THE INFLUENCE OF DEFOLIATION AND DEBLOSSOMING ON GROWTH AND RUNNER PRODUCTION IN STRAWBERRY (*FRAGARIA ANANASSA* DUTCH.) IN KENYA.

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

Ngugi — 17th Nov 87

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This thesis has been submitted for examination with my approval as University supervisor.

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To my parents,

Muthoni and Duncan Ngugi.

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ABSTRACT

The aim of this study was to use some physical manipulations on strawberry plants with the objective of increasing the propagative material under the Kenyan climatic conditions.

Defoliation alone promoted runner production in Tufts during 1980 short rains season and in Tufts and Tioga during 1981 long rains season. Defoliation alone or in combination with deblossoming failed to increase runner production in Aiko in both seasons. Deblossoming alone failed to stimulate runner production in Tioga and Aiko during 1980 short rains season and in Tufts and Aiko during 1981 long rains season compared to the control plants. Defoliated Tuft plants produced more runner plants than any other treatment in the 3 cultivars in both seasons. The number of runner plants decreased in deblossomed Tioga and Aiko plants during 1980 short rains season when compared to the control plants.

Deblossoming increased branch crown development in Tufts and Tioga plants but failed in Aiko plants in both seasons. Defoliation alone decreased the number of branch crowns in Tufts and

Tioga and decreased branch crown development only in Tioga during 1981 long rains season. Defoliated Tufts and Aiko plants were not significantly different in branch crown development from their control plants during 1981 long rains season

Defoliation alone or in combination with deblossoming decreased petiole length in all cultivars when compared to the control plants during 1980 short rains season. Deblossoming alone increased petiole length only in Tufts and failed in Tioga and Aiko during 1980 short rains season. There was no significant differences between the control and treated Aiko plants in petiole and runner lengths in 1980. In both seasons leaf area increased in defoliated and defoliated-deblossomed Tufts and Tioga plants. Deblossomed and control plants did not show any significant differences in leaf area in all cultivars in both seasons.

Deblossoming alone or in combination with defoliation did not inhibit the production of new flowers in the 3 cultivars in both seasons. However more flower clusters were produced in 1980 short rains season than during 1981 long rains season. In both seasons low flower production was associated with higher number of runners, more runner plants and large leaves.

INTRODUCTION

Strawberry (Fragaria ananassa Dutch.) production in Kenya has in the last ten years become an important enterprise in the horticultural industry. The crop was introduced into Kenya in the thirties from Europe by colonial farmers who used the fruit as a dessert. Before 1975, strawberries were mainly grown in home gardens for home consumption and domestic market. However, today, strawberry production has expanded tremendously and has been taken up by large scale farmers and commercial firms who mainly produce fresh fruit for the export market to Europe during winter months. Kenya is well placed for this European market in that strawberry plants come into fruiting during the European winter season.

However, one of the major problems limiting Kenya farmers from exploiting this market is the inability of the strawberry plants to produce enough propagative materials. For multiplication, farmers depend on uprooting existing plants and divide the crowns. This method does not give enough propagation material. Hence, farmers have continued to rely on imported propagation material from temperate countries. This creats a severe constraint in strawberry production because not enough material is imported at the time for planting and not all farmers can afford to import. For this reason, there is a growing demand among strawberry growers in Kenya to produce their own propgation material locally. The success in strawberry production is greatly dependent upon the ability of the available cultivars to produce enough propagation material either by crown division or daughter plants produced on runners.

Strawberry is a herbaceous perennial plant of temperate origin. It is propagated from branch crown and runner plants. The crown bears leaves at the nodes and an axillary bud at the axil of each leaf. Strawberry axillary buds may remain dormant and show no further growth; it may elongate markedly and form a runner; or it may elongate slightly and form a branch crown (Darrow, 1929; Guttridge, 1955; Dana, 1969). A runner produces a runner plant on every second node.

There are two kinds of strawberry plants commercially grown in the world (June and Everbearing cultivars). The June (seasonal) bearing cultivars induce and initiate flowers in short days (SD), and produce runners in long days (LD), while everbearing cultivars produce runners in LD and induce flowers in both LD and SD photoperiods (Dana, 1969). Generally, everbearing and a few June bearing cultivars are shy runner producers. In Kenya, only the everbearing cultivars have performed well in growth and fruiting.

In the tropics, runnering of strawberry is limited because there are no areas where LD conditions occur. Everbearing straberry cultivars grown in Kenya induce flowers throughout the year because Kenya has SD condition all year round. The available everbearing cultivars such as Tuft; Tioga and Aiko are however difficult to propagate due to limited runner production.

The objective of this study was to investigate the possibility of increasing propagation material in everbearing strawberry cultivars under tropical conditions. Physical manipulations such as defoliation, deblossoming or a combination of both were conducted to investigate their influence on improving runner production in 3 strawberry cultivars.

LITERATURE REVIEW

The Influence of Photoperiod on Vegetative Growth and Flowering in Strawberry.

It has been widely documented that photoperiod influences the growth habit of the strawberry plant (Darrow, 1929; Guttridge, 1960). The total photoperiodic response can be separated into several measurable components. Among these components are leaf size, leaf area, petiole length, runner and runner plants production, flower induction and initiation and branch crown formation.

Darrow (1929) reported that LD promoted vegetative growth by increasing leaf area, petiole length, runner production and the development of runner plants and inhibited flower induction. Short days stimulated flower induction, branch crown formation and development of small leaves and retarded runner production (Darrow, 1929; Guttridge, 1960; Dana, 1969). Other investigators reported similar results when they exposed strawberry plants to LD and SD photoperiods (Darrow, 1937; Hartmann, 1947; Smeets, 1955, 1956; Guttridge, 1959, 1968; Piringer, 1963; Dennis *et al.*, 1970; Tafazoli and Shybany, 1978). Petiole length, leaf size and runner production all increased with increasing day length while at the same time the number of flowers initiated decreased (Darrow and Waldo, 1934; Darrow, 1937; Guttridge, 1959, 1960, 1968; Leshem and Koller, 1966; Dana, 1969).

Dana (1969) reported that when strawberry plants were exposed to day lengths greater than 14 hours with warm temperature they produced many runners and few flowers. Darrow (1929) observed that strawberry plants seemed vegetative growth when they were exposed to 16 hours of light. Photoperiods shorter than 14 hours inhibited runner production and stimulated branch crown formation (Guttridge, 1959, 1960; Dana, 1969). The promotive effect of LD on vegetative growth was reduced by low temperatures, nutrient starvation and drought; and any of those factors promoted flower formation (Darrow, 1929, 1937; Guttridge, 1960, 1968). Thus flowering and branch crown development were stimulated by factors that reduced vegetative growth (Darrow, 1929).

Different cultivars have been shown to respond differently to photoperiod (Darrow, 1929; Smeets, 1956). Dennis *et al.* (1970) working with Geneva everbearing cultivar, reported that runner production was not affected by day lengths between 12 and 18 hours. However, he reported that runner development was promoted by day length greater than 12 hours in June bearing cultivars. This confirmed earlier findings by Borthwick and Parker (1952) who reported that LD promoted runner production in June bearers.

Darrow and Waldo (1934) and Darrow (1937) classified June bearing cultivars as SD plants and everbearing cultivars as LD plants on the basis of their flowering responses. June bearing cultivars induce flowers in SD and form runners in LD. Everbearing cultivars flower throughout the year, and have no specific photoperiodic requirement for flower formation (Darrow, 1929). Darrow (1929) and Guttridge (1960) reported that in the everbearing strawberry cultivars, flower buds formed in axillary buds in place of runners. Runner production was inversely proportional to flowering and was promoted in June bearers by LD and high temperatures (Darrow, 1929, 1937).

The Influence of Temperature on Vegetative Growth and Flowering in Strawberry.

Temperature has been shown to exert a great influence on strawberry growth (Darrow, 1937; smeets, 1955, 1956; Guttridge, 1955, 1959, 1960, 1968; Hartmann, 1947; Leshen and Koller, 1966; Dana, 1969). Hartmann (1947) and Smeets (1955) reported that runner formation was primarily dependent on temperature. Smeets (1956) confirmed this when he found that at 20°C and above strawberry plants produced runners in shorter days than at lower temperatures. This was in contrast to the results reported by Darrow (1937) that regardless of temperature, SD favoured flower induction and in hibited runner production. Temperatures at 20°C were not effective in promoting runner production in SD but stimulated the plants to flower freely (Darrow, 1937).

Long day condition and low temperature (12°c) reduced vegetative growth and flower induction occured, but temperature above 20°C increased vegetative growth and delayed flower induction and initiation (Darrow, 1937). At 20°C, lengthening the day length to 16 hours completely changed the growth response from flower initiation to runner production but shortening the day length to 14 hours at the same temperature stimulated flower initiation (Dana, 1969). Darrow (1929, 1937) and Guttridge (1960) reported that low temperature limited both vegetative growth and flower initiation. Smeets (1956) reported that the number of runners and leaves increased with increasing day temperatures. He concluded that at higher temperatures, the production of runners continued for a longer period than at lower temperatures.

Darrow (1937) and Smeets (1956) observed strawberry varietal differences in response to temperature effects on vegetative growth and flowering. Darrow (1937) reported that 6 plants of cultivar Klondile produced 74 runners and no flowers at 20°c with 16 hours light period, but 6 plants of cultivar Burril produced 23 runners and 24 flower clusters at similar temperature and day length.

For a given photoperiod, high temperatures induced LD responses and low temperatures induced SD responses in everbearing strawberry cultivars (Guttridge, 1959, 1960). This supported earlier observations of temperature effects on strawberry plant growth by Darrow (1937); on runner formation by Smeets (1955, 1956) and Went (1937); and flower initiation by Hartman (1947).

The Influence of Cultivar and Plant Age on Vegetative Growth and Flowering in Strawberry.

It is known that different strawberry cultivars vary in their extent of runner production (Loomis, 1938; Smeets, 1956) and older and larger runner plants produce more fruit (Schilleter and Richey, 1930; Morrow and Beaumont, 1932; Rogers, 1931; Davis and Blair, 1938). Older runner plants have also been associated with greater runner development (Davis, 1922; Darrow, 1929; Jahn and Dana, 1970) and large leaf area (Darrow, 1939; Jahn and Dana, 1970).

Large-sized cutlivars have been reported to produce many flowers (Darrow, 1929), large leaf areas (Darrow, 1937) and have good root development (Jahn and Dana, 1970) while small-sized cultivars have been reported to be slower in runner production (Darrow, 1929; Peacock, 1939; Jahn and Dana, 1970) and produced fewer flowers (Morrow and Darrow, 1940; Rogers and Edgar, 1938).

Sproat et al. (1936) and Morrow and Darrow (1940) reported that leaf production was related to the number of flowers produced and correlations as high as 0.75 were reported between leaf area and the weight of fruit produced by the plant.

Darrow (1929) reported that due to genetic characteristic there were many everbearing cultivars that did not produce any runners even in long day length and high temperatures. Runners production by different strawberry cultivars vary greatly in their length, thickness, rate and extent of production (Guttridge, 1960). Similar variations in vegetative growth and flowering have been reported in plants of the same cultivar (Darrow, 1929, 1937; Guttridge, 1959).

Influence of Nutrition on Vegetative Growth and Flowering in Strawberry

A close relationship between the nutritional condition of the plant and runner and flower production has been reported in strawberry (Darrow, 1929, 1937; Guttridge 1960, 1968; Tafazoli and Shybany, 1978). Earlier, Darrow (1929) reported an increased runner production when manure was added to the soil. Much later, Tafazoli and Shybany (1978) reported that nitrogen fertilizers increased runner production and delayed flowering in Gem, an everbearing cultivar.

Darrow (1937) reported that strawberry plants grown in pots formed flowers earlier than those grown in the field because they depleted their nutrients. Reduced plant vigour favoured flower initiation while higher plant vigour promoted vegetative growth and delayed flowering (Darrow, 1929, 1937; Guttridge, 1960; Dana, 1969). Darrow (1937) observed that when strawberry plants experienced drought condition, they initiated flowers and showed little vegetative growth.

Influence of Flowering on Vegetative Growth of Strawberry.

The antagonistic relationship between flowering and vegetative growth has long been recognised in strawberry, as in most fruiting plants. Chadler (1913) and Darrow (1929) reported a marked reduction in runner production from fruiting plants. Fruiting plants had reduced leaf size, leaf number (Guttridge, 1960; Jahn and Dana, 1966), and delayed leaf and runner emergence (Moore and Scott, 1965; Jahn and Dana, 1966). Arney (1953) reported that the initiation of an inflorescence delayed the appearance of the next leaf primodia which was on an axillary position. Later, Dana (1969) reported that the terminal flower bud prevented vegetative extension of the main vegetative axis. In everbearing cultivars, Darrow (1937) reported that the depressing effect of fruiting on vegetative growth was reduced by irrigation.

Increased runner production by deblossoming has been reported (Rogers, 1931; Scott and Marth, 1953; Robertson and Wood, 1954; Denisen, 1959).

Mann (1930) found that deblossomed strawberry plants developed more vigorous root system and better vegetative growth than fruiting plants. Rogers (1931) reported an increased plant size, and Scott and Marth (1953) reported an increased number of leaves as a result of deblossoming.

Deblossoming was found to have little effect upon runner initiation in everbearing strawberry cultivars (Dennis and Bennett, 1969) but increased yields in runner plants and promoted flowering in Geneva and Gem plants (Dennis and Bennett, 1969; Tafazoli and Shybany, 1978). From the results of Dennis and Bennett (1969) and Tafazoli and Shybany (1978) flowering did not compete with runner initiation, but instead competed with initiation of new flowers and devlopment of runner plants. These results are contrary to those of Moore and Scott (1965) and Denisen (1959) who reported the beneficial effect of deblossoming on runner production in both June and everbearing strawberries. Runner formation and flower induction have been reported to be independent processes (Dennis and Bennett, 1969; Tafazoli and Shybany, 1978) and both processes occured together provided the environmental conditions were favourable for both processes (Hartmann,1947).

Role of Leaves in Plant Growth

Photoperiodic inducing factor is received by the leaves and the response occurs at the growing apices (Hartmann,1947; Guttridge, 1960, 1968). Guttridge (1960, 1968) reported that a chemical stimulus was translocated from the leaves to the growing points. Plants in LD condition stimulated vegetative growth and delayed flower initiation in plants grown in SD condition when attached to each other by runners (Guttridge, 1959). Contrasting results were reported by Hartmann(1947) who observed that plants held under LD condition became reproductive when portions of the leaf area were exposed to SD condition. The larger the leaf area exposed to SD condition the higher the number of flowers initiated in plants in LD condition (Hartmann,1947). However, according to Guttridge (1960, 1968) no flower inducing substance were detected either in the leaf or in other parts of the plant.

Abscisic acid (ABA) was found in extracts of dormant strawberry leaves (Gabr and Guttridge, 1968). En-Atably *et al.* (1967) reported that ABA induced flower formation in strawberry and in some cases inhibited runner formation. However, Kender *et al*. (1971) reported that ABA did not function as a florigenic hormone although it reduced runner production and petiole length.

Although increased GA activity has been reported in strawberry leaves under LD condition (Leshem and Koller, 1966) there are suggestions that GA does not move from leaves to the growing apices. Guttridge (1968) reported that GA was not present in the assimilate stream which moves from the leaves to the growing points during LD condition since it would have promoted stem elongation as it moved to the growing apices of the strawberry plant.

Strawberry are defoliated after fruiting to encourage vegetative growth (Darrow, 1929, Denisen, 1959). The specific role played by leaves in the growth and development of strawberry plants has not been clearly documented. Hartmann (1947) reported the movement of a vegetative stimulus from non-defoliated to defoliated plants. Mason (1967) reported an increased flower initiation in defoliated Cambridge favourite and Royal Sovereign cultivars. Defoliation of old strawberry leaves did not decrease the perception area of the photoperiodic stimulus but decreased the photosynthetic area and probably removed a source of the growth inhibitor.

MATERIALS AND METHODS

Plant Material

Three everbearing strawberry cultivars namely Tuft, Tioga and Aiko were used for the study. The plants were imported from the USA in 1976. Hence, the plants were continuously subdivided into individual branch crowns and planted every 2 years. During this period, Tufts and Tioga were classified as moderate runner producers and Aiko a shy runner producer under Kenyan conditions. Healthy individual branch crowns obtained by subdivision of two year old mother plants were chosen and planted for use in this study.

Site Description

The study was conducted at the ADC farm at Limuru, Kenya, 1^{1} 08' S and 36° 40' E. The farm is situated at 2100 m above sea level and receives a mean annual rainfall of 1156.4 mm. Rainfall pattern is bimodial with short rains falling in September, October and November and long rains falling in March, April and May. Between May and September there is a cold cloudy dry spell with night temperatures going below 10°C. A hot dry spell occurs between December and March. July and August are the coldest months while December, January and February are the hottest. Annual minimum and maximum temperatures are 10.8°C and 20.8°C, respectively. However, sometimes day temperatures may rise up to 25°C during the hot months. The soil is red clay loam of volcanic origin with good drainage. The pH ranges from 4.5 and 5.5. A fine seedbed was prepared by ploughing twice, rotavating once and finally removing remnant weeds with forked hoes.

Planting and Spacing

The first experiment was planted on raised beds on 21st May, 1980; the second on 2nd February, 1981. Individual and uniform branch crowns were selected and planted in holes 10 cm deep at a spacing of 60 cm between rows and 50 cm within rows. At planting, 60 g of Double Superphosphate (P_2O_5, 46%) was added in each planting hole and thoroughly mixed with soil to reduce direct contact of fertilizer with plant roots. Roots were trimmed to 6 cm and only 3 youngest leaves were retained on the plant. Plants were placed in the holes with their roots straight and the soil was filled in and firmly pressed around them. Nitrogen fertilizer in the form of Calcium Ammonium Nitrate (26% N) was side dressed twice at the rate of 20 g per plant one and and two months after planting.

Experimental Design

Experiments were laid out in a randomized complete block design. There were 12 treatment combinations replicated 3 times. Each cultivar received 4 treatments. The treatments were: control defoliation, deblossoming, defoliation and deblossoming. 12 plots measuring 3.5 m long, 0.6 m wide were marked in the three replicates which were separated by a clean hand weeded path 1.0 m wide. Two rows, each with 7 plants, constituted a plot but the effective plot comprised of only 10 plants; 2 plants on each side of a plot served as guard plants. Irrigation was done every 3 days. Other routine field maintenance like weeding, spraying against disease and pests were carried out when necessary.

Plants were allowed to establish themselves for 2 months before old leaves, flower buds and open flowers were removed manually from all plants. Leaves were removed weekly, leaving at least 3 fully expanded and actively growing ones. Deblossoming was done whenever flowers were noticed. Treatment application started 2 months after planting when all plants had attained almost equal size and vigour. In the control, no leaves or flowers were removed after the start of treatment application. Plants grew normally and consequently formed flowers, fruits branch crowns, runners and runner plants. In the defoliation treatment leaves were removed weekly starting with the old ones and progressively moving upwards leaving 5 leaves on every plant. Leaves were plucked off the plant with their petioles. The number of leaves removed and their total weight was recorded. A total of 16 leaf pickings were done during the experimental period in both experiments. Defoliated plants initiated flowers and formed fruits just like the control plants. Deblossomed plants developed a normal leaf canopy but all flower buds and open flowers were continuously removed manually as they appeared. Flower buds and flowers were plucked off the plant with their flower stalks. Deblossoming was done continuously up to the termination of the experiment 5 months after planting. The number of flower clusters removed were recorded. In defoliation-deblossoming treatment both leaf and flower removal were carried out in the same way as in defoliation and deblossoming treatments.

Data Collected and Observations

The data collected were the total number of runner plants and branch crowns in each plot. Number of leaves removed and their fresh weights were only taken in defoliation and defoliation-deblossoming treatments while the number of flower clusters removed were recorded only in deblossoming and defoliation-deblossoming treatments. Averages of petiole length, runner length and leaf area were the average of 10 plants per plot. Leaf area was taken using a planimeter. Meteorological data, which included minimum and maximum temperatures and the amount of rainfall during the experimental period were recorded.

Data on the number of runners, runner plants, branch crowns, average petiole length, average runner length and average leaf area were subjected to analysis of variance. In order to test the differences between means, treatment means were ranked from the largest to the lowest and separated by using Duncan's New Multiple range test. A difference between any two means was considered significant if its value exceeded the corresponding least significant range (LSR) value and not significant if it was less than the corresponding LSR. Similar letters designated treatments which were not significantly different.

RESULTS

Runner Production

The results of 1980 short rains season are reported in Table 1. Defoliation alone promoted runner production in Tufts but failed in Tioga and Aiko. Deblossomed Tufts plants produced fewer runners than defoliated and defoliated-deblossomed plants. Although there was no significant difference in runner production between the defoliated and defoliated-deblossomed plants, the number of runners were slightly higher in defoliated-deblossomed plants. Deblossoming alone promoted runner production only in Futss and failed in Tioga and Aiko cultivars compared to the control plants. However, although deblossomed Tufts plants produced more runners than the control, there was no significant increase in runner production when deblossoming was done in combination with defoliation. Control plants in the 3 cultivars produced few or no runners during the short rains season (Table 1).

Table 1. Effect of defoliation and deblossoming in 3 strawberry cultivars during the 1980 short rains season (June - November). Number of runners per 10 plants.

Cultivar	Treatments			
	Control	Defoliated plants	Deblossomed plants	Defoliated and Deblossomed plants
Tuft	3.30a*	40.30c	19.30b	43.00c
Tioga	0.00a	0.00a	0.00a	1.70a
Aiko	0.30a	0.30a	0.30a	3.70a

*Mean separation by Duncan's new multiple range test, 5% level.

Generally, Tioga and Aiko plants responded poorly to defoliation, deblossoming or a combination of both treatments in runner production. None of the treatments markedly improved runner production in the 2 cultivars. However, when the 2 cultivars were defoliated and deblossomed concurrently a few runners were produced, but the increase was not significantly different from the control plants. Tioga plants only produced runners when they were deblossomed and defoliated.

All the 3 strawberry cultivars produced runners during the 1981 long rains season (Table 2). In Aiko, control plants produced more runners than defoliated, deblossomed and defoliated-deblossomed ones, however the difference was not significant. Defoliation alone stimulated more runner production compared to the control, deblossomed and defoliated-deblossomed treatments in Tufts plants. When defoliation was done in combination with deblossoming, runner production decreased significantly in Tufts and Aiko plants (Table 2). Deblossoming alone promoted runner production in Tufts compared to the control but failed in Tioga and Aiko plants. Tioga produced

Table 2. Effect of defoliation and deblossoming on runner production in 3 strawberry cultivars during the 1981 long rains season (February - June). Number of runners per 10 plants.

Cultivar	Treatments			
	Control	Defoliated plants	Deblossomed plants	Defoliated and Deblossomed plants
Tufts	49.00bc*	99.00f	67.67d	82.33e
Tioga	46.67bc	50.67bc	36.33b	58.67cd
Aiko	10.33a	6.33a	1.33a	7.67a

*Mean separation by Duncan's new multiple range test, 5% level.

runners in all treatments. However, the controls, defoliated and deblossomed plants did not show any significant difference in runner production. The control and deblossomed plants produced fewer runners than either defoliated or defoliated-deblossomed plants.

In Aiko, there was no significant difference in runner production among treatments (Table 2). Deblossomed plants produced the least number of runners while controls had the highest. Runner production was low and late in Aiko in both seasons compared to Tioga and Tufts plants (Table 3 and 4). Runner production in Tuft and Aiko control plants was not significantly different. Runners emerged during the first month of planting in Tuft and Tioga and in the second month in Aiko (Table 4).

Runner Plants

There was a close relationship between the number of runners and runner plants produced by the 3 strawberry cultivars in both seasons. A correlation coefficient of 0.98 was obtained

Table 3. Monthly runner production in 3 strawberry cultivars from May to November, 1980. Number of runners per 10 plants.

Month	Treatments											
	Control			Defoliated plats			Deblossomed			Defoliated and Deblossomed plants		
	Tufts	Tioga	Aiko	Tufts	Tioga	Aiko	Tufts	Tioga	Aiko	Tufts	Tioga	Aiko
May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
June	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
August	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	6.4	0.0	0.0	52.0	0.0	1.0	19.0	0.0	0.0	48.0	3.0	3.0
October	4.0	0.0	1.0	33.0	0.0	0.0	27.0	0.0	1.0	51.0	2.0	6.0
November	0.0	0.0	0.0	18.0	0.0	0.0	12.0	0.0	0.0	9.0	0.0	5.0
Total	10.0	0.0	1.0	121.0	0.0	1.0	58.0	0.0	1.0	129.0	5.0	14.0
Mean	1.4b*	0.0a	0.14a	17.3d	0.0a	0.14a	8.3c	0.0a	0.14a	18.4d	0.7a	2.0b

* Mean separation within row by Duncan's new multiple range test, 5% level.

Table 4. Monthly runner production in 3 strawberry cultivars from February to June 1981. Number of runners per 10 plants.

Month	Treatments											
	Control			Defoliated plants			Deblossomed plants			Defoliated and Deblossomed plants		
	Tufts	Tioga	Aiko	Tufts	Tioga	Aiko	Tufts	Tioga	Aiko	Tufts	Tioga	Aiko
February	2.0	1.0	0.0	11.0	2.0	0.0	3.0	0.0	0.0	7.0	3.0	0.0
March	38.0	29.0	3.0	56.0	45.0	1.0	39.0	17.0	0.0	42.0	24.0	5.0
April	55.0	45.0	7.0	69.0	65.0	5.0	59.0	48.0	1.0	62.0	60.0	11.0
May	30.0	36.0	13.0	87.0	30.0	7.0	70.0	34.0	1.0	77.0	69.0	4.0
June	22.0	34.0	8.0	74.0	12.0	6.0	29.0	10.0	2.0	59.0	20.0	30.0
Total	147.0	140.0	31.0	197.0	152.0	19.0	200.0	109.0	4.0	247.0	176.0	23.0
Mean	21.0b	20.0b	4.4a	42.3d	21.7b	2.7a	28.6c	15.6b	0.6a	35.3d	25.1bc	3.3a

*Mean separation within row by Duncan's new multiple range test, 5% level.

in Tufts plants in 1980 and 0.81 in 1981 (Fig. 1). Similar correlation coefficients were obtained in Tioga and Aiko plants. High correlation coefficients were recorded in 1980 short rains season than during 1981 long rains season. This difference was mainly because in 1980 short rains season every runner mostly produced a single runner plant. But in 1981 long rains season one runner produced in some cases more than one runner plant. Those cultivars which produced the highest number of runners produced more runner plants (Table 5).

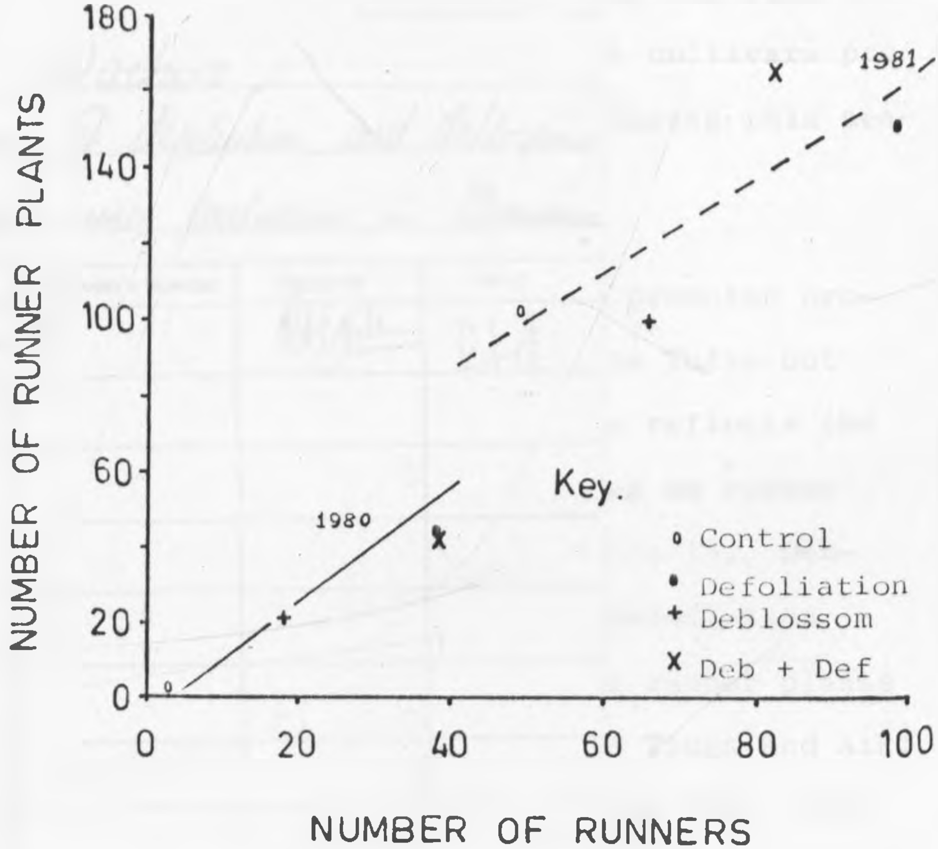
Defoliation promoted runner production and consequently increased the number of runner plants compared to the control and deblossomed plants in Tufts. When defoliation was combined with deblossoming, runner plants production was not significantly different from that of the defoliated Tufts plants. Defoliated Tufts plants produced more runner plants than defoliated-deblossomed plants. In Aiko and Tioga cultivars, there was no significant difference in runner plants production between the controls, defolia-

Table 5. Effect of defoliation and deblossoming on the number of runner plants produced by 3 strawberry cultivars during 1980 short rains season (June - November). Number of runner plants per 10 plants.

Cultivar	Treatments			
	Control	Defoliated plants	Deblossomed plants	Defoliated and Deblossomed plants
Tufts	3.30a*	46.30c	24.30b	43.30c
Tioga	0.00a	0.00a	0.70a	5.30a
Aiko	0.70a	0.30a	0.00a	3.70a

*Mean separation by Duncan's new multiple range test, 5% level.

Fig. 1: The relationship between the number of runners and runner plants in Turft cultivar during 1980 short rains season and 1981 long rains season.



TUFTS 1980	TUFTS 1981
r = 0.9882	r = 0.8132
a = -0.6229	a = 35.2625
b = 1.2300	b = 1.3022

ted, deblossomed and defoliated-deblossomed plants. This might be expected since in the 2 cultivars, no treatment significantly increased runner production during the 1980 short rains season. Thus, both cultivars produced few or no runner plants during this season (Table 5.)

Deblossoming alone promoted production of runner plants only in Tufts but failed in Tioga and Aiko. This reflects the promotive effect of deblossoming on runner production in Tufts plants (Table 1). Deblossoming in combination with defoliation failed to promote production of runner plants in Tioga and Aiko. Deblossomed Tioga and Aiko plants produced no runners during 1980 short rains season and therefore produced no runner plants during this season (Table 5). Compared to the control, a higher number of runner plants were produced by deblossomed, defoliated and defoliated-deblossomed Tufts plants.

Production of runner plants in 3

strawberry cultivars in 1981 long rains season are reported in Table 6. Defoliation alone increased runner production in Tioga and Tufts plants, thus, promoted production of runner plants compared to the control plants. Deblossomed and control plants of Tufts and Tioga did not show any significant difference in runner plants production. Defoliated and defoliated-deblossomed Aiko plants did not show any increase in runner plants production compared to the control plants. However, fewest runner plants were recorded in deblossomed aiko plants (Table 6).

Tufts plants produced the highest number of runner plants while Aiko plants produced the least. In this study more runner plants were produced in 1981 long rains season than in 1980 short rains season. Runner plants production followed a similar pattern as the production of runners in both seasons. Treated and untreated Aiko plants produced the least number of runner plants in both seasons compared to the other 2 cultivars. Tufts produced the

Table 6. Effect of defoliation and deblossoming on the number of runner plants produced by 3 strawberry cultivars during 1981 long rains season. (February - June). Number of runner plants per 10 plants.

Cultivar	Treatments			
	Control	Defoliated plants	Deblossomed plants	Defoliated and Deblossomed plants
Tufts	105.00c*	153.33d	100.67c	152.33d
Tioga	72.33b	102.00c	63.67b	112.33c
Aiko	11.67a	8.33a	3.33a	14.33a

*Mean separation by Duncan's new multiple range test, 5% level.

highest number of runner plants in both seasons (Table 5 and 6) while Tioga produced runner plants only during the 1981 long rains season.

Branch Crown Production

Deblossoming alone promoted branch crown development in Tufts and Tioga plants during 1980 short rains season. In Aiko, the number of branch crowns produced by deblossomed plants was not significantly different from that produced by the control plants (Table 7). Deblossomed Tioga plants produced the highest number of branch crowns during 1980 short rains season. Defoliation alone decreased branch crown developemnt in Tufts and Tioga plants. Also, when defoliation was done in combination with deblossoming, the number of branch crowns decreased in Tufts and Aiko plants. Untreated plants in all cultivars did not differ significantly in branch crown development during the 1980 short rains season. Defoliation in combination with deblossoming decreased the number of branch crowns in Tioga compared to the defoliated plants. Branch crown development was highest in Tioga plants (Table 7).

Table 7. Effect of defoliation and deblossoming on branch crowns development in 3 strawberry cultivars during the 1980 short rains season. Number of branch crowns per 10 plants.

Cultivar	Treatments			
	Control	Defoliated plants	Deblossomed plants	Defoliated and Deblossomed plants
Tufts	42.00ab*	39.30ab	85.30c	44.00ab
Tioga	57.00b	31.30a	133.30d	83.33c
Aiko	57.00b	48.00ab	58.00b	42.70ab

*Mean separation by Duncan's new multiple range test, 5% level.

From the results of 1981 long rains season reported in Table 7, deblossoming alone increased the number of branch crowns in Tufts, and Tioga plants and failed in Aiko. Deblossomed Tufts and Tioga plants produced more branch crowns than defoliated and the control plants. Deblossoming in combination with defoliation failed to increase branch crown development in all cultivars compared to the controls and defoliated plants (Table 8).

Defoliation alone reduced branch crown development in Tioga plants. However, defoliated Tufts and Aiko plants were not significantly different in branch crown development compared to their control plants. Tioga plants produced the highest number of branch crowns while Tufts produced the least during 1981 long rains season. Nevertheless more branch crowns were produced in all cultivars during 1981 long rains season than 1980 short rains season, however, branch crown development was not as conspicuous as runner production.

In both seasons, runner production and

Table 8. Effect of defoliation and deblossoming on branch crown development in 3 strawberry cultivars during 1981 long rains season. Number of branch crowns per 10 plants.

Cultivar	Treatments			
	Control	Defoliated plants	Deblossomed plants	Defoliated and Deblossomed plants
Tufts	48.67a	60.33ab	68.00b	60.33ab
Tioga	114.00d	84.33c	122.67e	82.33c
Aiko	66.33b	65.33b	64.00b	55.67ab

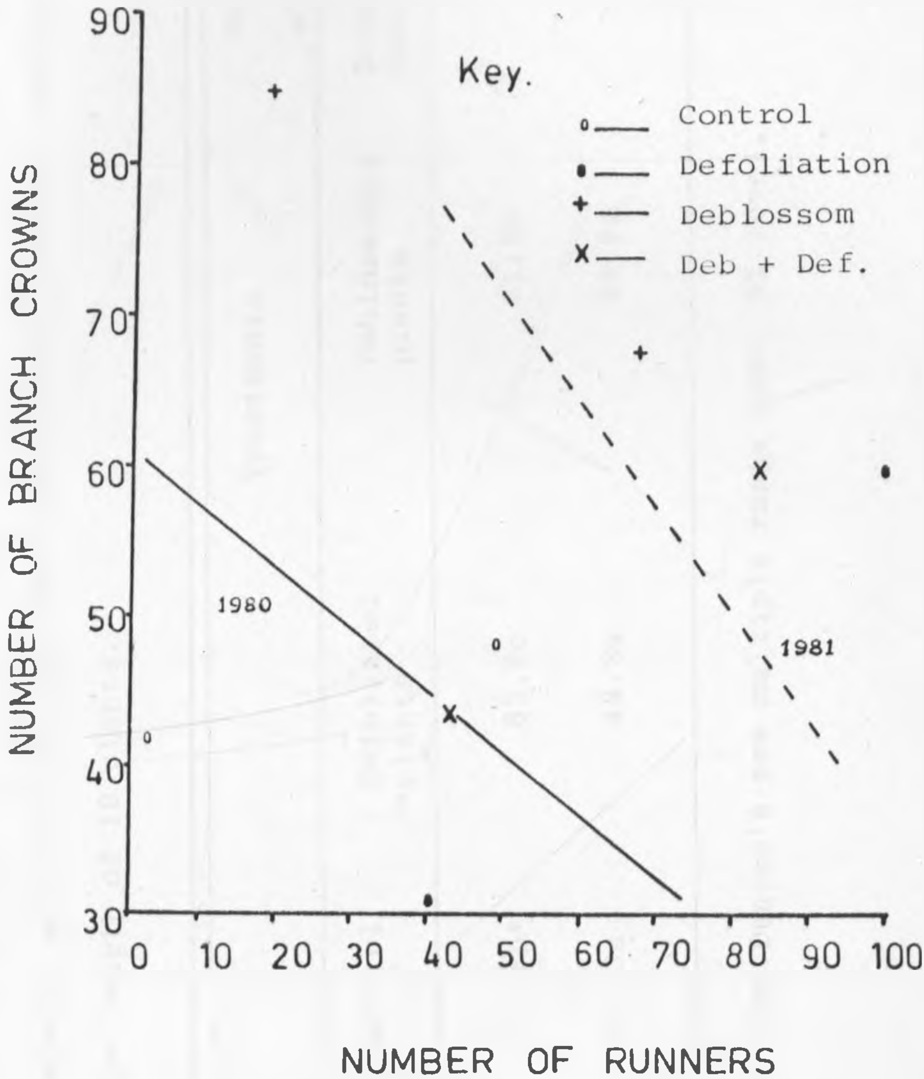
*Mean separation by Duncan's new multiple range test, 5% level.

branch crowns development were negatively correlated in the 3 strawberry cultivars. The correlation coefficients in Tufts were -0.32 in 1980 short rains season and -0.62 in 1981 long rains season (Fig. 2). Similar correlation coefficients are reported for Tioga and Aiko plants. It was evident from the results of this study that cultivars which produced more runners produced fewer branch crowns.

Runner Length

During 1980 short rains season Tioga failed to produce any runners in the control, defoliated and deblossomed plants, therefore data summarised on Table 9 represent average length in Tufts and Aiko plants only. Treated and untreated Aiko plants did not differ in runner length during 1980 short rains season. Untreated Tufts plants produced shorter runners than the treated plants but there was no significant differences in runner length among the treated plants (Table 9). Tufts plants produced longer runners when compared to Aiko

Fig.2 : The relationship between the number of runners and number of branch crowns in Turft cultivar during 1980 short rains season and 1981 long rains season.



TUFTS 1980	TUFTS 1981
r = -0.3187 a = 61.3519 b = 0.4042	r = -0.6232 a = 105.3368 b = 0.8014

Table 9. Effect of defoliation and deblossoming on runner length (cm) in 2 strawberry cultivars during 1980 short rains season. Average runner length of 10 plants.

Cultivar	Treatments			
	Control	Defoliated plants	Deblossomed plants	Defoliated and Deblossomed plants
Tufts	55.8b*	62.6c	61.3c	64.4d
Aiko	42.3a	42.3a	39.8a	39.7a

*Mean separation by Duncan's new multiple range test, 5% level.

plants in all treatments.

Runner length in 1981 long rains season increased markedly in all cultivars when compared to 1980 short rains season. Defoliation increasd runner length in Tufts but failed in Aiko. Untreated, deblossomed and defoliated-deblossomed Tufts plants produced runners which were not significantly different in length (Table 10). In Tioga and Aiko there was no difference in runner length among the treatments. Control plants in Tioga produced the longest runners within that cultivar and defoliated-deblossomed plants in Aiko produced the shortest runners.

Petiole Length

Defoliation alone or in combination with deblossoming decreased petiole length in all cultivars compared to deblossomed and the controls during 1980 short rains season (Table 11). Deblossoming increased petiole length in Tufts and there was no difference between deblossomed and control plants in petiole length in Tioga and Aiko. Defoliated Aiko plants had the shortest

Table 10. Effect of defoliation and deblossoming on runner length (cm) in 3 strawberry cultivars during 1981 long rains season. Average runner length of 10 plants.

Cultivar	Treatments			
	Control	Defoliated plants	Deblossomed plants	Defoliated and Deblossomed plants
Tufts	70.20c	75.10d	67.00c	67.40c
Tioga	61.00b	60.70ab	56.90a	57.40ab
Aiko	60.20ab	59.60ab	58.10ab	56.50a

*Mean separation by Duncan's new multiple range test, 5% level.

Table 11. Effect of defoliation and deblossoming on petiole length (cm) in 3 strawberry cultivars during 1980 short rains season. Average petiole length of 10 plants.

Cultivar	Treatments			
	Control	Defoliated	Deblossomed plants	Defoliated and Deblossomed plants
Tufts	10.60cd*	9.30ab	13.40e	7.90a
Tioga	11.80cde	8.30a	12.20de	8.50ab
Aiko	9.10ab	7.40a	8.80ab	8.30a

*Mean separation by Duncan's new multiple range test, 5% level.

petioles while deblossomed Tufts plants had the longest petioles. There was no significant difference in petiole length between treated and untreated Aiko plants. Defoliated Tufts and Tioga plants did not differ in petiole length. In general, the control and deblossomed plants produced leaves with onger petioles than defoliated-deblossomed plants in the 3 cultivars.

Defoliation and deblossoming stimulated petiole elongation in Tuft but failed in Tioga and Aiko during 1981 long rains season (Table 12). There was no significant differences in petiole length between defoliated and deblossomed Tioga plants. Defoliation in combination with deblossoming stimulated the production of leaves with shorter petioles than the control Tuft plants. In Tioga and Aiko plants, there was no significant difference in petiole length between treated and untreated plants. None of the treatments affected petiole length in both cultivars. Nevertheless, petiole length doubled during 1981 long rains season in Tufts and Tioga cultivars in all treatments as compared to the

Table 12. Effect of defoliation and deblossoming on petiole length (cm) in 3 strawberry cultivars during 1981 long rains season. Average petiole length of 10 plants.

Cultivar	Treatments			
	Control	Defoliated plants	Deblossomed plants	Defoliated and Deblossomed plants
Tufts	20.83c*	25.67d	24.50d	15.67b
Tioga	20.00c	18.17bc	19.87c	19.00c
Aiko	11.79a	12.27a	12.27a	11.77a

*Mean separation by Duncan's new multiple range test, 5% level.

1980 short rains season results. Aiko plants did not show a big increase in petiole length in 1981 as compared to Tufts and Tioga.

Leaf Area

Defoliation alone or in combination with deblossoming increased leaf area in Tufts and Tioga during 1980 short rains season (Table 13). Deblossomed and control plants did not show any difference in leaf area in all cultivars. In Aiko, leaf area was not affected by any of the treatments. During 1980 short rains season, Aiko plants had the smallest leaf area and the largest leaf area was recorded in defoliated and defoliated-deblossomed Tuft plants.

Leaf area increased markedly in all cultivars in 1981 long rains season (Table 14), Tufts plants had the largest leaf area in all treatments while Aiko plants had the smallest leaves. Defoliation stimulated large leaf areas in all cultivars compared to control plants. There was no significant difference in leaf area

Table 13. Effect of defoliation and deblossoming on leaf area (cm^2) in 3 strawberry cultivars during 1980 short rains season. Average leaf area of 10 plants.

Cultivar	Treatments			
	Control	Defoliated plants	Deblossomed plants	Defoliated and Deblossomed plants
Tufts	24.10c*	26.30cd	23.70c	28.80d
Tioga	22.00b	23.50c	20.60b	23.40c
Aiko	15.80a	15.90a	14.80a	15.70a

*Mean separation by Duncan's new multiple range test, 5% level.

Table 14. Effect of defoliation and deblossoming on leaf area (cm^2) in 3 strawberry cultivars during 1981 short rains season. Average leaf area of 10 plants.

Cultivar	Treatments			
	Control	Defoliated plants	Deblossomed plants	Defoliated and Deblossomed plants
Tufts	41.30b*	58.90f	50.00d	54.30e
Tioga	37.60b	52.30de	45.50c	45.50c
Aiko	21.10a	33.00b	29.00a	29.90ab

*Mean separation by Duncan's new multiple range test, 5% level.

among the controls, deblossomed and defoliated-deblossomed Aiko plants. In Tufts and Tioga there was a significant decrease in leaf when plants were both defoliated and deblossomed. There was no difference in leaf area between the control plants in Tioga and Tufts.

In 1981, long rains season, leaf area increased by over 50% in the 3 cultivars compared to the data recorded in 1980 short rains season. During 1981 long rains season Tufts plants had the largest leaf areas followed by Tioga and Aiko in all treatments. Defoliated and defoliated-deblossomed treatment produced leaves with the argest leaf areas compared to deblossomed and control plants in all the 3 cultivars. Compared to the control plants deblossomed Tufts and Tioga plants had larger leaf areas, however, there was no significant difference in leaf area between control and deblossomed Aiko plants.

Flower Formation

From the results summarized on Table 15, flower induction occured in all cultivars throughout the year. Deblossoming alone or in combination with defoliation did not inhibit the induction of new flowers when the old ones were removed. The strawberry cultivars used in this study produced more flowers during 1980 short rains season than during 1981 long rains season (Table 15 and 16). More flower clusters were removed in Tioga plants during the 1980 short rains season than in Tufts and Aiko plants.

In 1981, however the highest number of flower clusters were removed in Aiko and Tioga plants. High flower induction was associated with low runner production and pronounced branch crown development, shorter runners and leaf petioles (Table 15 and 16). Low flower induction was associated with a higher number of runners and long runners and leaf petioles. Deblossoming of plants during 1980 short rains and 1981 long rains season did not retard or promote vegetative growth in all cultivars.

Table 15. Influence of deblossoming on vegetative growth in 3 strawberry cultivars during 1980 short rains season. Data collected from 10 plants.

Parameter	Cultivars		
	Tufts	Tioga	Aiko
Flower clusters removed	206a*	274c	243b
Number of runners	19.3b	0.0a	0.3a
Number of runner plants	24.3b	0.0a	0.70a
Number of branch crowns	85.3b	133.3c	58.0a
Petiole length cm	13.4b	12.7b	8.8a
Leaf area (cm^2)	23.7b	20.6b	14.8a
Runner length (cm)	24.5c	19.9b	12.3a

*Mean separation within row by Duncan's new multiple range test, 5% level.

Table 16. Influence of deblossoming on vegetative growth in 3 strawberry cultivars during 1981 long rains season. Data collected from 10 plants.

Parameter	Cultivars		
	Tufts	Tioga	Aiko
Flower clusters removed	141b*	153c	132a
Number of runners	66.7c	36.3b	1.3a
Number of runners plants	100.7c	63.7b	3.3a
Number of branch crowns	68.0a	122.7b	64.0a
Petiole length (cm)	24.5c	19.9b	12.3a
Leaf area (cm^2)	50.0b	45.5b	29.0a
Runner length (cm)	67.6b	56.9a	58.1a

*Mean separation within row by Duncan's new multiple range test, 5% level.

Number of Leaves

More leaves were produced in 1981 long rains season than in 1980 short rains season (Tables 17 and 18). Varietal differences were noticed in leaf production with Tioga producing the highest and Aiko producing the least. Those conditions which stimulated flower induction retarded leaf production in all cultivars in both seasons. However, this phenomena was more pronounced in Tioga and Tufts. High leaf production and large leaf areas were associated with prolific runner production. This indicated that when the environmental conditions were favourable for vegetative growth, all parameters of growth would increase.

Leaves play a significant role in the growth of plants. Processes such as photosynthesis occur in the leaves. They also manufacture some of the plant hormones and perceive photoperiodic stimulus in the case of strawberry. From the results of this study, leaf removal did not affect flower induction or runner initiation. Defoliated plants were observed to grow more vigorously, especially during the 1981 long rains season.

Table 17. Influence of defoliation on vegetative growth in 3 strawberry cultivars during 1980 short rains season. Data collected from 10 plants.

Parameters	Cultivars		
	Tufts	Tioga	Aiko
Number of leaves removed and Fresh weight in brackets	254.0b* (23.4g)	261.0b (25.7g)	203.0a (18.2g)
Number of runner	40.3b	0.0a	0.3a
Number of runner plants	46.3b	0.0a	0.3a
Number of branch crowns	31.3a	48.0b	39.3ab
Petiole length	9.3a	8.3a	7.4a
Runner length	62.6b	-	42.3a

*Mean separation within row by Duncan's new multiple range test, 5% level.

DISCUSSION

The Influence of Defoliation on Growth and Runner Production in Strawberry.

The growth pattern of 3 strawberry cultivars studied showed a remarkable improvement in runner production when plants were defoliated. In this study, defoliation alone stimulated runner production in Tufts in both 1980 short rains and 1981 long rains seasons. During 1981 long rains season there was a tremendous increase in runner production in defoliated Tufts plants compared to 1980 short rains season. This could have mainly been due to the high temperatures in February, March, April and May, 1981. In Aiko and Tioga cultivars there was no significant difference in runner production between defoliated and control plants. Both Aiko and Tioga cultivars produced few or no runners at all during 1980 short rains season. However, when plants were exposed to warm temperatures in 1981 there was a marked improvement in runner production in all treatments in Tioga cultivar. Irrespective of season and physical manipulation done on Aiko plants, there was very little improvement in runner production. These differences in runner production showed that strawberry cultivars behave differently when exposed to similar conditions. These results also indicated that defoliation would only improve runner production in Tufts cultivar under warm conditions and have little or no effect in Tioga and Aiko cultivars. Many workers have reported that various strawberry cultivars respond differently when exposed to similar conditions (Darrow, 1929; Guttridge, 1960; Leshem and Koller, 1966; and Dennis and Bennette, 1969).

In this study, the number of runners and runner plants produced were found to be positively correlated. The number of runner plants produced followed a similar pattern to runner production. This relationship was expected because runner plants are produced only when the strawberry are producing runners. Those factors that stimulated runner production also favoured runner plant development. Defoliation increased the production of runner plants in Tufts in both seasons and had no effect in Tioga and Aiko. A higher number of runner plants was produced during 1981 long rains season than during 1980 short rains season in Tufts cultivar due to the warm temperatures in 1981.

Correlation coefficients as high as high as 0.99 and 0.94 between number of runners and runner plants produced were recorded in defoliated Tufts during 1980 short rains and 1981 long rains seasons, respectively. Jahn and Dana (1970) reported a correlation coefficient of 0.87 between the number of runners and runner plants produced by 'Sparkle' cultivar.

Petiole length decreased in defoliated Tufts plants compared to the control plants during 1980 short rains season. However, during the same season there was no difference in petiole length between treated and untreated Tioga and Aiko plants. It is possible that since defoliated Tufts plants were actively producing runners, most of the photosynthesates manufactured by the plants could have been diverted to the development of axillary buds thus resulting to short petioles. Hartmann (1947) and Guttridge (1968) reported that photosynthesates may shift to the actively growing sites at the expense of the other growing points. However, during 1981 long rains season petiole length increased tremendously in Tufts and Tioga in all treatments compared to 1980 short rains season. In Aiko, petiole length increased only slightly during 1981 long rains season as compared to 1980 short rains season. The results clearly showed that environmental conditions prevalent during February, March, April and May were very ideal for stimulation of vegetative growth.

High temperatures have been widely reported to stimulate vegetative growth in strawberry (Smeets, 1955, 1956; Leshem and Koller, 1966; Dana, 1969; Guttridge, 1960, 1968). Hartmann (1947) and Smeets (1955) reported that vegetative growth was primarily dependent on the prevailing temperature. Therefore, in this study, low temperature during 1980 short rains season may have reduced vegetative growth and high temperatures during 1981 long rains season may have favoured vegetative growth in Tufts and Tioga in all treatments.

At Limuru, Kenya, temperatures may drop as low as 7°C between May and August. During this period, the average minimum and maximum temperatures are 10°C and 18°C respectively. No runners were formed in any treatment during this period in all cultivars. However, when temperatures started to rise in September (20°C) runners started to emerge in defoliated Tufts plants only. Other cultivars remained reproductive and produced flowers freely. It was only after 5 months (September) after planting that Aiko plants produced some runners in defoliated-deblossomed plants. Tioga failed to produce any runners in any treatment during 1980 short rains season. From these results, it was apparent that not only does temperature affect the number of runners produced but also delays their production. Cultivars responded differently to temperature changes with defoliated Tufts plants recovering early from the cold season and produced runners while both defoliated and deblossomed Tioga plants completely failed to recover. These results agree with the early reports by Smeets (1955) who reported varietal differences in runner production when strawberry cultivars were exposed to different day temperatures.

In this study changes in temperature seemed to have greatly affected the growth behaviour of Tufts and Tioga than the actual treatments. For example, low temperatures (18°C) in June, July and August 1980 may have delayed and reduced runner production and may have stimulated flowering and branch crown development in all cultivars whether or not defoliated or deblossomed. High temperatures (>20°C) in February, March and April 1981 may have stimulated vigorous vegetative growth and reduced flower induction in defoliated and control plants in Tufts and Tioga cultivars. It could be concluded that while defoliation increased runner production in Tufts in both seasons, warm temperatures were necessary for better runner initiation. Darrow (1929) reported that different strawberry cultivars showed different growth responses when exposed to similar temperature conditions. Similar observations were noted in this study, whereby Tioga and Tufts plants were producing runners freely in all treatments during 1981, while treated Aiko plants showed little improvement in runner production.

Many workers have reported the presence of different types of growth substances in strawberry leaves. Increased amounts of GA_3 were reported in elongated strawberry petioles (Leshen and Koller, 1966) and leaves of both flowering and non-flowering strawberry plants (Guttridge, 1968; Kender et al., 1971). Abscisic acid has also been detected in mature strawberry leaves (Leshem and Koller, 1966). These reports showed that strawberry leaves play a significant role in the synthesis of indogenous hormones influencing plant growth.

Since plant hormones play an important role in the growth and development of plants, it is probably the balance between various hormones that determines which responses are expressed by plants when exposed to various growing conditions. Vegetative promoting hormones may be increased by long day lengths (Guttridge, 1960, 1968), high temperature (Guttridge, 1968; Kender *et al.*, 1971), high moisture content (Kender *et al.*, 1971) and physical manipulation of plants such as defoliation (Hartmann, 1947). In this study during 1980 short rains season, Tufts cultivar produced 40.3 runners in defoliated plants, 19.3 in deblossomed plants and 3.3 in control plants. It is very likely in this study that defoliation of mature leaves may have removed more ABA than GA_3, since old leaves contain more ABA. Thus, changing the hormonal balance in favour of GA_3 which stimulates cell division and elongation in axillary buds to form runners.

When exogenous GA_3 was applied to strawberry plants, it stimulated responses similar to those of LD (Moore and Scott, 1965 ; Guttridge, 1960, 1968; Dennis and Bennett, 1969; Tafazoli and shybany, 1978). On the other hand, when abscisic acid was applied to strawberry plants it stimulated flowering (Kender et al., 1971). From these results it may be concluded that treatments which remove flower inducting hormones will stimulate vegetative growth in some strawberry cultivars such as Tufts under warm temperatures. It is possible that endogenous ABA acts as an inhibitory substance in the development of strawberry axillary buds and prevents cell division and elongation. Waithaka et al., (1978) working with growth hormones in strawberry reported that cytokinins could overcome dormancy of axillary buds and GA_3 stimulated their elongation to become runners.

It may be concluded in this study that defoliation of mature strawberry leaves in Tufts shifts the hormonal balance in favour of GA_3 and cytokinins to stimulate runner production, however, for this response to occur the ideal temperature condition has to be met. In this study, during the cool season Tufts produced 40.3 and 3.3 runners in defoliated and control plants respectively, while the same cultivar produced 99.0 and 49.0 runners in defoliated and control plants respectively during 1981 warm season.

The Influence of Deblossoming on Growth and Runner Production in Strawberry.

In this study, deblossomed plants produced fewer runners than defoliation during 1980 short rains and 1981 long rains season in all cultivars. For example, deblossomed Tufts plants produced 19.3 runners while defoliated and control plants produced 40.3 and 3.3 runners respectively during 1980 season. Similarly, although there was a tremendous improvement in vegetative growth during 1981 long rains season deblossomed Tufts plants produced 66.7 runners while defoliated plants and control plants produced 99.0 and 49.0 runners respectively.

Hartmann (1947) and Moore and Scott (1965) reported increased runner production in deblossomed June and everbearing cultivars. The deblossoming effect on runner production was greater in the everbearing Gem and Geneva cultivars than in June bearing Earlidawn cultivar (Moore and Scott, 1965). Similar results were reported by Denisen (1959) who observed that after flower removal the plants became more vegetative and produced runners. However, according to the results reported in this study deblossoming was not as effective as defoliation in increasing runner production in the 3 strawberry cultivars in both seasons. Deblossoming alone or in combination with defoliation was not effective in stimulating runner production in all cultivars in both seasons. Thus, our results agree with those of Dennis and Bennett (1969) and Tafazoli and Shybany (1978) who reported that deblossoming did not increase runner production in everbearing Gem and Geneva cultivars. Indeed, Tafazoli and Shybany (1978) reported a 25% decrease in runner production in deblossomed strawberry plants. It has been suggested that runner production and flower induction are physiologically independent processes and each can occur independently of the other (Kender et al., 1971). In this study, provided the environment conditions were favourable both processes were observed to occur together without any inhibiting the other. This was mainly observed to occur when plants were grown under warm conditions. However, when plants were exposed to cool temperatures they remained reproductive and showed little vegetative growth regardless of the treatemnt. The positive response on runner production reported by Hartmann (1947), Moore and Scott (1965) and Denisen (1959) following deblossoming could be explained by the fact that they used few treatments where they compared only deblossomed and non-deblossomed plants.

In this study, it was found that provided strawberry platns were defolaited there was no need of deblossoming since there would be no improvement in the production of runners. However, if the farmers aim is to increase plant size, then deblossoming would be recommended. Dana (1969) reported that deblossomed strawberry plants tended to have a better branch crown development than non-deblossomed ones. In this study, petiole length was also noted to increase in deblossomed plants. Similar results were reported by Hartmann (1947) who noted that plants which were deblossomed had longer leaf petioles than non-deblossomed ones. The main cause for long petioles may be explained to occur due to the overcrowding of leaves which results to competition of nutrients and light. Although deblossoming was done continuously, flower induction continued upto the end of the experiments. Flower induction was not depressed by deblossoming in any of the strawberry cultivars studied.

Guttridge (1960, 1968) reported that most of the growth hormones are concentrated in the leaves and not in the flowers. This implies that the removal of flowers from a strawberry plant may not affect the growth response shown by the plants. It may also explain why deblossomed plants did not differ much from the control plants in runner production, and petiole length. Our results indicated that deblossoming alone or in combination with defoliation would be of no practical value in increasing runner production especially where strawberry plants are exposed to low temperatures. Defoliation or deblossoming or in combination could not overcome the effects of low temperature in inhibiting vegetative growth. It is possible that during low temperatures plant growth inhibitors or their balances with growth promoters would favour reduced growth and prolific flowering. It was found that for defoliation and deblossoming to stimulate vegetative growth in strawberry, plants should be exposed to warm temperatures first. The longer the plants are exposed to warm temperatures the higher the vegetative growth.

CONCLUSIONS AND RECOMMENDATIONS

In this study defoliation was found to be a better treatment in increasing propagative material in strawberry plants than deblossoming. Defoliation alone or in combination with deblossoming increased runner production and runner plant development in Tufts plants in both seasons and in Tioga during the long rains season. Defoliation failed to stimulate runner production in Aiko in any of the seasons. This lack of response to deblossoming and defoliation indicated that Aiko would not be able to produce runners in tropical regions. Defoliation reduced branch crown number in Tioga and Aiko in both seasons and had no effect in Tufts compared to the control plants. For defoliation to increase propagative materials, it was observed that the plants needed to be grown during the warm periods. When the results obtained during the cool season and the warm seasons were compared it showed clearly that strawberry plants grown in warm season produced more propagative materials and showed vigorous vegetative growth than those grown during the cool season. Strawberry plants intended for producing propagative materials could produce more runners if they were planted in November which is the starting month of the warm season in Kenya. Plants grown and defoliated during warm months of November, December, January, February and March would produce enough propagative material in Tufts and Tioga. Therefore, in Kenya, areas which would be recommended for producing strawberry propagative material would include Kibwezi, Machakos, Naivasha, Baringo and Thika because of their warm temperatures during those months. It is recommended that defoliation be done every other week during the vegetative growth period.

Deblossoming was found to be of no practical importance in increasing propagative materials from runners in strawberry cultivars studies in both cool and warm season. Even when plants were both deblossomed and defoliated the number of runners produced was similar to those produced by defoliated plants. Deblossoming increased the number of branch crowns in all cultivars. This resulted to larger propagating plants. This is desirable because larger plants produce more fruits than smaller plants. Deblossoming is always recommended for the newly set plants for better establishment and development of bigger plants which yield higher.

There is a possibility of increasing propagative material by GA_3 application and exposure to longer day lengths in Kenya, however, these methods are very expensive for any ordinary farmer. For the Kenyan farmer to produce enough propagative material, he needs to consider the choice of the cultivars, the time of planting, suitable areas for growing and physical manipulations of plants such as defoliation.

In summary, among the strawberry cultivars studied, defoliated Tufts and Tioga plants proved capable of producing enough planting materials under warm conditions. Aiko proved to be a poor runner producer and is not likely to produce enough propagation materials under Kenyan conditions. It is suggested that more studies on various aspects of strawberry growth and flowering could be conducted using more cultivars. The effects of temperature on strawberry growth under tropical conditions should be evaluated.

REFERENCES

ARNEY, S.F. 1953. The initiation growth and emergence of leaf primodia in *Fragaria*. *Annals Bot.* *17:* 477-492.

BORTHWICK, H.A. and M.W. PARKER, 1952. Light in relation to flowering and vegetative development. *Rept. 13th Inter. Hort. Cong. 1952.* 801-810.

CHANDLER, W.H. 1913. Commercial fertilizers for strawberries. *Mo. Agric. Exp. Sta. Bul.* 113.

DANA, M.W. 1969. The strawberry plant. *Proc. Amer. Soc. Hort. 122:* 109-121.

DARROW, G.M. 1929. Development of runners and runner plants in the strawberry. *U.S. Dept. Agric. Tech. Bul. 122.*

________________, 1937. Interrelationship of temperature and photoperiod in the production of runners and fruit buds in strawberry. *Proc. Amer. Soc. Hort. Sci. 34:* 360-363.

________________, and G. F. WALDO, 1934. Response of strawberry varieties and species duration of the light period. *U.S. Dept. Agric. Tech. Bul. 453.*

DAVIS, M.B. 1922. Correlation in the strawberry. Proc. Amer. Soc. Hort. Sci. 19: 260-262.

________________, and D.S. BLAIR, 1938. The strawberry and its cultivation in Canada. Dom. Can. Dept. Agric. Pub. 621.

DENISEN, E.L. 1959. Stimulate runner growth of strawberry plants. Iowa Farm Sci. 14(3): 14.

DENNIS, F.G. and H.O. BENNETT. 1969. Effects of gibberellic acid and deflowering upon runner and inflorescence development in an everbearing strawberry. J. Amer. Soc. Hort. Sci. 94: 534-537.

________________, J. LIPECKI, and CHI-LI KIANG, 1970. Effects of photoperiod and other factors upon flowering and runner development of three strawberry cultivars. J. Amer. Soc. Hort. Sci. 95(6): 750-754.

EN-ANTABLY, H.M.M., P.F. WAREING, and J. HILLMAN. 1967. Some physiological responses to abscisin. Planta. 73: 74-90.

GABR, O.M.K. and C.G. GUTTRIDGE. 1968. Identification of abscisic acid in strawberry leaves. Planta. 78: 305-309.

GUTTRIDGE, C.G. 1955. Observation on the shoot growth of cultivated strawberry plant. J. Hort. Sci. 30: 1-11.

________________, 1959. Further evidence for growth promoting and flower inhibiting hormone in strawberry. Annals Bot. 23: 612-621.

________________, 1960. The physiology of flower formation and vegetative growth in the strawberry. Bulletin de L'institut Agronomique et des Stations de Recherches Gembloux Hors serie. Vol. II: 941-948.

________________, 1968. Hormonal physiology of growth regulation in strawberry, Soc. Chem. Ind. Lond. Mo. 31: 157-169.

HARTMANN, H.T.1947. Some effects of temperature and photoperiod on flower formation and runner production in the strawberry. Plant physiol. 22: 407.

JAHN, O.L. and M.N. DANA. 1966. Fruiting and growth of the strawberry plant. Proc. Amer. Soc. Hort. Sci. 88: 352-359.

________________, and ____________, 1970. Effects of cultivar and plant age on vegetative growth of the strawberry. Amer. J. Bot. 57: 993-999.

KENDER, W.J.; S. CARPENTER, and J.W. BRAUN. 1971. Runner formation in everbearing strawberry as influenced by growth-promoting and inhibiting substances. _Ann. Bot. 35:_ 1045-52.

LESHEM, Y.; and D. KOLLER, 1966. The control of flowering in the strawberry _Fragaria ananassa_ Dutch _Ann. Bot. 30:_ 587-95.

LOOMIS, N.H. 1938. Runner production of strawberry varieties. _Proc. Amer. Soc. Hort. Sci. 35:_ 508-510.

MANN, C.E.T. 1930. Studies in the root and shoot growth of the strawberry. V. The origin, development and functions of the roots of the cultivated strawberry. _Annals. Bot. 44:_ 55.

MASON, D.T. 1967. Inflorescence initiation in the strawberry. II. Some effects on date and severity of post-harvest defoliation, _Hort. Sci. 7:_ 97-104.

MOORE, J.N. and D.H. SCOTT, 1965. Effects of gibberellic acid and blossom remvoal on runner production of strawberry varieties. _Proc. Amer. Soc. Hort. Sci. 87:_ 240-244.

MORROW, E.B. and J.H. BEAUMONT. 1932. Effect of age of plant on flower production and yield of strawberry in North Carolina. Proc. Amer. Soc. Hort. Sci. 28: 206-210.

__________, and G.M. DARROW. 1940. Relation of number of leaves in November to number of flowers the following spring in the Blackmore strawberry. Proc. Amer. Soc. Hort. Sci. 37: 571-573.

PEACOCK, N.D. 1939. The relative importance of various factors influencing profit in strawberry production. Mich Agric. Exp. Sta. Tech. Bul. 162.

PIRINGER, A.A. and D.H. SCOTT. 1963. Interrelation of photoperiod, chilling and flower cluster and Runner production by strawberries. Proc. Amer. Soc. Hort. Sci. 84: 295-301.

ROBERTSON, M. and C.A. WOOD. 1954. Studies on the development of the strawberry. II. Stolon production by first year plants in 1954. J. Hort. Sci. 29: 231-234.

ROGERS, W.S. 1931. Strawberry cultivatrion strain, time of planting and deblossoming. Ann. Rept. East Malling Sta. 1928-30. Suppl. II. 52-64.

__________, and J.L. EDGAR, 1938. Strawberry cultivation studies. I. The performance of individual plants of clonal families. J. Pom. Hort. Sci. 16: 63-90.

SCHILLETTER, J.C. and W.H. RICHEY. 1931. Four years study on the time of flower bud formation in Dunlope strawberry. Proc. Amer. Soc. Hort. Sci. 27: 175-178.

SCOTT, D.H. and P.C. MARTH. 1953. Effect of blossom removal on growth of newly set strawberry plants. Proc. Amer. Soc. Hort. Sci. 62: 255-256.

SMEETS, L. 1955. Runner formation on strawberry plants in autumn and winter, II. Influence of light intensity on the photoperiodic behaviour. Euphytica. 4: 204-244.

__________, 1956. Influence of temperature on runner production in five strawberry varieties. Euphytica. 5: 13-7.

SPROAT, B.B., G.M. DARROW, and J.M. BEAUMONT, 1936. Relation of leaf area to berry production in the strawberry. Proc. Amer. Soc. Hort. Sci. 33: 389-392.

TAFAZOLI, E. and B. SHYBANY. 1978. Infuence of nitrogen, deblossoming and growth regulator treatments on growth, flowering and runner production of the 'Gem' everbearing strawberry. J. Amer. Soc. Hort. Sci. 103: 372-374.

WAITHAKA, K., B.E. STRUCKMAYER and M.N. DANA. 1978. Growth substances and growth of stolons and leaves. J. Amer. Soc. Hort. Sci. 103: 480-482.

APPENDIX

Appendix 1A. Raw data on number of runners per plot in three strawberry cultivars during 1980 short rains seasons.

Treatment	Blocks Cultivar	Block 1	Block 2	Block 3	Treat Totals	Treat $\bar{X}$ Totals
	Tufts	5.0	4.0	1.0	10.0	3.30
Control	Tioga	0.0	0.0	0.0	0.0	0.00
	Aiko	0.0	0.0	1.0	1.0	0.30
	Tufts	54.0	41.0	26.0	121.0	40.30
Defoliated plants	Tioga	0.0	0.0	0.0	0.0	0.00
	Aiko	0.0	0.0	1.0	1.0	0.30
	Tufts	27.0	19.0	12.0	58.0	19.30
Deblossomed plants	Tioga	0.0	0.0	0.0	0.0	0.00
	Aiko	0.0	1.0	0.0	1.0	0.30
	Tufts	54.0	34.0	41.0	129.0	43.0
Defoliated and Deblossomed plants	Tioga	0.0	0.0	0.0	5.0	1.70
	Aiko	4.0	7.0	0.0	11.0	3.70
Block Totals		144.0	111.0	82.0	337.0	

Appendix 1B. Analysis of variance on number of runners per plot in three strawberry cultivars during 1980 short rains season.

Source	df	ss	ms	Observed f	Required 5%	F 1%
Total	36	12395.00				
Level	1	3154.69				
Blocks	2	160.39	80.20	2.93	3.44	5.72
Treatments	11	8476.98	770.03	28.11**	2.27	3.19
Error	22	602.94	27.41			

CV = 55.9%

SE 0 0.87

Appendix 1C. Raw data on number of runners per plot in three strawberry cultivars during 1981 long rains season.

Treatments	Blocks cultivar	Block 1	Block 2	Block 3	Treat Totals	Treat $\bar{X}$
Control	Tufts	52.0	45.0	50.0	147.0	49.00
	Tioga	55.0	46.0	39.0	140.0	46.67
	Aiko	3.0	7.0	21.0	31.0	10.33
Defoliated plants	Tufts	104.0	80.0	113.0	297.0	99.00
	Tioga	49.0	54.0	49.0	152.0	50.67
	Aiko	2.0	5.0	12.0	19.0	6.33
Deblossomed plants	Tufts	82.0	55.0	63.0	200.0	66.67
	Tioga	33.0	36.0	40.0	109.0	36.33
	Aiko	1.0	1.0	2.0	4.0	1.33
Defoliated and Deblossomed plants	Tufts	82.0	90.0	75.0	247.0	82.33
	Tioga	62.0	64.0	50.0	176.0	58.67
	Aiko	7.0	3.0	13.0	23.0	7.67
Block Totals		532.0	486.0	527.0	1545.0	

Appendix 1D. Analysis of variance on number of runners produced in three strawberry cultivars during 1981 long rains season.

Source	df	ss	ms	Observed f	Required F 5%	1%
Total	36	101091.00				
Level	1	66305.25				
Blocks	2	106.17	53.09	0.75	3.44	5.72
Treatments	11	33112.08	3010.19	42.28**	2.27	3.19
Error	22	1566.50	71.20			

CV = 19.7%

SE = 1.41

Appendix 2A. Raw data on number of runner plants per plot in three strawberry cultivars during 1980 short rains season.

Treatment	Blocks Cultivar	Block 1	Block 2	Block 3	Treat Totals	Treat $\bar{X}$
Control	Tufts	5.0	4.0	1.0	10.0	3.30
	Tioga	0.0	0.0	0.0	0.0	0.00
	Aiko	0.0	0.0	2.0	2.0	0.70
Defoliated plants	Tufts	59.0	48.0	32.0	139.0	46.30
	Tioga	0.0	0.0	0.0	0.0	0.00
	Aiko	0.0	0.0	1.0	1.0	0.30
Deblossomed plants	Tufts	41.0	18.0	14.0	73.0	24.30
	Tioga	0.0	2.0	0.0	2.0	0.70
	Aiko	0.0	0.0	0.0	0.0	0.00
Defoliated and Deblossomed plants	Tufts	56.0	40.0	34.0	130.0	43.30
	Tioga	9.0	7.0	0.0	16.0	5.30
	Aiko	0.0	11.0	0.0	11.0	3.70
Block Totals		170.0	130.0	84.0	384.0	

Appendix 2B. Analysis of variance on number of runner plants produced in three strawberry cultivars during 1980 short rains season.

Source	df	ss	ms	Observed f	Required F 5%	1%
Total	36	15204.00				
Level	1	4096.00				
Blocks	2	308.67	154.39	3.85*	3.44	5.72
Treatments	11	9916.00	901.45	22.45**	2.27	3.19
Error	22	883.33	40.15			

CV = 59.3%

SE = 1.06

Appendix 2C. Raw data on number of runner plants per plot in three strawberry cultivars during 1981 long rains season.

Treatment	Blocks Cultivar	Block 1	Block 2	Block 3	Treat Totals	Treat $\bar{X}$
Control	Tufts	110.0	90.0	115.0	315.0	105.00
	Tioga	62.0	80.0	75.0	217.0	72.33
	Aiko	4.0	9.0	22.0	35.0	11.67
Defoliated plants	Tufts	144.0	152.0	164.0	460.0	153.33
	Tioga	90.0	110.0	106.0	306.0	102.00
	Aiko	2.0	14.0	9.0	25.0	8.33
Deblossomed plants	Tufts	102.0	90.0	110.0	302.0	100.67
	Tioga	59.0	65.0	67.0	191.0	63.67
	Aiko	2.0	1.0	7.0	10.0	3.33
Defoliated and Deblossomed plants	Tufts	140.0	160.0	157.0	457.0	152.33
	Tioga	112.0	120.0	105.0	337.0	112.33
	Aiko	16.0	9.0	18.0	43.0	14.33
Block Totals		843.0	900.0	955.0	2698.0	

Appendix 2D. Analysis of variance on number of runner plants produced in three strawberry cultivars during 1981 long rains season.

Source	df	ss	ms	Observed f	Required F 5%	Required F 1%
Total	36	303660.00				
Level	1	202200.10				
Blocks	2	522.73	261.37	4.36*	3.44	5.72
Treatments	11	99617.23	9056.11	150.94**	2.27	3.19
Error	22	1319.94	60.00			

CV = 10.3%

SE = 1.29

Appendix 3A. Raw data on number of branch crowns per plot in three strawberry cultivars during 1980 short rains season.

Treatment	Blocks Cultivar	Block 1	Block 2	Block 3	Treat Totals	Treat $\bar{X}$
Control	Tufts	44.0	43.0	39.0	126.0	42.00
	Tioga	68.0	46.0	57.0	171.0	57.00
	Aiko	56.0	39.0	76.0	171.0	57.00
Defoliated plants	Tufts	44.0	27.0	23.0	94.0	31.30
	Tioga	57.0	36.0	51.0	144.0	48.00
	Aiko	50.0	40.0	28.0	118.0	39.30
Deblossomed plants	Tufts	86.0	85.0	85.0	256.0	85.30
	Tioga	154.0	113.0	133.0	400.0	133.30
	Aiko	74.0	60.0	40.0	174.0	58.00
Defoliated and Deblossomed plants	Tufts	43.0	50.0	39.0	132.0	44.00
	Tioga	81.0	61.0	76.0	218.0	72.70
	Aiko	32.0	41.0	55.0	128.0	42.70
Block Totals		789.0	641.0	702.0	2132.0	

Appendix 3B. Analysis of variance on number of branch crowns produced in three strawberry cultivars during 1980 short rains season.

Source	df	ss	ms	Observed f	Required F 5%	1%
Total	36	155306.00				
Level	1	126261.78				
Blocks	2	922.05	461.03	3.73*	3.44	5.72
Treatments	11	25404.22	2309.47	18.69**	2.27	3.19
Error	22	2717.95	123.54			

CV = 18.7%

SE = 1.85

Appendix 3C. Raw data on number of branch crowns per plot in three strawberry cultivars during 1981 long rains season.

Treatment	Block Cultivar	Block 1	Block 2	Block 3	Treat Totals	Treat $\bar{X}$
	Tufts	52	48	46	146	48.67
Control	Tioga	120	110	112	342	114.00
	Aiko	70	56	73	199	63.33
	Tufts	60	64	57	181	60.33
Defoliated plants	Tioga	90	75	88	253	84.33
	Aiko	63	60	73	196	65.33
	Tufts	63	73	68	204	68.00
Deblossomed plants	Tioga	130	123	115	368	122.67
	Aiko	63	63	66	192	64.00
Defoliated and Deblossomed plants	Tufts	60	57	64	181	60.33
	Tioga	72	85	90	247	82.33
	Aiko	41	50	76	167	55.67
Block Totals		884	864	928	2676	

Appendix 3D. Analysis of variance on number of branch crowns produced in three strawberry cultivars during 1981 long rains season.

Source	df	ss	ms	Observed f	Required F 5%	1%
Total	36	217726.00				
Level	1	198916.00				
Block	2	178.67	89.34	1.47	3.44	5.72
Treatments	11	17294.00	1572.18	25.86**	2.27	3.19
Error	22	1337.33	60.79			

CV = 10.5%

SE = 1.30

Appendix 4A. Raw data on average petiole length (cm) in three strawberry cultivars during 1980 short rains.

Treatment	Blocks Cultivar	Block 1	Block 2	Block 3	Treat Totals	Treat $\bar{X}$
Control	Tufts	13.90	8.80	9.20	31.90	10.60
	Tioga	13.80	9.60	11.90	35.30	11.80
	Aiko	11.30	8.20	7.90	27.40	9.10
Defoliated plants	Tufts	10.60	8.30	9.10	28.00	9.30
	Tioga	8.40	6.90	9.50	24.80	8.30
	Aiko	7.60	6.40	8.10	22.10	7.40
Deblossomed plants	Tufts	15.70	13.20	11.40	40.30	13.40
	Tioga	13.40	11.30	11.90	36.60	12.20
	Aiko	11.10	8.40	7.00	26.50	8.80
Defoliated and Deblossomed plants	Tufts	7.70	8.10	8.00	23.80	7.90
	Tioga	9.10	8.40	8.00	25.50	8.50
	Aiko	8.30	8.10	8.40	24.50	8.30
Block Totals		130.9	105.70	110.40	347.00	

Appendix 4B. Analysis of variance on average petiole length (cm^2) in three strawberry cultivars during 1980 short rains season.

Source	df	ss	ms	Observed f	Required F 5%	Required F 1%
Total	36	3527.30				
Level	1	3344.69		-		
Blocks	2	29.93	14.97	10.69**	3.44	5.72
Treatments	11	121.82	11.07	7.91**	2.27	3.19
Error	22	30.86	1.40			

CV = 12.3%

SE = 0.20

Appendix 4C. Raw data on average petiole length (cm) in three strawberry cultivars during 1981 long rains.

Treatment	Blocks Cultivar	Block 1	Block 2	Block 3	Total Totals	Treat $\bar{\bar{X}}$
	Tufts	23.0	20.0	19.5	62.50	20.83
Control	Tioga	20.0	17.5	22.5	60.00	20.00
	Aiko	13.0	9.0	13.3	35.30	11.77
	Tufts	26.5	27.0	24.0	79.50	25.67
Defoliated plants	Tioga	19.5	17.0	18.0	54.50	18.17
	Aiko	12.5	11.5	12.3	36.10	12.03
	Tufts	22.0	25.0	26.5	73.50	24.50
Deblossomed plants	Tioga	21.5	19.6	18.5	59.60	19.87
	Aiko	13.5	12.3	11.0	36.80	12.27
	Tufts	18.0	15	14.0	47.00	15.67
Defoliated and Deblossomed plants	Tioga	17.5	20	19.5	57.00	19.00
	Aiko	12.0	9	14.3	35.30	11.77
Block Totals		219.0	202.7	213.40	635.10	

Appendix 4D. Analysis of variance on average petiole length in three strawberry cultivars during 1981 long rains season.

Source	df	ss	ms	Observed f	Required F 5%	1%
Total	36	12099.81				
Level	1	11204.22				
Blocks	2	11.43	5.72	1.71	3.44	5.72
Treatments	11	810.71	73.70	22.07*	2.27	3.19
Error	22	73.45	3.33			

CV = 10.4%

SE = 0.31

Appendix 5A. Raw data on average runner length in two strawberry cultivars during 1980 short rains season.

Treatment	Blocks Cultivar	Block 1	Block 2	Block 3	Treat Totals	Treat $\bar{\bar{X}}$
Control	Tufts	55.80	57.4	54.2	167.00	55.8
	Aiko	40.9	42.6	43.5	127.00	42.33
Defoliated plants	Tufts	60.3	65.7	61.9	187.90	62.63
	Aiko	44.5	41.8	40.5	126.80	42.27
Deblossomed plants	Tufts	61.4	59.7	63.2	184.30	61.33
	Aiko	39.4	41.9	38.0	119.30	39.77
Defoliated and Deblossomed plants	Tufts	63.4	62.8	66.9	193.10	64.37
	Aiko	37.4	39.2	42.5	119.10	39.70
Block Totals		403.10	411.10	410.70	1224.90	

Appendix 5B. Analysis of variance on average runner length (cm^2) in three strawberry cultivars during 1980 short rains season.

Source	df	ss	ms	Observed f	Required 5%	F 1%
Total	24	65138.71				
Level	1	62515.83				
Blocks	2	5.08	2.54	0.43	3.74	6.51
Treatments	7	2553.44	364.78	79.30**	2.76	4.28
Error	14	64.36	4.60			

CV = 4.2%

SE = 0.44

Appendix 5C. Raw data on average runner length in three strawberry cultivars during 1981 long rains season.

Treatment	Blocks Cultivar	Block 1	Block 2	Block 3	Treat. Totals	Treat $\bar{\bar{X}}$
	Tufts	70.1	67.8	72.8	210.7	70.23
Control	Tioga	61.4	63.9	57.7	183.0	61.00
	Aiko	58.5	60.6	61.4	180.5	60.17
	Tuft	75.1	73.4	76.7	225.2	75.07
Defoliated plants	Tioga	60.4	62.9	58.7	182.0	60.67
	Aiko	62.5	57.1	59.1	178.7	59.57
	Tufts	67.4	69.2	66.3	202.9	67.63
Deblossomed plants	Tioga	56.4	58.3	56.0	170.7	56.90
	Aiko	61.2	55.9	57.3	174.4	58.13
	Tufts	67.1	69.6	65.4	202.1	67.37
Defoliated and Deblossomed plants	Tioga	57.4	59.9	56.0	173.3	57.77
	Aiko	54.9	58.1	56.5	169.5	56.50
Block Totals		752.4	756.7	743.9	1153.0	

Appendix 5D. Analysis of variance on average runner length in three strawberry cultivars during 1981 long rains season.

Source	df	ms	ss	Observed f	Required 5%	F 1%
Total	36	142298.76				
Level	1	141000.25				
Blocks	2	7.07	3.54	0.76	3.44	5.72
Treatments	11	118.51	108.05	23.09**	2.27	3.19
Error	22	102.93	4.68			

CV = 3.5%

SE = 0.36

Appendix 6A. Raw data on average leaf area (cm²) in three strawberry cultivars during 1980 short rains season.

Treatment	Blocks Cultivar	Block 1	Block 2	Block 3	Treat Totals	Treat $\bar{X}$
Control	Tufts	24.5	22.7	25.1	72.3	24.10
	Tioga	23.2	21.9	20.8	65.9	21.97
	Aiko	15.9	17.2	14.4	47.5	15.83
Defoliated plants	Tufts	24.6	27.5	26.9	79.0	26.33
	Tioga	22.3	24.9	23.4	70.6	23.53
	Aiko	15.5	16.1	16.2	47.8	15.93
Deblossomed plants	Tufts	23.8	22.7	24.5	71.0	23.67
	Tioga	20.7	20.0	21.1	61.8	20.60
	Aiko	14.2	15.1	15.0	44.3	14.77
Defoliated and Deblossomed plants	Tufts	25.4	24.8	26.0	76.2	25.40
	Tioga	23.0	24.7	22.5	70.2	23.40
	Aiko	15.7	14.9	14.8	45.4	15.13
Block Totals		248.8	252.5	250.7	752.0	

Appendix 6B. Analysis of variance on average leaf area in three strawberry cultivars during 1980 short rains season.

Source	df	ss	ms	Observed f	Required F 5%	Required F 1%
Total	36	16343.00				
Level	1	15708.44				
Blocks	2	0.575	0.29	0.26	3.44	5.75
Treatments	11	609.87	55.44	50.40**	2.27	3.19
Error	22	24.12	1.10			

CV = 5.02%

SE = 0.17

Appendix 6C. Raw data on average leaf area (cm^2) in three strawberry cultivars during 1981 long rains season.

Treatment	Blocks Cultivar	Block 1	Block 2	Block 3	Treat Totals	Treat $\bar{X}$
Control	Tufts	40.7	43.9	39.2	123.8	41.27
	Tioga	37.5	36.1	39.3	112.9	37.63
	Aiko	25.8	29.4	26.1	81.3	27.10
Defoliated plants	Tufts	56.4	58.6	61.7	176.7	58.90
	Tioga	50.1	52.3	54.6	157.0	52.33
	Aiko	33.7	30.1	35.2	99.0	33.0
Deblossomed plants	Tufts	48.3	50.2	51.5	150.0	50.00
	Tioga	45.1	47.9	43.5	136.5	45.50
	Aiko	28.9	30.8	27.2	86.9	28.97
Defoliated and Deblossomed plants	Tufts	52.3	54.8	55.8	162.9	54.30
	Tioga	44.7	47.8	43.9	136.4	45.47
	Aiko	27.4	32.3	30.1	89.8	29.83
Block Totals		490.90	514.20	508.20	1513.2	

Appendix 6D. Analysis of variance on average leaf area in three strawberry cultivars during 1981 long rains season.

Source	df	ss	ms	Observed f	Required F 5%	1%
Total	36	67526.22				
Level	1	63604.84				
Blocks	2	23.33	11.67	2.93*	3.44	5.72
Treatments	11	3810.06	346.37	86.81**	2.27	3.19
Error	22	87.99	3.99			

CV = 4.8%

SE = 0.33

Appendix 7A. Temperature and rainfall data for Limuru during 1980.

Month	Temperature °C		Rainfall mm
	Maximum	Minimum	
January	22.4	11.1	44.5
February	23.2	11.4	58.6
March	22.1	12.3	96.3
April	21.4	12.5	290.5
May	19.8	11.6	234.6
June	19.6	9.7	67.5
July	18.2	8.7	26.1
August	18.8	9.0	34.2
September	21.0	9.5	39.0
October	21.0	11.1	54.9
November	20.6	11.8	124.0
December	21.2	11.3	90.5

Appendix 7B. Temperature and rainfall for Limury during 1981.

Month	Temperature °C		Rainfall mm
	Maximum	Minimum	
January	22.7	11.0	44.3
February	23.5	11.7	56.7
March	23.1	12.3	98.8
April	21.4	12.5	298.5
May	19.5	11.6	230.3
June	19.0	9.5	67.5
July	18.3	8.9	26.0
August	18.5	9.1	33.2
September	21.4	9.0	40.4
October	21.0	10.8	55.3
November	20.3	11.5	125.9
December	21.3	11.3	85.5