STUDIES ON FORCING OF STRAWBERRY CULTIVARS

by

MOHAMED ABDUL-RAHIM SHAHEEN

B.Sc., Horticulture, Faculty of Agriculture
Cairo University, 1975

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Horticulture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1979

Approved by:

Major Professor

TABLE OF CONTENTS

LIST OF TABLES

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to Dr. Neil W. Miles, major professor, who accepted the author as a graduate student and for his unselfish assistance and patience in planning and conducting the experiments and preparing the manuscript.

I am grateful to Dr. Carl D. Clayberg and Dr. George H. Liang, members of my supervisory committee, for help and advice in this research. Dr. Arthur D. Dayton deserves thanks for his statistical advice. Thanks is also due to Mr. Thomas Slagle and Mr. F.B. Hadle for their help in the greenhouse and field work.

Thanks are also due to the Saudi Arabia government for sponsoring my graduate studies at Kansas State University.

Finally, I thank all my friends and my family especiallly my father and my mother, for their encouragement and support.

I. INTRODUCTION

The strawberry (Frageria x ananassa Duch.) is a favorite fruit crop of the home garden. In addition to producing abundant fruit during early summer for family consumption, it is adapted to many aesthetic uses in the garden. There has been some effort to adapt some types of strawberries for interior decorating. A potentially interesting possibility would be to force the garden strawberry indoors during late winter and then transfer the plants to the garden during spring planting time.

Strawberry growth and flowering is influenced by day length and temperature. As shown from two reports (8, 11), strawberry plants are affected by many factors in the greenhouse; mainly temperature and light. Downs and Piringer (8) found that everbearing strawberries produced more flowers and fewer runners under 11, 13, 15, and 17 hour photoperipd; while Junebearing strawberries produced more runners and fewer flowers under the same photoperiods. Hartman (11) showed that the plants under short light and long dark periods (24 hours cycle) at 70 and 80°F initiated flowers. Plants grown under long light and long dark periods (28 hours cycle) produced flowers and runners. Plants grown under long light and short dark (24 hours cycle) produced only runners.

No literature was found on greenhouse forcing of strawberries either for growing indoors or transferring to the garden or field during spring time.

This thesis research was to determine whether plants forced indoors can be successfully transferred to the field. The first experiment, in the greenhouse, was to determine differences among strawberry cultivars for late winter forcing and to determine the effect of light intensity on strawberry plant development. The second experiment was to determine whether greenhouse forced strawberry plants transplanted to the field require shading (partial sun) for transplant success.

II. REVIEW OF LITERATURE

Strawberry plant growth varies due to cultivar and environmental factors. Differences in numbers of runner have been found in response to variations of temperature and photoperiod. Smeets (23) found in The Netherlands that runners were produced in air conditioned glass houses at 17, 20, 23 and 26°C under natural day length (April to November). The number of runners increased as temperature increased for 'Deutsch Evern', 'Oberschlesien', 'Auchincruire Climax' and 'Jueunda' but not 'Madame Mautot'. It produced more runners at 20 and 23 than at 17 or 26°C.

Smeets and Kronenberg (24) described the photoperiod effect on strawberry plant growth. Plants of 'Deutsch Evern' brought indoors in glasshouses (early September and early October 1953) and grown under long days (winter day light followed by weak incandescent light until 16 hours) produced runners at 23°C but not at 17°C. Plants brought in during early September 1953 produced more runners than plants brought in during early October 1953. Plants grown under short days (winter day light) at 17 and 23°C did not produce runners. After some time (when the temperature started to affect the number of flowers) plants produced flowers continually throughout the winter. Smeets (22) found that plants of 'Deutsch Evern' brought indoors early in September 1954 and grown in air conditioned glasshouses under long days

(16 hrs) produced more runners when daylight intensity or the intensity of extended photoperiod light or both were increased. More runners were produced at 20 and 23 than at 17°C; the largest number of runners was produced by 'Deutsch Evern' with high light intensity at 23°C.

Proebsting (19) found in Davis, California under greenhouse conditions with 'Shasta' and 'Lassen', that more runners were produced at 75°F soil temperature than 45, 55, 65, 85 or 90°F. Darrow and Waldo (7) found that runner formation did not occur with 10-hour summer days with most Junebearing cultivars and only in a few cultivars under 12-hour days. Darrow (5) found that the higher rather than lower temperatures favored runner production but the most favorable temperature for flower production was dependent upon day length. Loomis (15) found that all cultivars ('Blakemore', 'Klondike', 'Southland', 'Missionary', 'Dorsett', and 'Fairfax') produced runners more freely during the summer than fall. Darrow (5) in Maryland found that at 70°F and 16-hour day 'Aberdeen', 'Blakemore', 'Burrill', 'Catskill', 'Dorsett', 'Fairfax', 'Howard 17', 'Klondike' and 'Bellmar' plants stopped flowering and produced only runners in the greenhouse. At a 14-hour day and 70°F both runners and flowers were produced. At all temperatures (55, 60 and 70°F) with normal day length (Spring 1975) more flowers and no runners were produced. Downs and Piringer (8) found that Junebearing cultivars ('Howard 17' and 'Klondike') produced

more runners with increasing day length up to 15 hours. They also found that the everbearing cultivars, 'Gem', 'Mastodon', and 'Red Rich' produced fewer runners than Junebearing cultivars at any photoperiod (11, 13, 15, and 17 hours); but more runners were produced on the 13-hour day than on the other photoperiods. Hartmann (10) found that strawberry plants of 'Marshall', 'Missionary', 'Fairfax', and 'Blakemore' continued to produce runners for a short time after the beginning of the treatment due to runner initials formed while plants were under longday greenhouse conditions. Morrow (16) showed that strawberry plants of 'Blakemore' 'Missionary', 'Klondike', 'Premier', 'Blakemore x Fairfax', and 'Missionary x Fairfax' had variations in the numbers and length of runners between two locations (Willard and Swannanoa).

Flower initiation has been the most extensively studied characteristic of strawberry plant growth. Hartmann (10) found that the strawberry plants of 'Marshall', 'Missionary', 'Fairfax', and 'Blakemore' in Davis, California under field and greenhouse conditions initiated flowers at 60°F even though they were under longday (15 hrs) conditions. No flowers were initiated under longday conditions at 70°F. The plants under shortday (10 hrs) initiated flowers at about the same rate at 60° and 70°F. Hartmann (11) showed that 'Missionary' plants initiated flowers under short light and long dark periods (24 hours cycle) at 70° and 80°F.

Plants grown under long light and long dark periods (28 hrs cycle) produced flowers and runners. Plants grown under long light and short dark (24 hrs cycle) produced only runners. Plants grown under short light and short dark periods (20 hrs cycle) produced only flowers. Downs and Piringer (8) found that all plants of everbearing, 'Gem', 'Mastodon', and 'Red Rich' had flower primodia under all photoperiods studied (11, 13, 15 and 17 hrs). The production of flower clusters by the everbearing plants was greater under longer photoperiods (15 and 17 hrs) than short photoperiods (11 and 13 hrs). They also showed that the June-bearing plants of 'Howard 17' and 'Klondike' produced a few flowers on 11-13 hrs photoperiods and produced no flowers under 15-17 hrs photoperiods. Hartmann (11) found that floral initiation was similar in the strawberry whether the plants were grown under constant temperature or normal diurnal temperatures. Darrow (5) found in greenhouse with 'Aberdeen', 'Blakemore', 'Burrill', 'Catskill', 'Dorsett', 'Fairfax', 'Howard 17', 'Klondike', and 'Bellmar' that short days favor flowering and inhibit runner production regardless of temperature. He also found that if summer temperatures were to go as low as 55°F on the California coast, the rate of growth and flower-cluster production would be slowed up, while if temperatures go as high as 70°F growth would be rapid but flower production retarded. Smeets and Kronenberg (24) found that the number of flowering plants under 23°C was

less than under 17°C if the plants brought indoors in early September. The former plants produced large numbers of runners. They also showed that temperature had little or no effect on the number of flowering plants under short days.

Morrow and Darrow (18) found that with an increase in plant size there was an increase in number of flowers per plant. Iyer and Smeets (12) found with 'Glasa' plants forced in The Netherlands that 12°C pre-treatment caused more rapid flowering than the controls and 9°C pre-treatment. The total number of flowers and number of inflorescences was larger at 12°C pre-treatment than the controls and 9°C pre-treatment. Robertson (21) found that with 'Inepuisable', 'Perle Rose', 'Liberation d' Orleans' and 'Ville de Paris' flowers appearing from late April until about early June were derived from primordia formed in late summer. Flowers borne from mid-or late July onwards were initiated a few weeks before their emergence. Morrow and Beaumont (17) found in North Carolina in the field with 'Blakemore', 'Klondike' and 'Missionary' that if the age (approximately 15 day intervals) of the plants increased the average number of flowers and berries per plant increased. Jahn and Dana (13) found with 'Dunlap', 'Sparkle', and 'Catskill' that the number of flower buds increased as the plant age (10-day intervals) and plant size increased. Darrow and Waldo (6) found with some cultivars grown under long photoperiod (extended until 10:00 p.m.), that fewer flowers were produced than for plants grown under normal light.

Differences in leaf growth have been found. Arney (22) found that small leaves were produced in early spring and larger leaves during the summer. Young plants (8-18 months old) had larger leaves than plants over 18 months old. Arney (2) found with 'Royal Sovereign' that differences in leaf size, whether among individual plants or among leaves on the same plant, were not due to cell size or rate of cell division, but to the direction of cell division phase. Sproat and Darrow (26) found that the number of flowers and berries increased directly as the number of leaves per plant increased. Jahn and Dana (13) showed that older plants (10-day intervals) produced larger leaf areas than the younger plants. Arney (1) found with 'Royal Sovereign' that the rate of leaf production of plants grown in a heated greenhouse was greater than the rate for outside plants during February through May. Jahn and Dana (13) found with 'Dunlap', 'Sparkle', and 'Catskill' that early differences in leaf area per plant were due to differences in size of individual leaves. Arney (3) found with 'Royal Sovereign' that leaf initiation during the winter months seems to depend upon severity of the season and locality. Arney (4) found that changes in temperature between 45° and 70°F had little effect on leaf size. Temperatures below 45°F caused small leaves.

Roberts and Kenworthy (20) reported that increasing root temperature from 45 to 65°F increased the dry weight of the aerial plant parts and the total plant dry weight but root

dry weight was not affected. Also the potassium content of leaves increased as the root temperature was increased. Guttridge (9) compared plants grown under an 11-hour photoperiod at 60° - 62°F with those grown at 30-40°F. At higher temperature, plants continued flower initiation, produced no runners, had short petioles, small leaves, and increased root and crown dry weight. Plants grown at 30 - 40°F made vigorous vegetative growth with strong runner production, longer petioles and large leaves but flower initiation was delayed for several weeks. Arney (1) found that the production of runners did not alter the rate of leaf formation of the parent plant. The division of crowns caused a small reduction in the rate of leaf production per crown. Jahn and Dana (14) found that the plants with largest leaf areas continued to grow more rapidly than smaller plants.

III. MATERIALS AND METHODS

A. Greenhouse Experiment

1. Cultural Procedures

Strawberries used were 8 Junebearing cultivars: 'Redchief', 'Surecrop', 'Atlas', 'Guardian', 'Delite', 'Apollo', 'Fairfax', and 'Raritan', and two everbearing cultivars: 'Quinalt' and 'Ozark Beauty'. The one-year old strawberry plants were obtained from W.F. Allen Company, Salisbury, Maryland; Conner Company, Inc., Augusta, Arkansas; and Norse Farms, Inc., South Deerfield, Massachusetts.

The experiment was conducted in the Horticulture greenhouse at Kansas State University, Manhattan, Kansas under temperatures of 21°C day and 15°C night and 16 hr photoperiod. Sixty-watt incandescent lamps spaced 107 cm apart, 38 cm above plants were used to extend the photoperiod beyond normal day length. On January 16, 1978, 18 plants selected from each cultivar were prepared for planting by removing all but emerged leaf from crown, and trimming roots to a uniform 12 cm. The plants were weighed and crowns dipped in Dicofol miticide (1 g Kelthane 35 WP/1) plus 1 drop of Tween 20/1. Prepared plants were planted in 13 cm pots containing a 1:1:1 mixture of field soil, peat moss, and haydite and watered immediately. Eight plants of each cultivar were placed on the greenhouse bench under full sun, eight plants under partial sun (described later) and two plants held in reserve for replacements.

The plants were watered as needed with a 1:1:1 NPK fertilizer solution at a concentration of 300 ppm N. The plants were sprayed weekly with Pentac insecticide (2 teaspoonsful - 50% WP/gallon of water). One week after starting some plants from cultivars 'Ozark Beauty', 'Guardian', and 'Delite' had grown atypically weak and were replaced with reserve plants.

2. Light Treatments

The two treatments were full sun and partial sun. Full sun was normal greenhouse sunlight conditions with photoperiod extended. Partial sun was provided by a 50 percent lath shade covering 61 cm above the bench and extending down the sides 31 cm.

3. Data Collected

Data were taken on individual plants. The number of days from the experiment starting date (January 16) until the first opened flower appeared was recorded. On March 14, 1978 (58 days after planting) the following data were collected; total number of flowers, number of flower clusters, number of flowers per clusters, number of leaves per plant, length of petiole (from stipule to the leaf blade for each fully expanded leaf), total leaf area (automatic leaf area meter, Model AAM-5 by Hayashi Co., Ltd., Tokyo, Japan), average leaf area (total leaf area/number of leaves), fresh weight of leaves (electronic balance); and dry weight of leaves (weight recorded after leaves were dried in an oven for 24 hrs at 65°C).

4. Experimental Design

A randomized split plot design with 8 replications was used for the experiment. Each replicate was divided into full sun and partial sun. One plant of each cultivar was represented in each sun treatment of each replicate (one plant plots). There were 160 plants in the experiment (10 cv x 8 reps x 2 sub plots). All data were analyzed by analysis of variance (ANOVA) at the 5% level of significance. Fisher's least significant difference (LSD) test (5% level of significance) was used to determine differences among means.

B. Field Experiment

1. Cultural Procedures

The strawberry cultivars used in this experiment were 'Ozark Beauty' (everbearing) and 'Delite' and 'Raritan' (Junebearing). The plants were obtained from one-year-old strawberry plants grown at W.F. Allen Company, Salisbury, Maryland.

The cultivars were treated and grown in the Horticulture greenhouse at Kansas State University, Manhattan, Kansas under the same conditions as the greenhouse experiment except all plants were grown under partial sun without randomizing. The experiment was started on February 2, 1978. Thirty plants of each cultivar were grown. The plants were transferred to the field on April 8, 1978, after 40 days growth in the greenhouse.

In the field at the Horticulture Farm, Manhattan, Kansas, the plants were planted under partial sun and full sun. Partial sun was provided by a lath shade (305 cm x 122 cm) similar in construction to that described before. The plants were spaced 91 cm between plants and 183 cm between rows. Flowers, runners, and all the poor leaves were removed from the plants before planting. Plants were watered after transplanting to the field and irrigated as needed.

2. Experimental Design

A randomized split-plot design was used. Sub-plots were full sun and partial sun. One plant from each cultivar was transplanted to the field to full sun and one to partial sun in each of the 10 replicates.

3. Data Collected

Data were taken on May 19, 1978, 41 days after the plants were transferred to the field. The variables measured included plant survival, number of leaves, number of stolons, rating of flowering (1 = flower open, 2 = flower bud, and 3 = no flowers), and visual comparisons of plant vigor made between full sun and partial sun and among cultivars.

4. Statistical Analysis

The number of leaves and stolons among cultivars was analyzed by ANOVA at the 5% level of significance. Fisher's LSD test (5% level of significance) was used to determine

differences among means. The differences in visual ratings between the plants were analyzed by Z test comparison (25, p 209-210). The visual ratings of plant vigor between full sun and partial sun or among cultivars were analyzed by Chi-square test. The ratings of flowering were analyzed by Chi-square test.

IV. RESULTS

A. Greenhouse Experiment

1. Full Sun vs Partial Sun

Differences between full sun and partial sun are shown in Table 1. Larger values were obtained for full sun treatments than partial sun treatments for average leaf area, total leaf area, fresh and dry weight of leaves, and total number of flowers. Larger values were obtained for partial sun for standard deviation of petiole length and coefficient of variation of petiole length. There were no differences between sun treatments for other variables.

2. Cultivar Effects

a. Petiole length

Differences in petiole length among cultivars are shown in Table 2. 'Redchief' had the longest average petiole length; the shortest was produced by 'Delite', 'Raritan' and 'Quinalt'. 'Redchief' plants also had the longest single petiole; the shortest maximum length of petiole was produced by 'Surecrop', 'Quinalt', 'Delite', 'Raritan', and 'Ozark Beauty' plants. The longest minimum petiole length was produced by 'Redchief', and 'Atlas' plants; the shortest was produced by 'Surecrop', 'Quinalt', 'Guardian', 'Delite', 'Apollo', 'Fairfax', 'Raritan', and 'Ozark Beauty' plants. The greatest standard deviation was among 'Apollo' plants.

Table 1. The effect of shading on growth and flowering characteristics of 10 strawberry cultivars forced in the greenhouse for 58 days.

Variables Measured	Full Sun	Partial Sun
Average leaf area	87.8* cm^2	70.3 cm^2
Total leaf area	601.8* cm^2	482.0 cm^2
Number of leaves per plant	7.0	7.1
Fresh weight of leaves	14.9* g	11.5 g
Dry weight of leaves	3.2* g	2.2 g
Number of days until first flower	32.0	33.8
Total number of flowers	16.8*	11.6
Number of flower clusters	2.4	2.1
Petiole length	12.4 cm	12.5 cm
Maximum petiole length	15.7 cm	16.4 cm
Minimum petiole length	8.6 cm	7.9 cm
Standard deviation of petiole length	2.8	3.2*
Coefficient of variation of petiole length	23.1	26.6*

*/Significant difference between columns by ANOVA, 5% level.

Table 2. Length of leaf petioles of strawberry plants forced in the greenhouse for 58 days under full sun and partial sun.[z]

Cultivars	Petiole length				
	Average cm	Maximum cm	Minimum cm	Standard Deviation	Coefficient of Variation
Redchief	15.4	18.5	11.3	2.9	19.1
Surecrop	12.3	15.3	8.5	2.4	20.2
Atlas	13.6	17.0	9.2	3.1	23.8
Quinalt	10.7	14.1	6.9	2.5	23.6
Guardian	12.9	16.7	8.0	3.1	24.8
Delite	11.2	15.1	8.5	3.1	28.0
Apollo	12.6	17.3	6.5	4.5	35.8
Fairfax	12.9	16.5	8.5	2.8	23.3
Raritan	11.0	14.8	6.6	3.2	30.0
Ozark Beauty	11.8	14.8	8.5	2.3	19.6
LSD 5%	1.1	1.3	2.2	0.69	5.9

[z]/Interaction of sun treatments x cultivars was N.S. Data are means of sun treatments within cultivar.

The smallest was among 'Redchief', 'Surecrop', 'Quinalt', 'Fairfax', and 'Ozark Beauty' plants. The greatest coefficient of variation was among 'Apollo' and 'Raritan' plants; and the smallest was among 'Redchief', 'Surecrop', 'Atlas', 'Quinalt', 'Guardian', 'Fairfax', and 'Ozark Beauty' plants.

b. Number of flowers

Differences in the number of flowers among cultivars are shown in Table 3. The greatest total number of flowers was produced by 'Surecrop', 'Guardian', 'Delite', and 'Raritan' plants; the smallest by 'Quinalt' and 'Ozark Beauty' plants. The greatest number of flower clusters was produced by 'Surecrop', 'Delite', and 'Raritan' plants; the smallest by 'Quinalt' and 'Ozark Beauty' plants. Table 4 presents the data on the number of flowers per cluster where the sun treatment x cultivar interaction was significant. More flowers per cluster were produced under full sun than partial sun by 'Redchief', 'Raritan', and 'Ozark Beauty'. No cultivar produced more flowers per cluster under partial sun. 'Redchief' produced the highest number of flowers per cluster under full sun and the lowest number under partial sun.

c. Number of days until first flower.

Differences in the number of days until the first flower opened among cultivars are shown in Table 3. Cultivars

Table 3. The effect of full sun and partial sun on the flowering of selected strawberry cultivars forced in the greenhouse for 58 days.[z]

Cultivars	Total number of flowers	Number of flower clusters	Number of days until first flower
Redchief	12.8	2.2	29.8
Surecrop	17.7	3.1	29.2
Atlas	11.3	1.9	33.6
Quinalt	5.8	1.6	23.8
Guardian	17.1	2.3	32.9
Delite	20.2	2.8	39.1
Apollo	14.0	2.4	38.4
Fairfax	16.9	2.3	39.2
Raritan	20.4	2.8	32.8
Ozark Beauty	6.0	1.2	30.1
LSD 5%	4.5	0.58	7.5

[z/] Interaction of sun treatments x cultivars N.S. Data are means of sun treatments within cultivar.

Table 4. Effect of shading on the average number of flowers per cluster of strawberry plants forced in the greenhouse for 58 days. Interaction of cultivar x sun treatment was significant.

	Number of flowers per cluster		
Cultivars	Full Sun	Partial Sun	Average
Redchief	8.8*	2.6	5.7
Surecrop	6.3	5.2	5.8
Atlas	6.1	5.8	6.0
Quinalt	4.1	3.4	3.8
Guardian	8.0	7.2	7.6
Delite	8.0	6.4	7.2
Apollo	6.1	5.3	5.7
Fairfax	7.0	7.4	7.2
Raritan	8.2*	5.7	6.9
Ozark Beauty	6.9*	3.2	5.1
Average	7.0*	5.2	
LSD 5%	2.5	2.5	

*/ Significant difference between columns by ANOVA, 5% level.

requiring the greatest number of days until the first flower opened included 'Atlas', 'Guardian', 'Delite', 'Apollo', 'Fairfax', and 'Raritan'; those requiring the least number of days included 'Redchief', 'Surecrop', 'Quinalt', and 'Ozark Beauty'.

d. Leaf area

Differences in leaf area among cultivars are shown in Table 5. The leaf area per leaf of 'Atlas' and 'Guardian' was larger than all other cultivars. The smallest leaf area per leaf was produced by 'Quinalt', 'Apollo', 'Fairfax', 'Raritan', and 'Ozark Beauty'. The greatest total leaf area was produced by 'Guardian' and 'Delite'; the smallest by 'Redchief', 'Apollo', 'Raritan', and 'Ozark Beauty'.

e. Number of leaves per plant

As shown in Table 5, the greatest number of leaves per plant was produced by 'Quinalt', 'Delite', and 'Fairfax'; the smallest number of leaves was produced by 'Redchief', 'Surecrop', 'Atlas', 'Apollo', 'Raritan', and 'Ozark Beauty' plants.

f. Fresh and dry weight

Differences in total fresh and dry weight of leaves per plant among cultivars are shown in Table 6. The greatest fresh weight of leaves was in 'Quinalt', 'Guardian', 'Delite', and 'Fairfax' plants; the smallest fresh weight in 'Redchief',

Table 5. Leaf area and leaf number of selected strawberry cultivars forced in the greenhouse for 58 days under full sun and partial sun.[z]

Cultivars	Average per leaf cm^2	Total cm^2	Number of leaves per plant
Redchief	81.3	425.7	5.3
Surecrop	77.0	484.8	6.7
Atlas	102.3	570.5	6.1
Quinalt	68.3	598.8	9.1
Guardian	98.3	682.9	7.1
Delite	84.9	750.0	8.9
Apollo	73.8	469.2	6.4
Fairfax	70.0	593.2	8.7
Raritan	73.5	476.4	6.5
Ozark Beauty	61.0	367.4	5.9
LSD 5%	13.1	114.9	1.6

[z]/Interaction of sun treatments x cultivars N.S. Data are means of sun treatments within cultivar.

Table 6. Fresh and dry weight of leaves of selected strawberry cultivars forced in the greenhouse for 58 days under full sun and partial sun.[z]

Cultivars	Fresh weight g	Dry weight g
Redchief	11.1	2.2
Surecrop	11.4	2.3
Atlas	13.6	3.0
Quinalt	14.6	2.8
Guardian	15.3	3.0
Delite	17.2	3.5
Apollo	12.0	2.5
Fairfax	15.6	2.9
Raritan	12.1	2.6
Ozark Beauty	9.4	1.8
LSD 5%	2.8	0.6

[z]/Interaction of sun treatments x cultivars N.S. Data are means of sun treatments within cultivar.

'Surecrop', 'Apollo', 'Raritan', and 'Ozark Beauty' plants. The greatest dry weight was in 'Atlas', 'Guardian', and 'Delite'; and the smallest was in 'Redchief', 'Surecrop', and 'Ozark Beauty'.

B. Field Experiment

All plants transferred to the field on April 8, 1978 after 40 days forcing in the greenhouse under partial sun, survived and made adequate growth.

Differences in number of leaves and stolons among cultivars are shown in Table 7. 'Ozark Beauty', and 'Delite' had the same number of leaves, but greater than 'Raritan'. 'Delite' had a greater number of stolons than 'Ozark Beauty' and 'Raritan' which were equal.

Data collected on flowering and plant vigor, although not tabulated, are described below. As shown by Chi-square test there was statistical significance in the number of flowers between the cultivars. Eighty percent of 'Ozark Beauty' plants flowered, while 'Delite' and 'Raritan' had no flowers. There were no differences in the number of flowers between full sun and partial sun. The differences in visual rating made 19 May 1978, 41 days after transplanting to the field, (Z-test comparison) showed that 'Delite' was more vigorous than 'Ozark Beauty' and 'Raritan' which were the same. There was no difference between full sun and partial sun for visual ratings of plant vigor (Chi-square test = 0).

Table 7. Average number of leaves and stolons of strawberry plants forced in the greenhouse for 40 days under partial sun, then grown in the field for 41 days under full sun and partial sun.[z]

Cultivars	Number of Leaves	Number of Stolons
Ozark Beauty	6.3	0.10
Delite	6.5	1.40
Raritan	4.6	0.35
LSD 5%	1.3	0.43

[z]/Interaction of sun treatments x cultivars N.S. Data are means of sun treatments within cultivar.

V. DISCUSSION

A. Greenhouse Experiment

The plants grown in the home are exposed to lower light intensities than plants grown in a greenhouse. For that reason the partial sun treatment was included in the experiment.

Strawberry plants grown in full sun had larger leaves, greater total leaf area, greater fresh and dry weight of leaves, and more flowers (Table 1). These are all desirable characteristics with the possible exception of average leaf area. Plants with small number of large leaves could be less desirable than plants with a large number of smaller leaves. Plants grown under partial sun had a greater standard deviation and coefficient of variation of petiole length, both indicating more variation of leaf height and a less uniform plant appearance. No difference was observed between full sun and partial sun for other variables measured. A more vigorous plant with larger leaves, more flowers, and greater uniformity of leaf petiole length was produced under full sun.

The interaction of cultivars vs light was significant for only number of flowers per cluster; and this variable was less important compared to the other variables measured. In general the cultivars studied are equally adapted for full

sun and partial sun. None of the cultivars proved to be ideal for partial sun.

The plants with shorter petiole length are considered desirable because they would have a more compact appearance than those with a longer average petiole length. Cultivars with shortest petiole length include 'Quinalt', 'Delite', 'Ozark Beauty' and 'Raritan' (Table 2). To be attractive, petioles of plants should be nearly the same length, thus giving a uniform plant appearance. The average maximum and minimum petiole length is presented in Table 2. The greatest maximum petiole length was 18.5 cm ('Redchief') and the least was 14.1 cm ('Quinalt'). However, 'Redchief' had the highest average petiole length (15.4 cm) and the difference between average and maximum was only 3.1 cm. The respective figure for 'Quinalt' was 3.4 cm and 4.7 cm for 'Apollo'.

A large minimum length of petiole is desirable if it is assumed that this figure would be close to the average petiole length. The longest minimum length was 11.3 cm ('Redchief') and the shortest was 6.5 cm ('Apollo'). The smallest difference between the average and minimum petiole length was 3.3 cm 'Ozark Beauty' and the greatest difference was 6.1 cm 'Apollo'. 'Apollo' had the greatest range both above and below the average length.

The standard deviation indicates the range of centimeters above and below the average to include 68.26 percent of the petioles measured. This range is highest for 'Apollo'

(4.5 cm) and lowest for 'Ozark Beauty' (2.3 cm). The coefficient of variation presents a measurement of the degree of variation among petioles measured. Cultivars that were most variable were 'Apollo' and 'Raritan' and would be undesirable for greenhouse forcing because plants would lack a uniform and a symmetrical appearance. 'Redchief', 'Surecrop', 'Atlas', 'Quinalt', 'Guardian', 'Fairfax', and 'Ozark Beauty' were among the cultivars with least variable petiole length. These would be considered most desirable for greenhouse forcing.

Considering all aspects of petiole length, we found the cultivars 'Guardian', 'Quinalt', and 'Ozark Beauty' most desirable, while 'Fairfax' and 'Apollo' are acceptable. 'Redchief', 'Atlas', 'Surecrop', 'Delite', and 'Raritan' are least desirable.

Plants with larger total leaf area are considered desirable because they would have more photosynthetic potential for growth, flowering, and fruiting. A large number of leaves is desirable since this would give the plant a more compact, attractive and uniform appearance. A few very large leaves, although having considerable photosynthetic potential, would cause the plant to appear asymetrical. Thus it seems most desirable that plants have many smaller leaves than fewer large leaves.

The greatest total leaf area (Table 5) was produced by 'Delite' (750.0cm^2) and 'Guardian' (682.9cm^2) and the

smallest was 'Redchief' (425.7cm^2), 'Apollo' (469.2cm^2) and 'Ozark Beauty' (367.4cm^2). However, the highest number of leaves per plant was produced by 'Quinalt' (9.1), 'Delite' (8.9) and 'Fairfax' (8.7); and the smallest number of leaves was produced by 'Redchief' (5.3), 'Surecrop' (6.7), 'Atlas' (6.1), 'Apollo' (6.4), 'Raritan' (6.5) and 'Ozark Beauty' (5.9). The larger leaf area per leaf was produced by 'Atlas' (102.3cm^2) and 'Guardian' (98.3cm^2). The smaller leaf area per leaf was produced by 'Quinalt' (68.3cm^2), 'Delite' (84.9cm^2), and 'Fairfax' (70.0cm^2). Thus 'Delite was among the cultivars with the largest leaf area, the largest number of leaves and the smallest leaf size. We found 'Delite' most desirable for forcing while 'Fairfax' and 'Quinalt' were acceptable. 'Apollo', 'Ozark Beauty' and 'Atlas' were undesirable. 'Guardian' had a large individual leaf area but large total leaf area per plant.

Fresh weight and dry weight are a measurement of total plant vigor. The plants with greater fresh weight and dry weight are considered desirable because larger plants tend to be more attractive and vigorous. It is likely that they can produce more and larger fruit. Table 6 shows that the highest total fresh weight was produced by 'Quinalt' (14.6g), 'Guardian' (15.3g), 'Delite' (17.2g), and 'Fairfax' (15.6g); and the lowest by 'Redchief' (11.1g), 'Surecrop' (11.4g), 'Apollo' (12.0g), 'Raritan' (12.1g), and 'Ozark Beauty' (9.4g). The highest total dry weight was produced by

'Atlas' (3.0g), 'Guardian' (3.0g) and 'Delite' (3.5g); and the lowest by 'Redchief' (2.2g), 'Surecrop' (2.3g), and 'Ozark Beauty' (1.8g). Thus the most vigorous cultivars were 'Guardian' and 'Delite' would be considered most disirable for greenhouse forcing. 'Ozark Beauty', 'Surecrop', and 'Redchief' were least vigorous and undesirable for forcing.

The plants with a large number of flowers, 'Surecrop' (17.7), 'Guardian' (17.1), 'Delite' (20.2), and 'Raritan (20.4), were considered desirable (Table 3). The plants with small number of flowers, 'Quinalt' (3.8), and 'Ozark Beauty' (6.0), were considered undesirable. A large number of flowers indicates a potential to produce a large quantity of fruit and would be more attractive.

Plants with a large number of flower clusters are considered desirable because they produce more primary fruits which tend to "set" more readily under greenhouse conditions and grow larger. The largest number of flower clusters was produced by 'Surecrop' (3.1), 'Delite' (2.8), and 'Raritan (2.8); and the smallest number was produced by 'Quinalt (1.6) and 'Ozark Beauty' (1.2).

The plants with a small number of flowers per clusters were considered more desirable because the small number of flowers per cluster could give larger and more attractive berries Table 4. More flowers per cluster produced under full sun than partial sun by 'Redchief (8.8), 'Raritan' (8.2)

and 'Ozark Beauty' (6.9). No cultivar produced more flowers per cluster under partial sun. 'Redchief' produced the highest number of flowers per cluster under full sun and the lowest under partial sun. So the partial sun would be considered desirable for number of flowers per cluster in the greenhouse; but with consideration total number of flowers and the number of clusters would be undesirable.

A longer time before flowering gave plants more time to establish root systems and foliage to support the developing fruits. Cultivars that required a large number of days until first flower opened were 'Guardian' (32.9), 'Delite' (39.1), 'Atlas' (33.6), 'Apollo' (38.4), 'Fairfax' (39.2), and 'Raritan' (23.8), all considered desirable in this respect (Table 3). Cultivars that required the fewest days until the first flower opened were 'Redchief' (29.8), 'Surecrop' (29.2), 'Quinalt' (23.8), and 'Ozark Beauty' (30.1), considered undesirable. The cultivars 'Guardian', 'Delite', 'Atlas', 'Apollo', 'Fairfax', and 'Raritan' are considered desirable for greenhouse forcing.

The best flowering is several small clusters producing many flowers and potential fruit, so cultivars 'Delite' and 'Raritan' are desirable; 'Guardian' and 'Surecrop' are acceptable; and 'Atlas', 'Apollo', and 'Fairfax' are undesirable for greenhouse forcing.

From this discussion, when strawberries are grown in the lower light intensities of the home, plants will have a

smaller leaf area, fresh and dry weight of leaves, total number of flowers and number of flowers per clusters compared to those forced in the greenhouse. No cultivar studied was highly adapted to the low light intensity of the home. Those that seem best are 'Delite', 'Guardian', 'Quinalt', 'Fairfax', and 'Raritan' for greenhouse forcing.

B. Field Experiment

It is clear from the results that strawberry plants forced in the greenhouse 40 days under partial sun can be transferred to the field, as all the plants survived and grew well. Weather after transplanting to the field was cloudy and cool, ideal for transplant survival. The leaves on the plants when transplanted seriously deteriorated and became non-functional. Regrowth and development of new leaves was quite vigorous and some plants formed flowers and stolons. Cultivars 'Delite' (6.5) and 'Ozark Beauty' (6.3) had a greater number of leaves than 'Raritan' (4.6) (Table 7) indicating more vigor during the immediate post transplant period. Plants with large number of stolons are considered desirable because large numbers of stolons would produce enough daughter plants for fruit production the following year. 'Delite' had the largest number of stolons (1.40). Only 'Ozark Beauty' produced flowers immediately after transplanting to the field. 'Delite' had greater number of flowers in the greenhouse, but no flowers in the

field. 'Ozark Beauty' which had a small number of flowers in the greenhouse was the only cultivar to produce flowers in the field initially. These results agree with Downs and Piringer (8) who found that Junebearing cultivars produced more runners and fewer flowers under 11, 13, 15 and 17 hour photoperiods. The everbearing cultivars produced more flowers and fewer runners under the same photoperiods.

Strawberry plants grown under partial sun in the greenhouse were successfully transplanted to the field to either full or partial sun. Visual ratings indicated no difference in plant vigor between full sun and partial sun. No shading is required when strawberry plants grown indoors are transplanted to the field during the spring.

There was a difference in rating among cultivars. 'Delite', which performed well in the greenhouse, grew most vigorously in the field. So 'Delite' seems best for growing indoors during spring time and grows vigorously when transferred to the field. 'Ozark Beauty', which did not perform well in the greenhouse, because it is an everbearing cultivar, did flower and fruit when transplanted to the field.

VI. SUMMARY AND CONCLUSIONS

Cultivars of strawberry forced in the greenhouse under 16 hours photoperiod and either full sun or partial sun varried in growth parameters measured. The following summarized the findings of this study.

1. Strawberry plants grown under full sun produced larger average leaf area, greater total leaf area, greater fresh and dry weight of leaves, larger number of flowers, than those grown under partial sun. There also was more uniformity of petiole length as indicated by a lower standard deviation and coefficient of variation of petiole length.

2. Desirable short petiole length was found in 'Quinalt', 'Delite', 'Raritan', and 'Ozark Beauty'. Least variability of petiole length was found in 'Redchief', 'Surecrop', 'Atlas', 'Quinalt', 'Guardian', and 'Fairfax' (coefficient of variation).

3. 'Quinalt', 'Delite' and 'Fairfax' produced the greatest number of leaves per plant. Desirable small leaves were produced on 'Quinalt', 'Apollo', 'Fairfax', 'Raritan', and 'Ozark Beauty' but the largest total leaf area were found on 'Guardian' and 'Delite'.

4. Those cultivars with largest total leaf fresh weight were 'Quinalt', 'Guardian', 'Delite', and 'Fairfax' while largest dry weight was found in 'Atlas, 'Guardian', and 'Delite.'

5. Cultivars requiring the greatest number of days until the first flower opened were 'Atlas', 'Guardian', 'Delite', 'Apollo', 'Fairfax', and 'Raritan'.

6. The greatest number of flowers were found on 'Surecrop', 'Guardian', 'Delite', 'Fairfax', and 'Raritan'. The most flower clusters were on 'Surecrop', 'Delite', and 'Raritan'.

7. A cultivar x sun treatment interaction was observed for only one character measured, number of flowers per cluster. 'Redchief' produced the greatest number of flowers per cluster under full sun and the least under partial sun.

8. None of the cultivars tested were highly adapted for forcing under the partial sun conditions since none performed better under partial sun than full sun for any character measured.

9. Considering all data 'Delite' had good, vigorous plant growth and flowering characteristics. 'Fairfax' was uniform in growth, had good vigor, and good flowering characteristics. 'Quinalt' had good plant growth characteristics but flowered poorly.

All strawberry plants transplanted to the field survived. Only 'Ozark Beauty', the everbearing cultivar, flowered directly after transplanting. There was no difference in growth between partial sun and full sun. 'Delite' produced more leaves and 'Delite' and 'Raritan' produced more stolons. 'Delite' which performed well in the greenhouse also grew well in the field.

LITERATURE CITED

1. Arney, S.E. 1953. Studies of growth and development in the genus Fragaria. I. Factors affecting the rate of leaf production in Royal Sovereign strawberry. J. Hort. Sci. 28:73-84.

2. Arney, S.E. 1954. Studies of growth and development in the genus Fragaria. III. The growth of leaves and shoot. Ann. Bot. 18:349-65.

3. Arney, S.E. 1955. Studies of growth and development in the genus Fragaria. IV. Winter growth. Ann. Bot. 19:265-76.

4. Arney, S.E. 1956. Studies of growth and development in the genus Fragaria. VI. The effect of photoperiod and temperature on leaf size. J. Exp. Bot. 7:65-79.

5. Darrow, G.M. 1937. Interrelation of temperature and photoperiodism in the production of fruit-buds and runners in the strawberry. Proc. Amer. Soc. Hort. Sci. 34:360-63.

6. Darrow, G.M. and G.F. Waldo. 1933. Photoperiodism as a cause of the rest period in strawberries. Science 77:353-54.

7. Darrow, G.M. and G.F. Waldo. 1934. Responses of strawberry varieties and species to duration of the daily light period. U.S. Dept. Agr. Tech. Bul. 453.

8. Downs, R.J. and A.A. Piringer. 1955. Differences in photoperiodic response of everbearing and June-bearing strawberries. Proc. Amer. Soc. Hort. Sci. 66:234-36.

9. Guttridge, C.G. 1958. The effects of winter chilling on the subsequent growth and development of the cultivated strawberry plant. J. Hort. Sci. 33:119-27.

10. Hartmann, H.T. 1947. The influence of temperature on the photoperiodic response of several strawberry varieties grown under controlled environment conditions. Proc. Amer. Soc. Hort. Sci. 50:243-45.

11. Hartmann, H.T. 1947. Some effects of temperature and photoperiod on flower formation and runner production in the strawberry. Plant Phys. 22:407-20.

12. Iyer, C.P.A. and L. Smeets. 1966. Effects of temperature pretreatments on the forcing of strawberry plants (CV. Glasa). Euphytica. 15:297-303.

13. Jahn, O.L. and M.N. Dana. 1970. Effects of cultivar and plant age on vegetative growth of the strawberry, Fragaria ananssa. Amer. J. Bot. 57:993-999.

14. Jahn. O.L. and M.N. Dana. 1970. Growth Relationships in the strawberry plant. J. Amer. Soc. Hort. Sci. 95:745-749.

15. Loomis. N.H. 1938. Runner production of strawberry varieties. Proc. Amer. Soc. Hort. Sci. 35:508-10.

16. Morrow, E.B. 1938. Number and length of runners of strawberry varieties. Proc. Amer. Soc. Hort. Sci. 35:511-13.

17. Morrow, E.B. and J.H. Beaumont. 1932. Effect of age of plant on flower production and yield of strawberries in North Carolina. Proc. Amer. Soc. Hort. Sci. 28:206-10.

18. Morrow, E.B. and G.M. Darrow. 1940. Relation of number of leaves in November to number of flowers the following spring in the Blakemore strawberry. Proc. Amer. Soc. Hort. Sci. 37:571-73.

19. Proebsting, E.G. Sr. 1956. The effect of soil temperature on the mineral nutrition of the strawberry. Proc. Amer. Soc. Hort. Sci. 69:278-281.

20. Roberts, A.N. and A.L. Kenworthy. 1956. Growth and composition of the strawberry plant in relation to root temperature and intensity of nutrition. Proc. Amer. Soc. Hort. Sci. 68:157-68.

21. Robertson, Margaret. 1955. Studies on the development of the strawberry. III. Flower bud initiation and development in large-fruited perpetual ("Remontant") strawberries. J. Hort. Sci. 30:62-68.

22. Smeets, L. 1955. Runner formation on strawberry plants in autumn and winter. II. Influence of the light intensity on the photoperiodic behavior. Euphytica 4:240-44.

23. Smeets, L. 1956. Influence of the temperature on runner production in five strawberry varieties. Euphytica 5:13-17.

24. Smeets, L. and H.G. Kronenberg. 1955. Runner formation on strawberry plants in autumn and winter. Euphytica 4:53-57.

25. Snedecor, G.W. and W.G. Cochran. 1967. Statistical methods. Sixth Edition. The State University Press, Ames, Iowa. p 593.

26. Sproat, B.B., G.M. Darrow and J.H. Beaumont. 1936. Relation of leaf area to berry production in the strawberry. Proc. Amer. Soc. Hort. Sci. 33:389-92.

STUDIES ON FORCING OF STRAWBERRY CULTIVARS

by

MOHAMED ABDUL-RAHIM SHAHEEN

B.Sc., Horticulture, Faculty of Agriculture
Cairo University, 1975

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Horticulture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1979

ABSTRACT

To test the feasibility of late winter forcing of strawberry plants, 10 cultivars were compared -- 'Redchief', 'Surecrop', 'Atlas', 'Guardian', 'Delite', 'Apollo', 'Fairfax', and 'Raritan' (Junebearers) and 'Quinalt' and 'Ozark Beauty' (everbearers). All were grown in the greenhouse at Kansas State University under 21°C day, 15°C night and 16 hours photoperiod. Two treatments tested under the split-plot design were full sun and partial sun provided by lath shading structure.

Plants of 'Delite', 'Ozark Beauty' and 'Raritan' were transferred to the field on April 8, 1978 after forcing for 40 days in greenhouse under partial sun. They were planted in a splot-plot design testing full sun and partial sun treatments.

In the greenhouse, plants grown under full sun produced larger average leaf area, greater total leaf area, greater fresh and dry weight of leaves, larger number of flowers, than those grown under partial sun. There also was more uniformity of petiole length as indicated by a lower standard deviation and coefficient of variation of petiole length. A significant cultivar x sun treatment interaction was observed for only one variable measured, number of flowers per cluster. None of the cultivars tested performed better under partial sun than full sun for any variable measured.

'Delite' was adapted to greenhouse forcing since it a desirable short petiole length, a large number of leaves, large total leaf area, a large fresh and dry weight of leaves, required a desirable long number of days to flower, and had a large number of flowers and flower clusters. 'Fairfax' also produced good plant and flowering characteristics and had desirable uniform petiole length. 'Quinalt' produced good plant growth characteristics but flowered poorly.

All strawberry plants transplanted to the field survived. Only 'Ozark Beauty', the everbearing cultivar, flowered directly after transplanting. There was no difference in growth between partial sun and full sun. 'Delite' produced more leaves and 'Delite' and 'Raritan' produced more stolons. 'Delite' which performed well in the greenhouse also grew well in the field.