is generally grown in the open, its cultivation as an intercrop in coconut gardens of Kerala has been necessitated in recent times due to limited land resources. The efficiency in utilization of solar energy ultimately decides the suitability of a crop in the multiple cropping system. No detailed information is available on the different aspects of growth, flowering and fruiting in pineapple under shaded or partially shaded conditions. It is in this context the present investigation assumes greater significance with practical adaptability under Kerala conditions. Pineapple has perhaps been hitherto considered as a shade intolerant species which is evidently due to lack of detailed studies on shade tolerance of this crop.

In the present investigation, growth, flowering and fruiting behaviour of 'Kew' variety of pineapple under different intensities of shade viz., 0, 25, 50 and 75 per cent were studied.

Parameters such as the number of leaves per plant, 'D' leaf area, fresh as well as dry weight of 'D' leaf and the percentage dry weight of 'D' leaf were studied at three different stages of growth, to find out the effect of shading on vegetative characters. The number of leaves produced per plant was not found to be influenced by shading even up to an intensity of 75 per cent. Experiments conducted by Rolfs (1903) had also shown that the leaf production in pineapple was not affected by shade. On the contrary, in citrus, a shade intolerant species, shading was found to result in a reduction in the number of leaves produced per plant (Rolfs, 1903). The fact that the number of leaves produced per plant was not decreased by shading in pineapple probably indicates its shade tolerance.

Increase in leaf area of plants is the immediate perceptible morphological adaptation generally associated with low intensities of light, both in shade tolerant and shade intolerant species. Obviously, the larger leaf surface is a compensation mechanism for absorption of light energy. Increased leaf area consequent to shading was observed in citrus and apple (Rolfs, 1903; Gourley and Nightingale, 1921 and Streitberg, 1975).

In the present study also, it was found that the leaf area progressively increased with shading intensities (Table 1). The increase in leaf area in pineapple without any reduction in the number of leaves per plant has resulted in a larger leaf area per plant. The adaptation of pineapple to shaded condition as against in many other fruit crops is thus evident.

Comparable values were obtained for fresh weight of 'D' leaves under shaded and in open conditions during the early stages of growth suggesting a uniform moisture regime in plants under shade and in the open. Significant increase in the fresh weight of leaves at the time of flowering in shaded plants observed in the present study might be considered as a better physiological basis for plant growth. Increased moisture content of leaves as a result of shading was reported in apple (Kraybill, 1922) and in cocoa (Guers, 1971). A uniform soil moisture regime under shade (Wolfs, 1903) and the decreased transpiration rate of plants due to low intensity of light (Martin, 1935 and Turrell, 1936) might be the contributory factors for higher water content of leaves.

The adaptability of pineapple to shaded conditions is perhaps best reflected in the dry matter accumulation in leaves (Table 3). Dry matter accumulation in plants is generally considered as an indication of the photosynthetic efficiency. In shade intolerant plants like apple (Edmond et al., 1964; Misko, 1970 and Barden, 1977) and black currant (Karnatz, 1971) grown under conditions of low light intensities, dry matter accumulation was found to reduce considerably. On the other hand, increase in dry matter accumulation under shade was characteristic of coffee, a shade loving species, where maximum accumulation was noticed under 50 per cent light intensity (Silveira and Maestri, 1973). In the present study, the dry matter accumulation in the leaves was comparable both in shade and in open till flowering although there was a reduction in the same at flowering (from 14.5 per cent in open to 12.7 per cent under shade). Flowering of pineapples in the open was late by 38 to 42 days than those grown under shade. This increased time lag between planting to flowering might have helped for an increased dry matter accumulation in the leaves of unshaded plants at flowering. The reduction in dry matter accumulation was not considerable in spite of shading upto 75 per cent. This suggests that even under highly shaded conditions, the photosynthetic rate in pineapple is not reduced to an extent to inhibit the growth processes of the plant.

The general vigour of suckers produced by the shaded plants in terms of the height of suckers, number of leaves per sucker, 'D' leaf area and fresh weight of 'D' leaf, was found to be more than that of the suckers produced in the open (Table 16). This again indicated that shading was favourable for enhanced vegetative growth of suckers as in the case of mother plants. The dry matter accumulation in suckers was also not affected by shading.

The total chlorophyll content of leaves of shade grown plants has been found to increase in comparison of sun grown plants (Bjorkman, 1968 and Goodchild et al., 1972). In the present study also the total chlorophyll content of leaves increased progressively (0.02 to 0.07 per cent) with the intensity of shade. Accumulation of chlorophyll in shaded leaves is generally attributed to the decreased utilisation of the pigment for photosynthetic activity under reduced light intensities. However, this theory might not hold good for pineapple since the photosynthetic rate was not greatly affected by shading as reflected in the dry matter accumulation in leaves. Alternatively, the reduced destruction of chlorophyll under low light intensity might offer a better explanation for the accumulation of chlorophyll in pineapple. The leaves of pineapple grown in the open presented a pinkish appearance especially during summer in contrast to the dark green colour of the leaves under shade. The chlorophyll destruction due to high intensity of light in pineapple is thus evident. Chlorophyll destruction under higher intensities of light and its resultant reduction in leaves was reported by Clark (1905), Bunding (1952) and Gauhl (1969).

Studies on the nutrient status of leaves showed that nitrogen content increased in the leaves under shaded conditions except during the early stages of growth. This might be attributed either to the increased uptake of the nutrient element or due to the decreased utilisation of the same under shade. In banana a process termed as 'nutrient sparing action' under shade was reported by Simmonds (1966). A similar process is also possible in pineapple under shade. If this was so, it might indicate the possibility of using reduced amounts of nitrogenous fertilizers for pineapple under shade. Further work on this direction will be of interest. The phosphorus and potassium contents of leaves did not show differences both under shade and in open. Magnesium content of leaves increased as intensity of shade increased whereas calcium content decreased under shade intensities above 25 per cent.

Delayed and reduced flowering were the immediate consequences due to shading in most of the horticultural plants belonging to 'sun species' (Kraybill, 1922; Capellini and Monastra, 1971 and Jackson and Palmer, 1977). A shade loving plant like cocoa was an exception to this (Hoyer, 1974). In the present study, shading was found to be beneficial for earlier, uniform and higher percentage of flowering (Table 4). This indicated that the physiology of flowering was considerably altered by shade treatments. This is interesting since lack of uniformity in flowering is one of the serious problems in pineapple culture. Under natural conditions, flowering is normally restricted to about less than 20 per cent in a plant crop (Randhawa *et al.*, 1971). It may thus benefit pineapple growing under shade to obtain higher and uniform flowering. Elimination of the practice of hormonal induction of flowering appears to be possible in pineapples grown under partial shade as in coconut plantations. It would however, be reasonable to presume that a shade limit upto 50 per cent is more desirable in pineapple since at 75 per cent shade, a reduction in flowering was observed, which was however higher than in open.

Pineapple is remarkable in that initiation of flowering is elicited by the application of auxins (Clark and Kerns, 1942 and Van Overbeek, 1946). Interestingly, the effect of shading on flower induction was comparable to auxin or Ethrel application. Presumably the shade treatments might have caused physiological changes in leaves similar to that of ethylene application which might have in turn helped lower the internal active auxin levels ultimately forcing the plants to flowering. Increased flowering in pineapple was associated with a decrease in the normal auxin levels by the treatment of ethylene in pineapple (Van Overbeek, 1958).

In contrast to the report of Guyot and Py (1970) that in pineapple the presence or absence of light had no effect on the flowering response of Ethrel, in the present study, it was found that the plants under shade did not respond to Ethrel application as in the case of plants in the open (Fig 2). The lack of response to Ethrel application was more perceptible under higher intensities of shade. At 25 per cent shade, flowering was increased from 75 to 86 per cent which however reduced under 50 per cent shade from 83 to 64 per cent. Thus the present study indicated that under higher intensities of shade Ethrel had an inhibitory action on flowering in pineapple. This perhaps suggests that the shade tolerance limit of pineapple from the point of productivity is 50 per cent. The applied Ethrel might have increased or decreased the internal auxin content to a level inhibitory to flowering under higher intensities of shade.

The ultimate benefit of pineapple growing under partially shaded condition is decided by the yield obtained. In the present study it was found that the weight of fruits with crown under open as well as under shade was comparable. But when the weight of fruits without crown was taken into account, there was significant reduction in yield in shaded plants. While the crown weight accounted only 15.72 per cent of the fruit weight in the open, it was 27.14 to 30.65 per cent under shade (Fig 4). The vigorous nature of the crowns is thus a drawback for fruits produced in shade. However, shading did not alter the developmental pattern of fruits.

In spite of the above defects it will be found that the per hectare yield was considerably increased under shaded conditions even without the application of Ethrel (Table 7).

The higher yield per hectare was due to the higher percentage of flowering under shade as discussed earlier. Increased yield under shade was reported in pineapple (Rolfs, 1903) and in tomato (Edmond et al., 1964).

An added advantage of the pineapple fruits grown under shade above 25 per cent intensity was reduced peel and core contents. Thus, it could be seen that as the fruit weight without crown decreased under shade, simultaneously the quantum of non edible portions like peel and core of fruits also decreased. On an overall analysis, no reduction in terms of the 'effective yield' could be attributed to plants grown in shade.

More than the fruit weight, the quality of fruits was considerably influenced by shading. It is well established that the high intensity of light favours high quality of fruits. The acidity increased with the intensity of shade, while reverse was true in the sugar and ascorbic acid contents of fruits (Table 9). Duggar (1903) reported increase in organic acid content of leaves grown in shade. The probable reasons for the accumulation of organic acids in the plant parts under shade might be either increased synthesis or the decreased destruction of the acid constituents under low light intensities. The blockage in the conversion process of organic acids to sugars might also be another reason for low sugar content of the fruits under shade. The only defect of growing pineapple especially under high shade was the slight deterioration in quality of the fruits. Restoration of the quality of fruits by the application of fertilizers like potash with a reduction in doses of nitrogen might be a possible solution on which further investigations are necessary.

SUMMARY

SUMMARY

The present investigations were carried out in the department of Pomology, College of Horticulture, Vellanikkara from 1976 to 1979. The effects of shading on growth, flowering and fruiting in pineapple variety 'Kew' were studied and the following conclusions were made.

1. Number of leaves produced per plant was not found to be influenced by shading.

2. Leaf area increased especially at the later stages of growth under shade intensities higher than 25 per cent.

3. The dry matter accumulation of leaves was not affected by shading till flowering, but at the time of flowering the dry matter accumulation under shade was found to be reduced.

4. The vigour of the suckers in terms of the height of the suckers, number of leaves per sucker, 'D' leaf area and fresh weight of 'D' leaf produced by plants under shade was found to increase with the intensities of shade.

5. The uptake pattern of major nutrients was not greatly influenced by shading. Shading increased the magnesium content of leaves at all stages of growth and nitrogen content at later stages of growth. However, shading above 25 per cent intensity resulted in reduced contents of calcium in the leaves at all stages of growth.

6. Chlorophyll 'a', 'b' and total were found to

progressively increase with intensities of shade.

7. In shaded plants generally flowering was uniform, early and higher. The possible reasons for this has been discussed.

8. Ethrel was found to have an inhibitory action on flowering of pineapple under intensities of shade above 25 per cent.

9. Fruit weight with crown was not influenced by shading. But the contribution of crowns to the fruit weight increased as the intensity of shade increased. Consequently there was a reduction in fruit weight without crown by shading.

10. Fruit developmental pattern was not influenced by shading to any significant extent.

11. Shading above 25 per cent was beneficial to the extent of reducing peel and core weight of the fruits.

12. Quality of the fruits in general was decreased under shaded conditions. While the acidity of fruits increased, there was a general reduction in sugar and ascorbic acid contents.

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*Originals not seen

PLATE-I. A general view of the field.

PLATE-II. Variation in fruit size due to shade treatments.

1 - 0 per cent shade

2 - 25 per cent shade

3 - 50 per cent shade

4 - 75 per cent shade

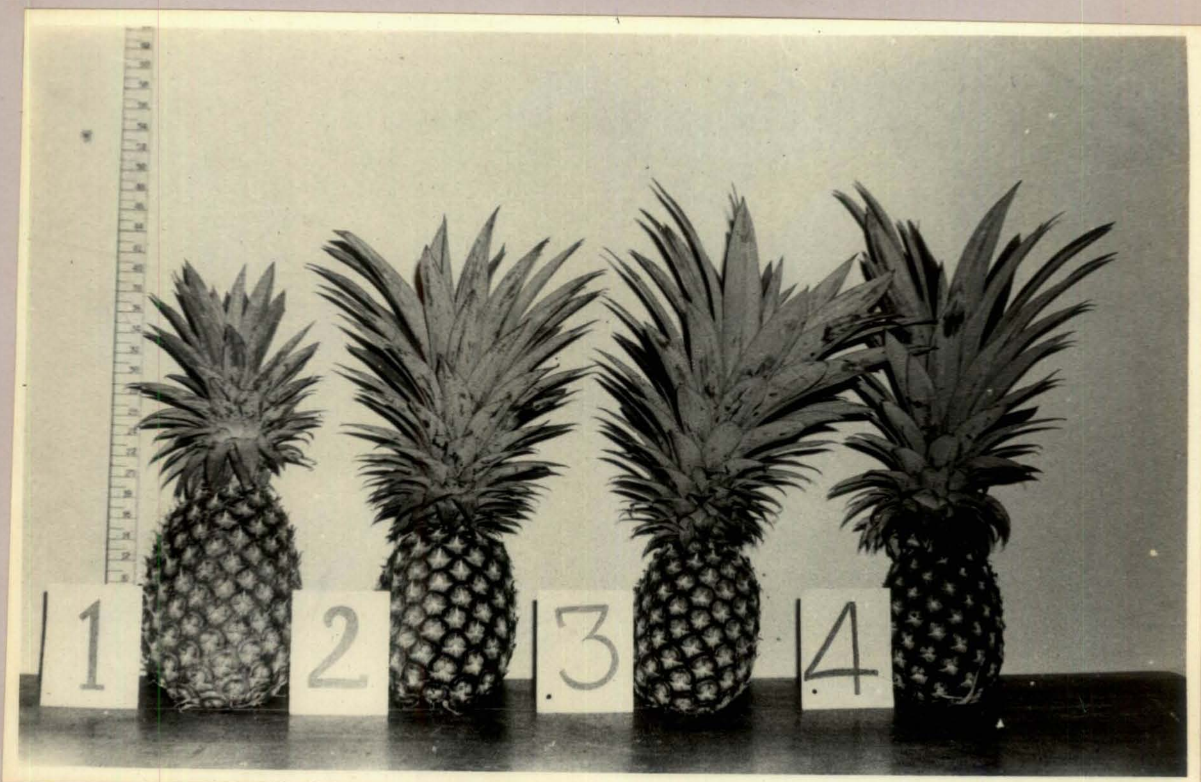
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PLATE-III. Variation in crown size due to shade treatments.

1. 0 per cent shade

2- 25 per cent shade

3- 50 per cent shade

4- 75 per cent shade

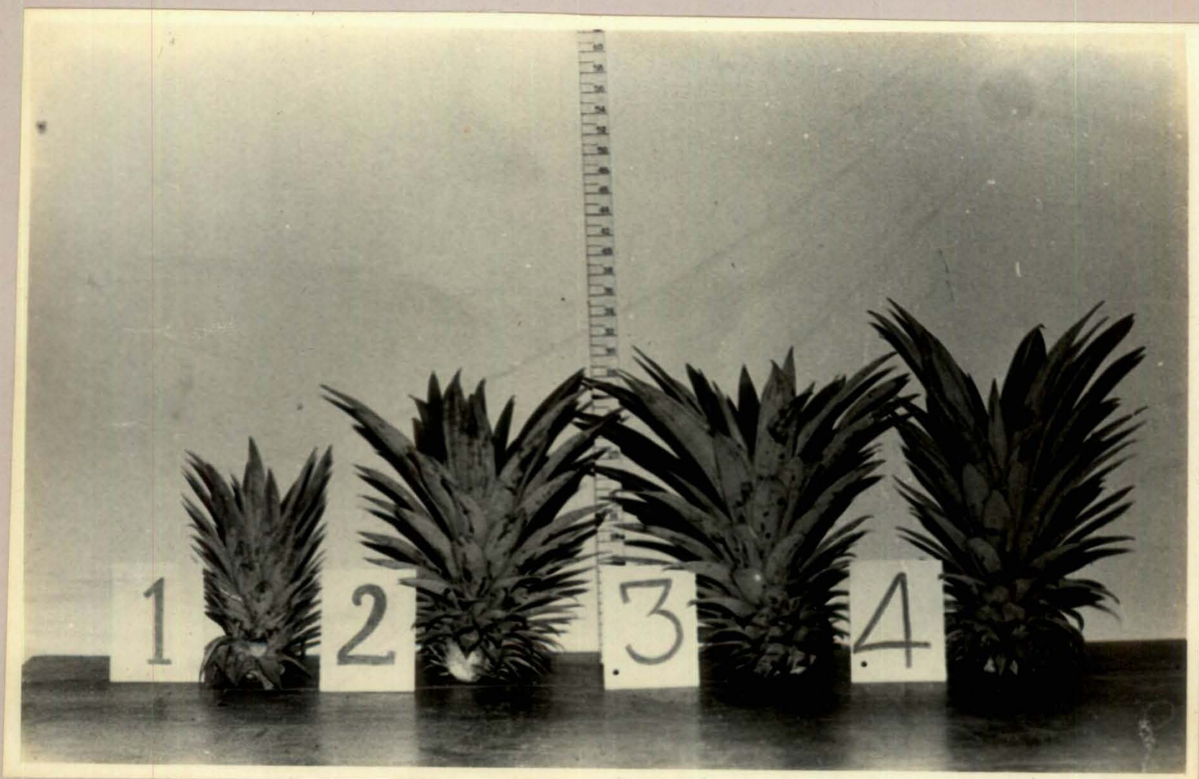
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PLATE-IV. Variation in the size of suckers due to shade treatments.

1 - 0 per cent shade

2.- 25 per cent shade

3 - 50 per cent shade

4 - 75 per cent shade


1
2
3
4

APPENDIX I

***WEATHER DATA FOR THE PERIOD FROM AUGUST, 1976 TO JULY, 1978**

(1) Year/Month	(2) Temperature °C		(3) Relative humidity per cent		(4) Total Rainfall mm	(5) Sunshine hours/day
	Maximum	Minimum	Maximum	Minimum		
1976						
August	30.9	21.8	97	60	375.6	7.7
September	32.1	21.6	95	61	104.5	8.8
October	33.4	21.9	95	59	154.7	9.5
November	32.9	21.9	96	53	201.7	9.6
December	32.4	19.4	93	35	1.6	9.4
1977						
January	33.5	17.2	95	34	nil	9.6
February	37.7	19.4	95	18	8.6	9.5
March	38.5	21.8	93	15	7.2	9.4
April	37.2	20.2	93	40	61.4	8.2
May	36.3	21.6	95	55	294.6	7.0
June	31.8	21.3	97	66	586.2	5.1
July	30.9	21.6	98	66	721.1	6.4
August	30.9	22.0	96	64	194.2	5.8
September	32.5	22.6	98	61	162.6	7.3
October	32.8	22.0	95	55	389.9	9.4
November	32.8	21.1	97	57	440.8	9.6
December	32.1	17.6	94	40	nil	9.5
1978						
January	34.3	18.8	93	18	nil	9.5
February	35.4	19.4	95	27	40.3	9.7
March	37.5	22.1	96	24	5.2	9.5
April	38.0	22.9	95	44	19.9	9.0
May	36.1	21.6	97	46	287.5	7.5
June	30.9	21.4	98	68	848.5	3.9
July	30.0	21.1	98	70	790.4	5.6

*Data collected from the 'B' class Observatory, Mannuthy

APPENDIX II

Analysis of variance for effect of shading on vegetative characters
(six months after planting)

Source	Degrees of freedom	Mean squares				
		Leaf number	'D' leaf area	Fresh weight of 'D' leaf	Dry weight of 'D' leaf	Percentage dry weight of 'D' leaf
Block	4	3.51	379.22	1.60	0.20	3.53
Treatment	3	5.80 NS	5724.15*	62.64*	0.56*	0.54 NS
Error	12	2.38	1264.68	17.48	0.16	1.57
Total	19					

* - Significant at 5 per cent level
NS -Not significant

APPENDIX III

Analysis of variance for effect of shading on vegetative characters (one year after planting)

Source	Degrees of freedom	Mean squares				
		Leaf number	'D' leaf area	Fresh weight of 'D' leaf	Dry weight of 'D' leaf	Percentage dry weight of 'D' leaf
Block	4	2.52	1426.63	8.18	0.76	2.56
Treatment	3	4.77 NS	2964.21 *	31.05 NS	0.35 NS	2.56 NS
Error	12	3.50	756.49	26.17	0.52	1.51
Total	19					

* - Significant at 5 per cent level
NS - Not significant

APPENDIX III

Analysis of variance for effect of shading on vegetative characters

(one year after planting)

Source	Degrees of freedom	Mean squares				
		Leaf number	'D' leaf area	Fresh weight of 'D' leaf	Dry weight of 'D' leaf	Percentage dry weight of 'D' leaf
Block	4	2.52	1428.63	8.18	0.76	2.56
Treatment	3	4.77 NS	2964.21 *	31.05 NS	0.35 NS	2.56 NS
Error	12	3.50	756.49	26.17	0.52	1.51
Total	19					

* - Significant at 5 per cent level
NS - Not significant

APPENDIX IV

Analysis of variance for effect of shading on vegetative characters (at flowering)

Source	Degrees of freedom	Mean squares				
		Leaf number	'D' leaf area	Fresh weight of 'D' leaf	Dry weight of 'D' leaf	Percentage dry weight of 'D' leaf
Block	4	6.63	237.0	9.04	0.30	1.61
Treatment	3	3.78[NS]	4008.04**	48.20**	0.19[NS]	2.57*
Error	12	11.55	148.21	7.61	0.19	0.61
Total	19					

* - Significant at 5 per cent level
**- Significant at 1 per cent level
NS- Not significant

APPENDIX V

Analysis of variance for effect of shading on flowering

Source	Degre of freedom	Mean squares	
		Number of days from planting to flowering	Flowering percentage
Block	4	6.85	0.93
Treatment	3	1955.44**	3416.15**
Error	12	13.93	0.83
Total	19		

** - Significant at 1 per cent level

APPENDIX VI

Analysis of variance for effect of shading on time taken for fruit maturity and yield/hectare

Source	Degrees of freedom	Mean squares	
		Time taken for fruit maturity	Yield/hectare
Block	4	2.34	3.75
Treatment	3	281.14**	1637.76**
Error	12	1.94	7.07
Total	19		

** - Significant at 1 per cent level

APPENDIX VII

Analysis of variance for effect of shading on fruit characters

Source	Degrees of freedom	Mean squares								
		Fruit weight with crown	Fruit weight without crown	Length of fruit	Breadth of fruit	Canning ratio	Weight of peel	Weight of core	Weight of pulp	Peel/pulp ratio
Block	4	0.005	0.005	5.84	0.07	0.04	2187.54	2371.21	30035.84	0.005
Treatment	3	0.016 NS	0.11 **	17.07 **	0.61 NS	0.073 *	12774.57 **	6505.81 *	230803.31 **	0.027 **
Error	12	0.005	0.004	1.90	0.34	0.02	1893.09	1666.94	14617.77	0.003
Total	19									

* - Significant at 5 per cent level
** - Significant at 1 per cent level
NS - Not significant

APPENDIX VIII

Analysis of variance for effect of shading on crown characters

Source	Degrees of freedom	Mean squares		
		Weight of crown	Crown weight as percentage of fruit weight	Crown leaf number
Block	4	190.73	1.62	54.64
Treatment	3	51246.83**	215.58**	2290.9**
Error	12	509.66	4.31	16.04
Total	19			

** - Significant at 1 per cent level

APPENDIX IX

Analysis of variance for effect of shading on fruit quality

Source	Degrees of freedom	Mean square						
		Total soluble solids	Acidity	Reducing sugars	Non reducing sugars	Total sugars	Sugar/acid ratio	Ascorbic acid
Block	4	0.49	0.009	0.01	0.09	0.05	0.60	0.49
Treatment	3	0.56 NS	0.27**	1.95**	1.77**	6.02**	113.81**	7.62**
Error	12	0.40	0.003	0.11	0.11	0.08	0.46	0.23
Total	19							

** - Significant at 1 per cent level
NS - Not significant

APPENDIX X

Analysis of variance for effect of shading on nutrient status of leaves (six months after planting)

Source	Degrees of freedom	Mean squares				
		Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Block	4	0.02	0.0007	0.05	0.002	0.00075
Treatment	3	0.04 NS	0.0003 NS	0.12 NS	0.080**	0.0067**
Error	12	0.02	0.00031	0.08	0.0008	0.0005
Total	19					

** - Significant at 1 per cent level

NS - Significant

APPENDIX XI

Analysis of variance for effect of shading on nutrient status of leaves (one year after planting)

Source	Degree of freedom	Mean squares				
		Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Block	4	0.03	0.0001	0.40	0.001	0.001
Treatment	3	0.10**	0.0002NS	0.21NS	0.013**	0.006**
Error	12	0.01	0.00007	0.15	0.0009	0.0005
Total	19					

** - Significant at 1 per cent level
NS - Not significant

APPENDIX XII

Analysis of variance for effect of shading on nutrient status of leaves

(at flowering)

Source	Degrees of freedom	Mean squares				
		Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Block	4	0.01	0.0001	0.12	0.003	0.0005
Treatment	3	0.07**	0.0002NS	0.14NS	0.013**	0.0083**
Error	12	0.01	0.00007	0.08	0.002	0.0003
Total	19					

** - Significant at 1 per cent level
NS - Not significant

APPENDIX XIII

Analysis of variance for effect of shading on chlorophyll 'a', 'b' and total contents of leaves.

Source	Degree of freedom	Mean squares		
		Chlorophyll 'a'	Chlorophyll 'b'	Total chlorophyll
Block	4	0.00002	0.000002	0.00002
Treatment	3	0.00103**	0.00036**	0.00274**
Error	12	0.000016	0.000007	0.00002
Total	19			

** - Significant at 1 per cent level

APPENDIX XIV

Analysis of variance for effect of shading on sucker production and vegetative characters of suckers

Source	Degrees of freedom	Mean squares						
		Number of suckers/ plant	Height of suckers	Number of leaves/ sucker	'D' leaf area of sucker	Fresh weight of 'D' leaf of sucker	Dry weight of 'D' leaf of sucker	Percentage dry weight of 'D' leaf of sucker
Block	4	0.003	5.14	6.36	48.78	0.33	0.07	1.98
Treatment	3	0.04**	388.09**	59.18**	270.10*	1.09*	0.11NS	3.08NS
Error	12	0.001	4.56	7.56	46.17	0.26	0.04	1.67
Total	19							

* - Significant at 5 per cent level
**- Significant at 1 per cent level
NS - Not significant

APPENDIX XV

Analysis of variance for effect of shading on flowering of Ethrel treated plants

Source	Degrees of freedom	Mean square		
		Number of days from planting to flowering	Percentage of flowering	Time taken for fruit maturity
Block	4	0.32	2.05	2.40
Treatment	3	378.13**	866.67**	279.63**
Error	12	2.85	4.92	0.74
Total	19			

** - Significant at 1 per cent level

APPENDIX XVI

't' test for comparaing the percentage of flowering in Ethrel treated and non treated plants, under different intensities of shade.

Treatments	$\bar{d} = \frac{\Sigma d}{n}$	$Sd = \sqrt{\frac{\Sigma d^2 - \frac{(\Sigma d)^2}{n}}{n}}$	n	Computed 't' = $\frac{\lvert \bar{d} \rvert}{Sd/\sqrt{n-1}}$
1. 0 per cent shade	-1.99	1.27	5	3.13 Significant
2. 25 per cent shade	-0.196	0.34	5	1.15 Not significant
3. 50 per cent shade	1.714	0.49	5	6.99 Significant
4. 75 per cent shade	0.242	0.121	5	4.0 Significant

Note: 't' test was done after transferming the data into angles.

EFFECT OF SHADE ON GROWTH AND FRUITING IN PINEAPPLE

BY

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ABSTRACT OF A THESIS

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COLLEGE OF HORTICULTURE

Vellanikkara, Trichur.

1979

ABSTRACT

The present investigations were carried out in the College of Horticulture, Kerala Agricultural University during the years 1976-1979. The object of the study was to find out the effects of shading on the growth, flowering and fruiting behaviour of pineapple variety 'Kew'.

The treatments consisted of four levels of shade viz., 0, 25, 50 and 75 per cent. Shading was provided by coconut leaves on erected pandals over the plants and the intensity adjusted by using an 'Aplab' lux meter periodically.

The number of leaves produced per plant was not influenced by shading. In fact the leaf area was found to increase especially at the later stages of growth under shade. Dry matter accumulation in the leaves also was not reduced considerably in shade indicating the capacity of pineapple to tolerate shade.

Early, uniform and increased flowering was noticed in plants grown under shade. Percentage of flowering was maximum at 50 per cent shade which probably indicated that the shade tolerance limit of pineapple is upto 50 per cent. Ethrel was found to exhibit an inhibitory effect on flowering in the case of plants grown under shade above 25 per cent intensity.

Crown growth of fruits was greatly enhanced by shade treatments and therefore the contribution of crown weight to the total fruit weight was higher in the shaded plants. Fruit weight with crown was comparable in shade and in open. Developmental pattern of fruits was not found to be influenced by shade treatments.

Quality of the fruits in general, was decreased by shading. The acidity increased with shade intensity while the sugar and ascorbic acid contents decreased.

Nitrogen content of leaves increased by shading, during the later stages of growth. The shaded leaves also possessed higher magnesium and lower calcium contents at all stages of estimation. Chlorophyll 'a', 'b' and total contents of leaves increased as the intensity of shade increased. Destruction of chlorophyll in the leaves in the open as evidenced by the yellowish appearance of leaves was not noticed under shade.

Number of suckers produced per plant was not considerably affected by shading. Suckers produced by shaded plants were more vigorous than those produced by plants grown in the open.