SHADING EFFECTS ON GROWTH, YIELD AND FRUIT QUALITY OF STRAWBERRY

By

OMMY ASMA
REGISTRATION NO. 05-01721

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Approved by:

(Prof. A.M.M. Shamsuzzaman)
Department of Agricultural Botany
Research Supervisor

(Dr. A.F.M. Jamal Uddin)
Associate Professor
Department of Horticulture
Research Co-supervisor

(Prof. Asim Kumar Bhadra)

Chairman
Examination Committee
Department of Agricultural Botany

DEPARTMENT OF AGRICULTURAL BOTANY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

Memo No: SAU/ABOT/

CERTIFICATE

This is to certify that the thesis entitled **"SHADING EFFECTS ON GROWTH, YIELD AND FRUIT QUALITY OF STRAWBERRY"** submitted to the **DEPARTMENT OF AGRICULTURAL BOTANY**, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURAL BOTANY**, embodies the results of a piece of bonafide research work carried out by **OMMY ASMA**, Registration number: **05-01721** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has duly been acknowledged.

Dated:
Dhaka, Bangladesh

Prof. A.M.M. Shamsuzzaman
Department of Agricultural Botany
Research Supervisor
Sher-e-Bangla Agricultural University
Dhaka-1207

DEDICATED

TO MY

PARENTS

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ABSTRACT

This pot experiment was conducted at Horticulture Research Farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2010 to March 2011. The experiment was laid out in split plot design with four replications and each main plot had three subplot with three pot. Three genotypes of strawberry namely, RABI-3, Camarosa, Nohime were grown with three shade treatments namely, 100% sunlight, 20% shade, 35% shade.

RABI-3 and Camarosa produced better yield and marketable quality. In case of Soluble Solid Content and ascorbic acid, Camarosa performed better under 20% shade. Result indicated that 100% sunlight is required for the best strawberry production but under 20% shade fruit quality was better. Under 35% shade all the genotypes had ill performance for all parameters studied. The genotype Nohime failed to show better performance in quality attributes. The highest yield was observed in Camarosa followed by RABI-3 and the lowest in Nohime. The highest yield and the best vegetative growth were obtained under full sunlight followed by 20% shade treatment. Results also revealed that 35% shade was unsuitable for strawberry cultivation.

CHAPTER I

INTRODUCTION

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CHAPTER I

INTRODUCTION

Strawberry (*Fragaria x ananassa* Duch.) is one of the most delicious and fragrantly sweet flavoured fruit of the world, which is very popular in many countries.. The fruit is widely appreciated for its characteristic aroma, bright red color, juicy texture, and sweetness. *Fragaria* is a genus of flowering plants in the Rosaceae family.. The most common strawberries grown commercially are cultivars of the garden strawberry, a hybrid known as (*Fragaria× ananassa* Duch.).

The strawberry is in technical terms, an aggregate accessory fruit, meaning that the fleshy part is derived not from the plant's ovaries but from the "receptacle" that holds the ovaries. Each apparent "seed" (achene) on the outside of the fruit is actually one of the ovaries of the flower, with a seed inside it. In both culinary and botanical terms, the entire structure is considered a fruit. Strawberry fruit is non-climacteric and ripens rapidly (Perkins- Veazie, 1995). Fruit develop a fully red (ripe) stage within 30 to 40 days after anthesis, depending on cultivar and environment (Perkins-Veazie, 1995). Many physiological changes occur in the ripening of fruit that determine consumer perception of fruit quality (Wills et al., 1998). During ripening, fruit continue to increase in size, accumulate soluble solid content (SSC) and shows distinct changes in pigmentation and softening (Spayd and Morris, 1981).

Strawberry has adapted to extremely different environmental condition. It is grown extensively in cool region and also in semi tropical regions. Full sunlight and available water are key components for producing high quality strawberry fruit. As

strawberry fruit bearing and maturity occur in a short time (20-40 days after pollination) and also strawberries have shallow root systems (the plants are growing via stolons) light and water management are critical for achieving high yield and fruit quality. Light is one of the most important and variable components of the plant environment. It is also a major factor in determining the photosynthesis and photomorphogenesis of the plant.

Netting is used in agriculture to protect crops from either excessive solar radiation (i.e. shading), or environmental hazards (e.g. hail, strong winds, sand storms), or flying pests (birds, fruit-bats, insects). The nets most commonly used for shading of ornamental crops and nurseries are black shade nets of 40-80% shading. The Nets represent a new agro-technological concept, which aims at combining the physical protection, together with differential filtration of the solar radiation, for specifically promoting desired physiological responses that are light regulated. The target responses are those determining the commercial value of each crop, including yield, product quality, and rate of maturation. Strawberries have a reasonably high light requirement to produce good yield and quality fruit. Strawberry plants become light saturated at light levels between 800 to 1200 μMol m^{-2} s^{-1} photosynthetic photon flux, at ambient CO_2 and a temperature of 25^0C (Morgan, 2006). In forcing the strawberry cultivar 'Glasa' under poor light conditions in the glasshouse, a sharp drop in light intensity, leading to a low light level for some days, resulted in stamen abortion in those flower buds which were due to open in a few days, led to poor fruit set (Smeets, 1976). It is also said that Light intensity affected the flowering-date, the number of inflorescences, the number of flowers per inflorescence, stamen development and fruit set (Smeets, 1980). Similarly another studies carried out by Miura *et al.* (1993) that

the fruits in the shade treatment required a longer period of time after anthesis to reach the full red stage, the size (minor diameter, fresh weight and dry weight) was smaller, e.g., 18% decrease in dry weight, and the contents of fructose, glucose, and sucrose were also lower than those in the fruits in the absence of shading. Shading had a significant effect on glucose and sucrose concentrations (Watson *et al.*, 2002). Strawberry cultivar cv. Elsanta were grown in peat bags in a glasshouse and subjected to three shading levels (0%, 25%, and 47%) for 2 weeks. In that case, sucrose concentration showed a decrease throughout the harvest period, whereas glucose and citric acid showed less clear trends.

Bangladesh is situated in a sub-tropical region and the duration of winter is very short here- only two months. On the other hand, strawberry is a fruit of mainly cool regions. In our country when strawberry plants get into reproductive stage the temperature raises gradually. For that reason production reduces to a lower state. Hence, the aim of this study were to observe yield and fruit quality responses of strawberry under different shade conditions.

OBJECTIVES

The present study was carried out with the following objectives

1. To determine the influence of shades on the growth of strawberry plants ;
2. To observe the effects of shades on the yield and yield components of strawberry and
3. To investigate the influences of shades on the strawberry fruit quality.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Strawberry (*Fragaria x Ananassa* Duch.) is an important fruit crop and its commercial production is possible in Bangladesh. The country's weather proved suitable for strawberry farming although this delicious fruit is normally produced in countries having cold weather. Some of the published reports relevant to research topic are reviewed under the following headings:

2.1 Shading effects on growth of strawberry plants

Smeets (1976) observed that in forcing the strawberry cultivar 'Glasa' under poor light conditions in the glasshouse, a sharp drop in light intensity, leading to a low light level for some days, resulted in stamen abortion in those flower buds which were due to open in a few days.

Thomas et al., (1982) found that high-light leaves were thicker than low-light leaves and had greater development of the mesophyll. Within a light level, high-nutrient leaves were thicker, but the proportions of leaf tissues did not change with nutrient level. Leaf size was greatest in high-light, high-nutrient leaves and lowest in high-light, low-nutrient leaves. This may explain the observation that the largest leaves produced by wild strawberries in the field occur in high-light, mesic habitats, rather than in shady habitats.

According to Awang & Atherton (1995), low irradiance decrease total leaf growth, total leaf area, dry weight and number crowns per plant. Shading also have a strong

inhibitory effect on floral development. It can reduce the number of inflorescence per plant, as well as the number of flowers and fruits per inflorescence.

Yahya et al.,(1995) found that strawberry cultivar 'Rapella' grown in a glasshouse responded to shade with reductions in leaf area, number of leaves, crowns and inflorescences and shoot dry weight. There was no apparent interaction of shading and salinity on vegetative growth. Increased concentration of reducing sugars per unit fruit fresh weight at high salinity was only apparent in unshaded plants. Unshaded plants allocated more dry matter to fruits at the expense of leaf growth.

Rowcover application has had variable effects on yield, depending on growing conditions. Strawberry *(Fragaria* × *ananassa* Duch.) cvs. Chandler, Milcin, Milsei and Oso Grande response to rowcover was studied under a plasticulture-tunnel system on the Mediterranean coast of Beirut. Flowering and leaf number early in the season were comparable among covered and non-covered control groups (Ibrahim et al., 1997).

Fletcher et al., (2002) found that the use of protected structures is now common practice in the European strawberry industry for the purpose of extending the season. As a consequence, light interception to the crop is reduced. This present work attempts to understand the effect of reduced light intensity (shading) on vegetative growth and yield in *Fragaria ananassa* ('Elsanta'). Plants were grown from the green-fruit stage under three light integrals (31%, 48%, and 63% shade) and without shading (control). Fruits were picked when they had reached orange-red ripeness. Berry number and weight were recorded for each treatment. The fruit was then graded into

two classes: marketable and unmarketable. Analysis of the results revealed differences in fruit size and marketability and plant vegetative growth. Shading reduced fruit size and increased the number and weight of unmarketable fruits. Plant vegetative growth was reduced as shading increased. Leaf area, leaf number, and leaf fresh and dry weight were reduced.

Studies of several crops grown under various colored shade nets of the same shading factor (50-80% shade, depending on the crop and season) as the common practice black net, yielded rather dramatic results. Compared with the black net, the Red and Yellow nets markedly stimulated overall vegetative growth, while the Blue caused dwarfing. The Grey, on the other hand, enhanced branching, yielding "bushy" plants with short branches, smaller leaves and less variegation. In cut flower crops, the Color nets also differentially affected the flowering time and quality (Oren-Shamir et al., 2001, Priel 2001, Shahak et al., 2002).

This study aimed to determine the effects of different shading treatments on yield and growth in Camarosa strawberry cv. Five different treatments including temporary shading 1 and 2, constant shading, no shading in plastic greenhouse and open field were carried out. The highest inflorescence number, flower number and yield were obtained from temporary shading treatments. The lowest inflorescence number, flower number and yield were obtained from constant shading and open field. The plants grown in temporary shading 1 , 2 and control in plastic greenhouse. Leaf number, leaf area, petiole length of the plants grown in constant shading and open field were lower than those of the other treatments (Ozturk et al.,2004)

The effects of shading treatments at different time periods on yield and growth in the june bearing strawberry "Sweet Charlie" were evaluated. The plants were covered with 50% shading material in a green house during the following periods: 1) greenhouse check (GC) ,no shade, 2) flower initiation period (FIP1) in fall 2002, 3) flower initiation period(FIP2) in fall 2002 3) the fruiting period (FP) in spring 2003, 5) constant shading (CS), 6) open field (OF), no shade. Shading during the FP reduced runnering. In fact there is no consistent effect of shading on the crown and leaf number in the experiment. The leaf area of the plants in the CS treatment was generally larger than that in the other treatments in the spring and summer period. Also the petiole length of the plants in the GC and CS was higher than that of the plants in OF in the spring and summer periods (Demirsoy, 2007).

Chang et al., (2011) found that in a controlled environment growth chamber using T5 light or LED as light source for 6-8 weeks. The result showed cool white light (6500 and 5000 K) combined with high light intensity (6 lamps) not only enhanced plant growth, but also promoted runner formation and ramet growth. The treatment of 70% red light+30% blue light (R+B) had the highest SPAD value, dry weight, crown diameter, carbohydrate and starch content and produced the most runners.

2.2 Shading effects on yield and yield attributing characters of strawberry plants

Smeets (1976) reported that low light intensity turn led to poor fruit set. Under controlled light conditions stamen abortion was found to occur when the light intensity dropped to 4.4 W/m^2 or less.

Smeets (1980) also found that light intensity affected the flowering-date, the number of inflorescences, the number of flowers per inflorescence, stamen development and fruit set. For successful forcing, a light intensity of at least 24 W m^{-2} is necessary.

A field study in which plants were either shaded in the fall or in the fall and spring demonstrated a decreasing trend in berry number for plots which were shaded in the fall and spring. Berry number decreased in fall-shaded plants after 30% shade. In both cases, berry weight decreased with increasing shade (Garrison et al.,1990)

According to Miura et al. (1993a), fruits of strawberry plants under a black net with a 60% light transmittance took longer to reach the full red stage than fruits than without shade treatment. They were also smaller than fruits of unshaded plants.

According to Awang & Atherton (1995), fruit yield under shaded conditions can be lower.

Yahya et al., (1995) found that shading depressed the fruit dry weight of strawberry fruit but not fresh weight, resulting in fruits with higher moisture content. Fruit number was reduced under shaded conditions. The percentage of dry matter was highest in unshaded fruits produced at high salinity.

Rowcover reduced fruit yield and number in all cvs., primarily by the reduction in fruit number. Cultivars varied in yield, irrespective of the cover treatment and in yield

distribution during the four months of harvest. The shading effect of row covers offset the effect of the slight rise in soil temperature (1-2°C) it caused (Ibrahim et al., 1997)

Durner (1999) reported that 40 g decrease in yield plant^{-1} was observed with every 30 cm decrease in planting height. This was attributed to a bigger shading effect on lower levels of the vertical production system.

Full sunlight exposure through the canopies is a key factor for maximizing fruit bearing (Watson et al., 2002; Rieger, 2005).

Any conditions such as limited leaf area, low light/temperature ratio or plant diseases that limit photosynthesis can have a negative effect on fruit size and can even cause flower shedding before fruit set. Small fruit size is a common problem with plants grown with low winter light conditions as out of season crops. This problem can be overcome by the use of artificial light and CO_2 enrichment to boost photosynthesis (Morgan, 2006).

Yield was significantly reduced in the FIP1 (1st flower initiation period in fall 2002) and FIP2 (2nd flower initiation period in fall 2002) treatments. Shading during FP (fruiting period in spring 2003) reduced inflorescence number and yield. CS (constant shading) significantly reduced all of the yield parameters. In OF (open field), the number of inflorescences and flowers and the yield per plant was significantly reduced compared to other treatments possibly because of lower temperature preventing flowering or injuring the flowers. The increased fruit weight with CS and

of treatments was the result of reduced inflorescence and flower numbers. Fruit was the smallest in FIP1. The amount of discarded fruit (deformed, rotten and small fruit) on plants shaded during FP was the highest while the least amount of total discarded was from the plants in the open field (Demirsoy, 2007) .

Although not significant, plants subjected to 20% shading tended to produce on average higher yields plant^{-1} . These plants also produced more fruits. The yield, number of leaves plant^{-1} and total leaf weight plant^{-1} were not affected by a 50% shade tretment, but a tendency to reduce the yield was observed. Shading did not affect the rate of fruit development, even though shaded fruit took slightly longer to reach the full red stage. Fruit size was also not significantly afected by shading, but the average fruit size slightly decreased with an increase in shading. Plants subjected to 50% shading produced significantly more malformed fruits. In this study 20% shading tended to have a positive effect on yield.Therefore, 20% shade net might be used to overcome the negative effect of elevated temperatures in areas where high light levels prevail (Johannes, 2008).

2.3 Shading effects on fruit quality of strawberry plants

The pH of strawberry fruit remain at about 3.5 during fruit development , although titratable acidity , representing predominantly organic acids like citric acids and malic acid , gradually drops during fruit development (Spayd & Morris ,1981).

Miura et al., (1984) found that strawberry plants, cultivated in a plastic greenhouse, were shaded by black cheesecloth with about 60% light transmittance to investigate

the effect of the light intensity on the growth, size, coloration and sugar content of a primary fruit in a truss. In the absence of treatment, the changes in the fruit minor diameter after anthesis followed a double sigmoidal pattern, that is, the growth rate (mm/day) showed an early peak 5–6 day after anthesis, immediately after the onset of the measurement, and a second peak 27–29 days after anthesis. The L* value (lightness) of the fruit surface color slightly increased from 23 days to 28 days after anthesis (white stage), and thereafter it decreased considerably. The a* value (redness) rapidly increased after 28 days, then it reached a value of 10 at 30 days (turning-red stage) and a value of 40 at 36 days after anthesis (full red stage). The L* value was high from 23 to 30 days after anthesis (white stage). A rapid increase of the a* value occured after 30 days, while the value of 10 was reached at 32 days (turning-red stage) and the value of 40 at 38 days after anthesis (full red stage). Although the fruits in the shade treatment required a longer period of time after anthesis to reach the full red stage, the size (minor diameter, fresh weight and dry weight) was smaller, e.g., 18% decrease in dry weight.

Miura et al., (1993a) also found that fruits of shaded plants had lower fructose, glucose and sucrose content.

Yahya et al., (1995) acidity in fresh fruit was promoted by increased salinity both under shaded and unshaded conditions. Shading increased acid concentration per unit dry weight but not on a fresh weight or a per fruit basis.

Sucrose levels are generally much lower and only start to accumulate around the middle of fruit development . The average sugar level of strawberry fruit is around a brix of 8 to 10, which gives acceptable flavor (Hancock, 1999).

Watson et al., (2002) found that strawberry cv. Elsanta were grown in peat bags in a glasshouse and subjected to three shading levels (0%, 25%, 47%) for 2 weeks, commencing 1 week prior to first fruit ripening. Fruit was harvested at five intervals and analysed using Atmospheric Pressure Chemical Ionization (APCI) and direct liquid-mass spectrometry techniques. Thirteen volatiles implicated in strawberry flavour and three non-volatiles, sucrose, glucose and citric acid, were measured. Highly significant differences in volatile and non-volatile concentrations existed between harvest dates. Shading had a significant effect on hexanal, ethyl methyl butyrate, and methyl butyrate concentrations at some harvests. In general, at each harvest the higher the level of shading the lower the level of the volatile in the fruit. Sucrose concentration showed a decrease throughout the harvest period, whereas glucose and citric acid showed less clear trends. Shading had a significant effect on glucose and sucrose concentrations. Some possible reasons for the variability in strawberry flavor are discussed.

Sweetness is a function of sugar quantity and type. Therefore, the relative sugar composition is an important factor that affects fruit quality. Sugar content and composition is dependent upon the ripening stage, cultivar and growth conditions (Hamano et al., 2002).

Acid levels in the fruit seem to be less affected by low light conditions compared to sugar level, thus out of season fruit can be acidic without the required sweetness to balance the flavor. (Morgan , 2006).

The soluble content of the fruits in OF (open field) was the highest possibly due to the high light intensity while those of the fruits in CS (constant shading) and FP (fruiting period in spring 2003) was the lowest.

Plants subjected to 50% shading produced with lower level of soluble solids compared to fruits subjected to 0% and 20% shading. Overall, 50% shading only had a minor negative affect on fruit quality. Fruit quality of plants subjected to 20% shading was also good (Johannes, 2008).

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods were used in carrying out the experiment.

3.1 Experimental site and duration

The experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2010 to April 2011 to find out the effects of partial shading on growth, yield and quality of three strawberry genotypes.

3.2 Climatic condition of the experimental site

The experimental area was situated in the sub-tropical climatic zone which had three distinct seasons *viz*. the monsoon or rainy season extending from May to October, winter or dry season from November to February and the pre-monsoon period or hot season from March to April. The detailed meteorological data in respect of temperature, rainfall, relative humidity recorded by the Bangladesh Meteorological Department, Dhaka during the experimental period presented in Appendix I.

3.3 Experimental material

In the research work, the strawberry genotypes "RABI-3, Camarosa and Nohime" were used. Saplings from runner were collected from Krishibid Upokaran nursery of Dhaka city.

3.4 Treatments of the experiment

The experiment had two factors

Factor A: Three genotypes of strawberry

i) RABI-3 (V_1)

ii) Camarosa (V_2)

iii) Nohime (V_3)

Factor B: There were 3 shading levels as follows :

i) No shadding (P_o): Plants grown under no shading (control) with 100% sunlight.

ii) Single net (P_1): Plants grown under 20% shade condition.

iii) Double net (P_2): Plants grown under 35% shade condition.

After the strawberry seedlings establishment,nylone nets were hanged at a height of 1.3 m to reduce light intensity.Single layer net reduced 20% light intensity.Double layer net reduced 35% light intensity. Light intensity was measured by a light intensity meter (LX-1102, Taiwan) in lux.

The treatment combinations were :

P_0V_1, P_0V_2, P_0V_3, P_1V_1, P_1V_2, P_1V_3, P_2V_1, P_2V_2, P_2V_3

3.5 Design and layout of the experiment

The experiment was laid out in split plot design with four replications. A total of 36 pots were required in the experiment. (Fig 1: Layout of the experiment)

The whole experimental pots were divided into four blocks, each of which was then divided into 3 sub plots with 3 pots in every plot. The size of each unit pot was 25 cm (10 inches) in diameter and 20 cm in (8 inches) in height.

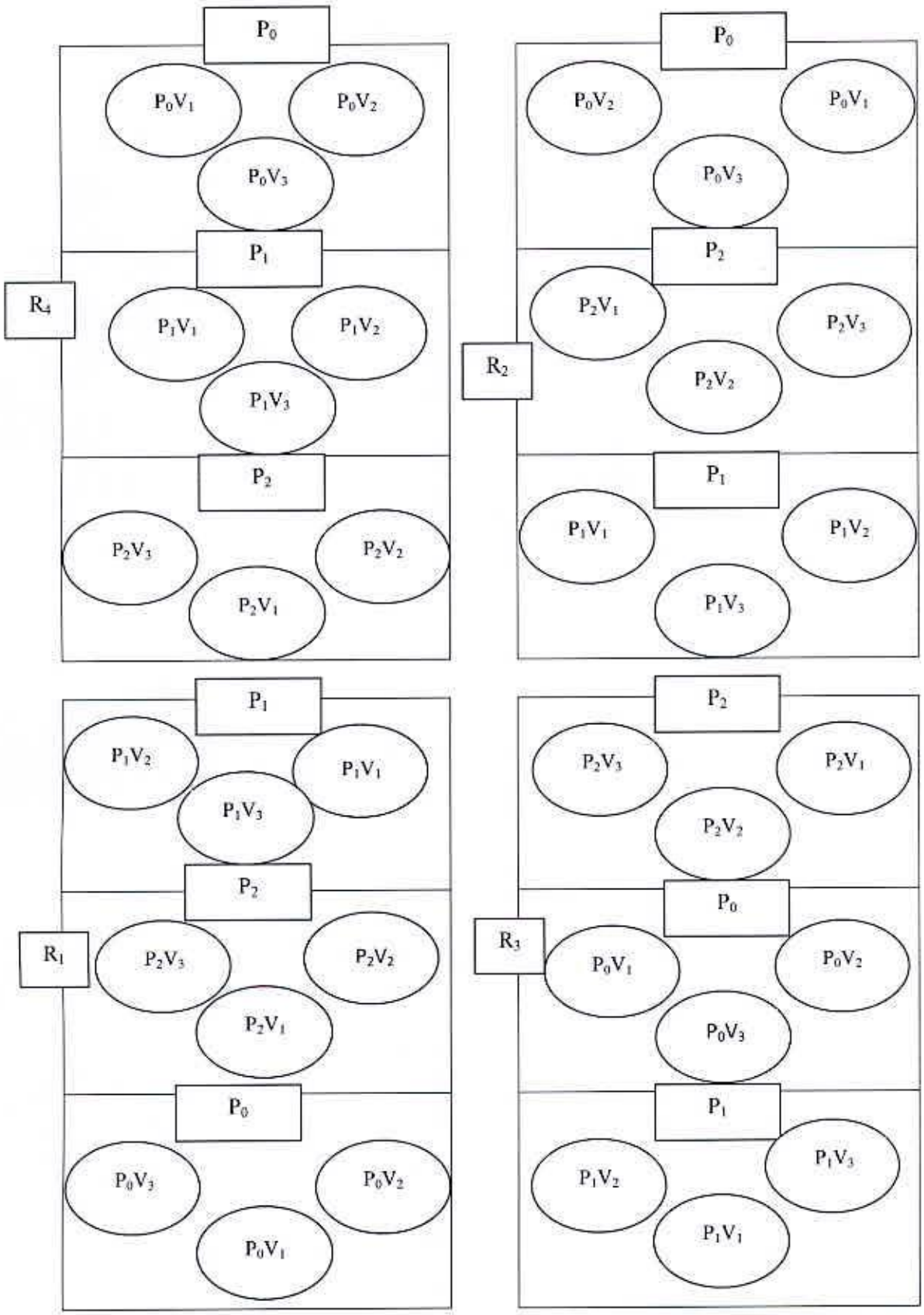


Fig 1: Layout of the experiment

3.6 Pot preparation

In this experiment earthen pots were used. At first the pots were sun dried. Loamy soils were used for pot preparation. Soil and cow dung were mixed and pots were filled 7 days before transplanting. Pots were filled on 2nd November 2010. The weeds and stubbles were completely removed from the soil. The pH of the soil was 6.0-6.5 that means slightly acidic.

3.7 Transplanting of seedlings

Runners were transplanted in such a way that the crown did not go much under the soil or nor remained in shallow. On an average runners were planted at 7 cm depth in pot on 4th November 2010. There will be 36 pots, 12 for each genotypes. A single propagule was grown in a single pot.

3.8 Manure and fertilizers application

Only cowdung and vermicompost were used as fertilizer @ 0.75kg/pot and 0.25kg/pot, respectively.

3.9 Intercultural operations

3.9.1 Weeding

Weeding was done whenever necessary to keep the crop free from weeds and to pulverize the soil. Weeding was done manually by 'Khurpi'.

3.9.2 Irrigation

Frequency of watering depended upon the moisture status of the soil. However, water logging was avoided, as it is harmful to plants.

3.9.3 Protection

During fruit ripening time the pots were covered with net to protect the fruit from bird, squirrel and rat.

3.9.4 Disease and pest control

During the flowering stage experimental crop was infested by grey mold. It was controlled by spraying Endofil M-45@ 1mg/L. Fungicide was sprayed two times at 15 days interval. Crop was also attacked by leaf feeder during the growing stage and flowering stage. The larvae were controlled by Pyrethrum @ 1.5 ml/L. The insecticides were sprayed 7 days after transplanting of runners.

3.9.5 Harvesting of fruits

Fruits were harvested from 26th January 2011 when the fruit reached at harvesting stage. In harvesting period the fruits turned red in color with waxy layer on the surface of fruit.

3.10 Data collection (Growth ,Yield and Fruit Quality)

3.10.1 Leaf Area Index (LAI)

Leaf area was measured by using CL-202 Leaf Area Meter and expressed in cm^2. For leaf area measurement the mature leaf were collected randomly from each plant. Leaf area Index was measured by following formula:

$$LAI = \frac{\text{Total leaf area of a plant}}{\text{Ground area covered by the plant canopy}}$$

3.10.2 Days to 1st bud initiation from sapling transplanting

Days to 1st bud initiation was obtained counting the days from date of transplanting propagules.

3.10.3 Days to 1st flowering from transplanting

Days to 1stflowering was obtained counting the days from date of transplanting propagules.

3.10.4 Days to 1st fruit setting from transplanting

Days to 1stfruit setting was obtained counting the days from date of transplanting propagules.

3.10.5 Days to 1st fruit ripening from transplanting

Days to 1stfruit ripening was obtained counting the days from date of transplanting propagules.

3.10.6 Total no of bud / plant

Total number of flower buds was recorded by counting all flower bud from each plant of each pot and the mean was calculated.

3.10.7 Total no of flower / plant

Total number of flowers was recorded by counting all flowers from each plant of each pot and the mean was calculated.

3.10.8 Total no of fruit / plant

Total number of fruits was recorded by counting all fruits from each plant of each pot and the mean was calculated.

3.10.9 Percentage of fruit set

It was determined by the formula:

$$\text{Percentage of fruitset} = \frac{\text{No. of seeded fruits per umbel}}{\text{No. of flowers per umbel}} \times 100$$

3.10.10 Total fruit weight (g) per plant

Every fruit weight was weighed with the help of electrical weight balance. The total weight of each pot was obtained by addition the weight of total fruits.

3.10.11 Weight (g) of each fruit per plant

Weight of each fruit was obtained from division of the total fruit weight by total number of fruit.

3.10.12 pH of the fruit

The pH content was measured by pH meter (Model-pH-208, Lutron electronic Enterprise Company Limited, Taiwan). To measure the pH content 10 g fruits were sampled and blended with distilled water. After blending the juice was collected made its volume 20 ml by adding distilled water . Then juice sample was analyzed with the pH meter.

3.10.13 Soluble Solid Content (SSC)

The soluble solid content (SSC) was measured by a refractometer (ERMA, Tokyo¬Japan). To measure the SSC percentage 5 g fruits were sampled and blended. After blending the juice was collected. The brix percentage of fruits was measured at 20^0C. When the temperature was more or less than 20°C the reading was corrected by using the temperature correction table.

3.10.14 Ascorbic acid

Ascorbic acid (%) was measured by 2,4 dichlorophenol indophenol visual titration method (Ranganna, 1986).

Reagents:

1. 3% Meta phosphoric acid (HPO_3): Pellets of HPO_3 was dissolved in glass distilled water.

2. Ascorbic acid standard: 100 mg of l-ascorbic acid was taken and was made up to 100ml with 3% HPO_3. 10ml was diluted to 100ml with 3% HPO_3. (1 ml=0.1mg of ascorbic acid)
3. Dye solution : 50 mg of sodium salt of 2,6 –dichlorophenol-indophenol was dissolved in approximately 150 ml of hot glass distilled water containing 42 mg of sodium bicarbonate. It was diluted and cool with glass distilled water to 200 ml than it was stored in a refrigerator and standardized everyday.

Procedure:

Standardization of dye: 5 ml of standard ascorbic solution was taken and 5 ml of HPO_3 was added. A micro burette was filled with the dye. Titration with the dye solution was done to a pink colour that persisted for 15 seconds. Dye factor was determined, i.e. mg of ascorbic acid per ml of the dye, using the formula:

Dye factor=0.5/titre

Preparation of sample:

10 ml of sample was taken and was made up to 100ml with 3% HPO_3. After that the solution is filtrated with filter paper.

5 ml of the HPO_3 extract of the sample was taken and titrated with the standard dye to a pink end point which should persist for at least 15 sec.

Calculation:

Calcultion of ascorbic acid content of the sample was done by using the following formula-

$$\text{Ascorbic acid}(\%) = \frac{\text{Titre} \times \text{Dye factor} \times \text{volume made up} \times 100}{\text{Extract taken for estimation} \times \text{Volume of sample taken for estimation}}$$

3.11 Statistical analysis

Data regarding various characteristics under study were statistically analyzed by the computer using statistical package programme MSTAT–C. The means for all the treatments were calculated and the analysis of variance was performed by F-variance test. The difference between pair of means was performed by Least Significant Difference (LSD) test (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The research work was conducted to find out the shading effects on growth, yield and fruit quality of strawberry. The results of this experiment have been presented and discussed in this chapter. A summary of the analysis of variance of all the parameters studied together with their sources of variation and corresponding degrees of freedom have been shown in the Appendices II to VI. Results of the different parameters studied in the experiment have been presented and discussed under the following headings.

4.1 Growth characters of strawberry genotypes under different levels of shading

4.1.1 Leaf Area Index (LAI)

Leaf Area Index was measured in 25 and 50 DAT. LAI 25 days after transplanting is presented on Table 4.1, which show that there were a significant variation of leaf area index 25 days after transplanting among the shade treatment and the shade × genotype interactions.

Genotype V_2 (Camarosa) found the maximum leaf area index (7.910), which is statistically identical with V_1 (RABI-3) and V_3 (Nohime) genotypes. There was no significant variation of LAI among the genotypes.

Table 4.1: Growth characters of strawberry genotypes under different levels of shading[x]

Genotype[y]	Leaf Area Index (LAI) Index	
	25 DAT	50 DAT
V_1	7.093	8.950
V_2	7.910	9.450
V_3	6.638	9.147
$LSD_{0.05}$	2.093	1.079
Shade[z]		
P_0	8.097	10.82
P_1	7.146	9.108
P_2	6.398	7.617
$LSD_{0.05}$	1.688	1.466
Interaction		
$P_0 V_1$	8.273 ab	10.70 ab
$P_1 V_1$	6.997 bc	8.6000 cd
$P_2 V_1$	6.010 c	7.550 d
$P_0 V_2$	8.910 a	11.05 a
$P_1 V_2$	7.860 abc	9.325 bc
$P_2 V_2$	6.960 bc	7.975 cd
$P_0 V_3$	7.108 abc	10.72 ab
$P_1 V_3$	6.580 bc	9.400 bc
$P_2 V_3$	6.225 c	7.325 d
$LSD_{0.05}$	2.093	1.639
CV (%)	13.32	9.09

[x] In a column means having similar letter(s) or without letter are statistically identical and those having dissimilar letter(s) differ significantly at $\alpha \leq 0.05$ level of significance by LSD range test

[y] V_1; RABI-3, V_2; Camarosa and V_3; Nohime

[z] P_0; 100% sunlight, P_1; 20% shade, P_2; 35% shade

There was a variation in leaf area index from transplanting under all the three shade treatments. The maximum leaf area index 25 days after transplanting (8.097) was obtained under P_0 (100% sunlight), which was statistically identical to P_1 (20% shade). The minimum LAI (6.398) was found under P_3 (35% shade).

Under different interaction effects of shade and genotypes a significant variation was observed in Leaf Area Index 25 days after transplanting. The maximum Leaf Area Index 25 days after transplanting (8.910) was obtained under P_0V_2 (100% sunlight × Camarosa), which was however statistically identical with P_0V_1(100% sunlight ×RABI-3), P_1V_2 (20% shade × Camarosa) and P_0V_3 (100% sunlight ×Nohime).P_1V_1(35% shade × RABI-3) showed the next maximum Leaf Area Index from transplanting (6.997) and that was however statistically similar with P_1V_3 (20% shade × Nohime) and P_2V_2 (35% shade× Camarosa). The minimum Leaf Area Index 25 days after transplanting (6.010) was observed under P_2V_1 (35% shade × RABI-3), which was however statistically similar with P_2V_3 (35% shade × Nohime).

Vegetative growth stage of a plant can be determined by Leaf area index. It is predominantly a genetic character. From the all shade treatments P_0 (100% sunlight) performed the best. From the interaction effect it is notified that Camarosa under 100% sunlight give the best performance. Thomas et al., (1982) also found that leaf size was greatest in the high-light. According to Awang and Atherton(1995), low irradiance decrease total leaf growth and total leaf area. Fletcher et al.,(2002) described that leaf area, leaf number, leaf fresh and dry weight were reduced under shading.

Table 4.1 is also showinng that were a significant variation of LAI 50 days after transplanting in shade treatment and the shade × genotype interactions.

Though genotype V_2 (Camarosa) found the maximum Leaf Area Index (9.450) but there was no significant variation among the genotypes.

There was a variation in LAI from transplanting under all the three shade treatments. The maximum LAI 50 days after transplanting (10.82) was obtained under P_0 (100% sunlight), followed by (9.108) treated with P_1 (20% shade). The minimum LAI 50 days after transplanting (7.617) was found under P_3 (35% shade).

A significant variation in LAI 50 days after transplanting was also observed under different interaction effects of shade and genotypes. The maximum Leaf Area Index 50 days after transplanting (11.05) was obtained under P_0V_2 (100% sunlight × Camarosa), which was however statistically identical to P_0V_1 (100% sunlight × RABI-3) and P_0V_3 (100% sunlight × Nohime). The minimum Leaf Area Index 50 days after transplanting (7.325) was found under P_2V_3 (35% shade × Nohime), which was however statistically similar to P_2V_1 (35% shade × RABI-3).

LAI is an important character in vegetative growth stage of strawberry plant. It is predominantly a genetic character. Genotype V_2 (Camarosa) required showed the best vegetative growth. From the all shade treatments P_0 (100% sunlight) performed the best and Leaf Area Index in this treatment is the maximum. From the interaction

effect it is clearly identified that P_0V_2 and P_0V_1 treatment combination give the best performance.

Table 4.2 Reproductive characters of strawberry genotypes under different levels of shading[x]

Genotype[y]	Days to 1st bud initiation from transplanting	Days to 1st flowering from transplanting	Days to 1st fruit setting from transplanting	Days to 1st fruit ripening from transplanting
V_1	83.50	95.75	101.8	116.1
V_2	79.33	93.08	100.3	112.7
V_3	98.33	110.6	117.9	125.6
$LSD_{0.05}$	8.519	4.263	3.194	4.948
Shade[z]				
P_0	71.08	83.50	91.50	108.3
P_1	89.00	101.7	108.7	117.8
P_2	101.1	114.3	119.9	128.3
$LSD_{0.05}$	3.501	7.262	7.242	8.248
Interaction				
$P_0 V_1$	69.50 d	80.25 d	86.00 d	106.5 ef
$P_1 V_1$	85.50 c	97.00 c	103.5 c	116.3 cd
$P_2 V_1$	95.50 b	110.0 b	116.0 b	125.5 b
$P_0 V_2$	62.50 d	75.75 d	83.25 d	103.8 f
$P_1 V_2$	79.50 c	94.25 c	102.5 c	111.0 def
$P_2 V_2$	96.00 b	109.3 b	115.3 b	123.3 bc
$P_0 V_3$	81.25 c	94.50 c	105.3 c	114.5 cde
$P_1 V_3$	102.0 b	113.8 b	120.0 b	126.3 b
$P_2 V_3$	111.8 a	123.5 a	128.5 a	136.0 a
$LSD_{0.05}$	8.070	8.117	8.095	9.218
CV (%)	4.72	4.14	3.86	3.98

[x] In a column means having similar letter(s) or without letter are statistically identical and those having dissimilar letter(s) differ significantly at $\alpha \leq 0.05$ level of significance

[y] V_1; RABI-3, V_2; Camarosa and V_3; Nohime

[z] P_0; 100% sunlight, P_1; 20% shade, P_2; 35% shade

4.2 Reproductive characters of strawberry genotypes under different levels of shading

4.2.1 Days to 1st bud initiation

The days to 1st floral bud initiation from transplanting is shown on Table 4.2, which show that there was a significant variation of days to 1st floral bud initiation from transplanting among the genotypes, shade treatments and the shade × genotype interactions.

Genotype V_3 (Nohime) took the maximum days to 1st bud initiation from transplanting (98.33 days) whereas, V_1 (RABI-3) took (83.50 days) for 1st bud initiation from transplanting .The genotype V_2 (Camarosa) took the lowest days to 1st bud initiation from transplanting (79.33 days) which was significantly different from V_1 and V_3.

The shade treatments had a variation in days to 1st bud initiation from transplanting. P_2 (35% shade) needed more days to 1st bud initiation from transplanting (101.1 days) than days to 1st bud initiation from transplanting (89 days) under P_1 (20% shade). The minimum days to 1st bud initiation from transplanting (71.08 days) was found under P_0 (100% sunlight).

Number of days required to first bud initiation increased with increasing shading level (Table 4.2). The highest days to 1st bud initiation from transplanting (111.8 days plant

[1]) was observed under P_2V_3 (35% shade × Nohime), followed by P_1V_3, which was however statistically identical with P_2V_2 (35% shade × Camarosa) and P_2V_1 (35% shade × RABI-3). The third highest days to 1st bud initiation from transplanting (85.50 days) was found under P_1V_1 (20% shade× RABI-3) which was however statistically identical with P_0V_3 (100% sunlight × Nohime) and P_1V_2 (20% shade × Camarosa). P_0V_2 (100% sunlight × Camarosa) required the minimum days to 1st bud initiation from transplanting (62.50 days), statistically similar with P_0V_1 (100% sunlight × RABI-3).

From days to 1st floral bud initiation vegetative growth of strawberry plant can clearly realize. The total flower number is fully rely on the days to 1st bud initiation and so the total yield of a plant. It is predominantly a genetic character. Genotype V_2 (Camarosa) required the minimum time for bud initiation. From the all shade treatments P_0 (100% sunlight) performed the best and time required in this treatment is the minimum.

4.2.2 Days to 1st flowering

The days to 1st flowering from transplanting is presented on Table 4.2, showing that there was a significant variation on days to 1st flowering from transplanting among the genotypes, shade treatments and the shade × genotype interactions.

Days to 1st flowering from transplanting occurred a significant variation in different genotypes. Genotype V_3 (Nohime) required the maximum days to 1st flowering from

transplanting (110.6 days) and next maximum days to 1st flowering from transplanting (95.75 days) was found under V_1 (RABI-3). Genotype V_2 (Camarosa) showed best performance, required the minimum days to 1st flowering from transplanting (93.08 days) which was significantly different from that under V_1 and V_3.

There was a variation in days to 1st floral bud initiation from transplanting under all the three shade treatments. The maximum days to 1st flowering from transplanting (114.3 days plant^{-1}) was required under P_2 (35% shade) and the minimum days (83.50 days) was needed for P_0(100% sunlight).

There was a significant variation in days to 1st flowering from transplanting under different interaction effects of shade and genotypes. The maximum days to 1st flowering from transplanting (123.5 days) was required for P_2V_3 (35% shade × Nohime), followed by P_1V_3, which was however statistically identical with P_2V_1 (35% shade ×RABI-3) and P_2V_2 (35% shade ×Camarosa). The nearest maximum days to 1st flowering from transplanting (97.00 days) was found under P_1V_1 (20% shade× RABI-3), statistically identical with P_0V_3 (100% sunlight × Nohime) and P_1V_2 (20% shade × Camarosa). P_0V_2 (100% sunlight × Camarosa) took minimum days to 1st flowering from transplanting (75.75 days), which was however statistically similar with P_0V_1 (100% sunlight × RABI-3).

Vegetative growth stage of strawberry plant can be realized by days to 1st flowering. The total fruit number and yield of a plant are fully depended on the days to 1st

flowering. It is predominantly a genetic character. Genotype V_2 (Camarosa) and P_0 (100% sunlight) performed the best and time required for flowering in this treatments is the lowest. Smeets (1980) found that light intensity affected the flowering date. Oren-Shamir et al., (2001), Priel (2001), Shahak et al., (2002), Orner-Shamir et al., (2003) found that nets differentially affected the flowering time and quality.

4.2.3 Days to 1st fruit setting

Table 4.2 presented the days to 1st fruit setting from transplanting showing that there was a significant variation of days to 1st fruit setting from transplanting among the genotypes, shade treatments and the shade × genotype interactions.

Genotype V_3 (Nohime) found the maximum days to 1st fruit setting from transplanting (117.9 days). The nearest maximum days to 1st flowering from transplanting (101.8 days) was found under V_1 (RABI-3). Genotype V_2 (Camarosa) needed the minimum days to 1st fruit setting from transplanting (100.3 days plant^{-1}) which was significantly different from that under V_1 and V_3.

There was a variation in days to 1st fruit setting from transplanting under all the three shade treatments. The maximum days to 1st fruit setting from transplanting (119.9 days) was occurred under P_2 (35% shade) then (108.7 days) was found under P_1 (20% shade). The minimum days to 1st fruit setting from transplanting (91.50 days plant^{-1}) was required for P_0 (100% sunlight).

A significant variation in days to 1st fruit setting from transplanting was also observed under different interaction effects of shade and genotypes. The maximum days to 1st fruit setting from transplanting (128.5 days) was obtained under P_2V_3 (35% shade × Nohime),followed by P_1V_3(20% shade × Nohime) ,which was statistically similar with P_2V_1 (35% shade × RABI-3) and P_2V_2 (35% shade × Camarosa) treatment combinations. The minimum days to 1st fruit setting from transplanting (83.25 days) was found under P_0V_2 (100% sunlight × Camarosa), which was however statistically similar with P_0V_1 (100% sunlight × RABI-3) treatment combinations.

An important character for growth stage of strawberry plant is days to 1st fruit setting. The total fruit number, size and quality of the fruit is fully depended on the days to 1st fruit setting. It is predominantly a genietic character. Genotype V_2 (Camarosa) and P_0 (100% sunlight) required the minimum time for fruit setting. From the interaction effect it is clearly identified that P_0V_1 and P_0V_2 treatment combination give the best performance. So, 100% sunlight is very much effective in strawberry production.

4.2.4 Days to 1st fruit ripening

The days to 1st fruit ripening from transplanting is presented on Table 4.2, which shows that there was a significant variation of days to 1st fruit ripening from transplanting among the genotypes, shade treatment and the shade × genotype interactions.

Genotype V_3 (Nohime) required the maximum days to 1st fruit ripening from transplanting (125.6 days) . The nearest maximum days required to 1st fruit ripening from transplanting (116.1 days) was found under V_1 (RABI-3), statistically similar with V_2 (Camarosa) and its required minimum days to 1st fruit ripening from transplanting (112.7 days) and significantly different from that under V_3.

Variation was observed under all the shade treatments in days to 1st fruit ripening from transplanting. The maximum days to 1st fruit ripening from transplanting (128.3 days) was required under P_2 (35% shade). The second maximum days to 1st fruit ripening from transplanting (117.8 days) was found under P_1 (20% shade). P_0 (100% sunlight) performed the minimum days to 1st fruit ripening from transplanting (108.3 days) , statistically dissimilar with P_1 and P_2.

Maximum days to 1st fruit ripening from transplanting (136.0 days) was obtained under P_2V_3 (35% shade × Nohime),followed by P_1V_3(20% shade × Nohime) ,which was however statistically similar with P_2V_1 (35% shade × RABI-3). The minimum days to 1st fruit ripening from transplanting (103.8 days) was found under P_0V_2 (100% sunlight × Camarosa), which was however statistically similar with P_0V_1 (100% sunlight × RABI-3) treatment combinations. So, a significant variation in days to 1st fruit ripening from transplanting was found under different interaction effects of shade and genotypes.

The fruit size and quality of the fruit is rely on the days to 1st fruit ripening. That's why Days to 1st fruit ripening is an important character of growth stage of strawberry plant is It is predominantly a genietic character. From all P_0V_2 treatment combination give the best performance and it is realized that the effective treatment in strawberry production is 100% sunlight in Camarosa.

4.3 Yield contributing characters of strawberry under different levels of shading

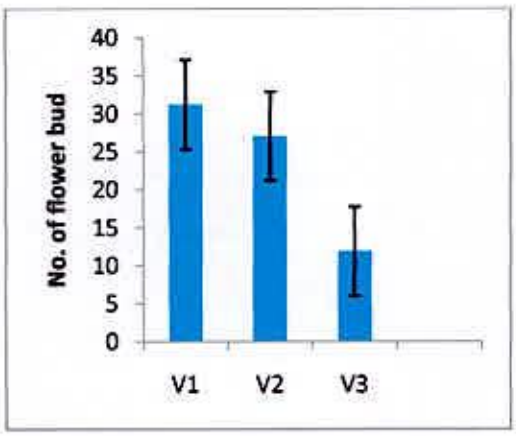
4.3.1 Total number of bud plant^{-1}

The total number of bud plant^{-1} is presented on Fig 2, which show that there was a significant variation of bud plant^{-1} among the genotypes, shade treatments and the shade × genotype interactions.

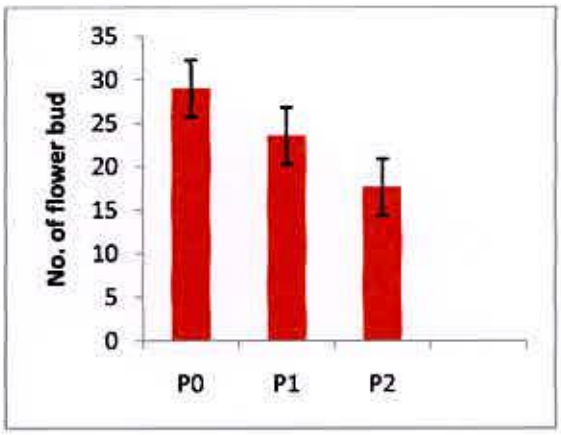
Variety V_1 (RABI-3) produced the maximum bud plant^{-1}(31.25) which was however statistically identical with V_2 (Camarosa). The genotype V_3 (Nohime) produced the minimum total number of bud (11.92), which was significantly different from that under V_1 and V_2.

The maximum total number of bud plant^{-1} (29.00) was obtained underP_0 (100% sunlight).The immediate highest total number of flower bud plant^{-1} (23.58) was found under P_1 (20% shade). The minimum total number of bud plant^{-1} (17.67) was found under P_2 (35% shade). A significant variation in total number of bud plant^{-1} was shown under all the three shade treatments.

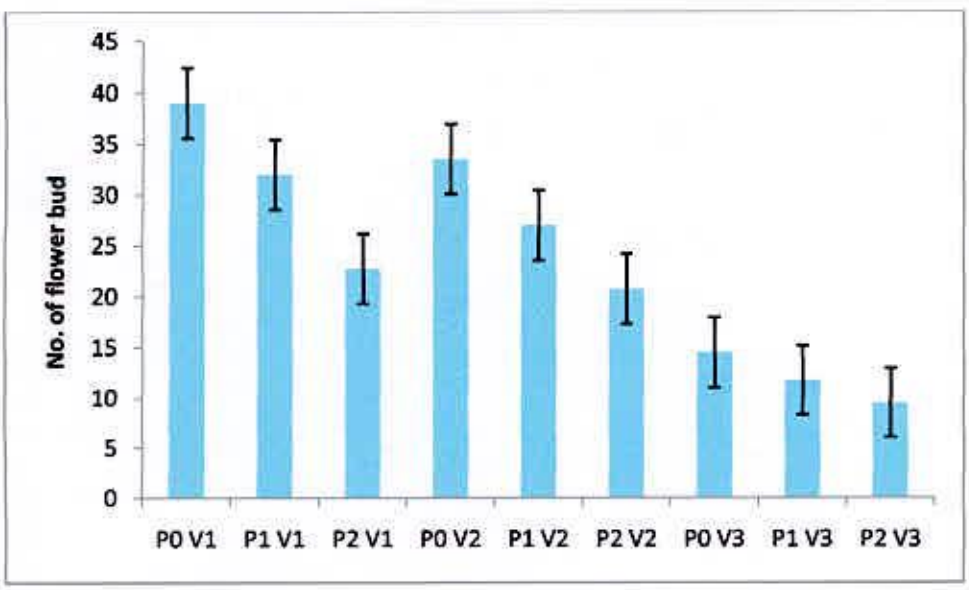
Total number of bud of strawberry under different levels of shading



(a)



(b)



(c)

Fig2: Graph showing total number of flower bud as influenced by (a) genotypes, (b) shade and (c) genotypes × shade interactions (narrow vertical bars indicate SE value at alpha level 0.05).

Here, V_1; RABI-3, V_2; Camarosa and V_3; Nohime and P_0; 100% sunlight, P_1; 20% shade, P_2; 35% shade

Total bud plant^{-1} showed a significant variation under different interaction effects of shade and genotypes. The maximum total bud plant^{-1} (39.00) was produced under P_0V_1 (100% sunlight × RABI-3), followed by P_0V_2 and P_1V_1 treatment combination. And the minimum total flower bud plant^{-1} (9.500) was found under P_2V_3 (35% shade × Nohime).

The total flower plant^{-1} is fully depending on total flower bud plant^{-1}. Total number of bud plant^{-1} play an important role to yield. It is predominantly a genetic character. Genotype V_1 (RABI-3) have the maximum bud treated with different shade. In the interaction effects it is observed that P_0V_1 treatment combination perform the best. So it is easily realized that RABI-3 under 100% sunlight increase the total bud plant^{-1}. Smeets (1976) showed that a sharp drop in light intensity cause stamen abortion in flower buds. Morgan, (2006) observed that low light cause flower shedding before fruit set.

4.3.2 Total number of flower plant^{-1}

The total number of flower plant^{-1} which is presented on Fig 3, showing that there was a significant variation of total number of flower plant^{-1} among the genotypes, shade treatments and the shade × genotype interactions.

Genotype V_1 (RABI-3) produced the maximum total number of flower plant^{-1} (28.67). In case of V_2 (Camarosa) ,the total number of flower plant^{-1} was (24). The genotype

V_3 (Nohime) produced the minimum total number of flower plant^{-1} (9.750), which was significantly different from that under V_1 and V_2.

Total number of flower of strawberry under different levels of shading

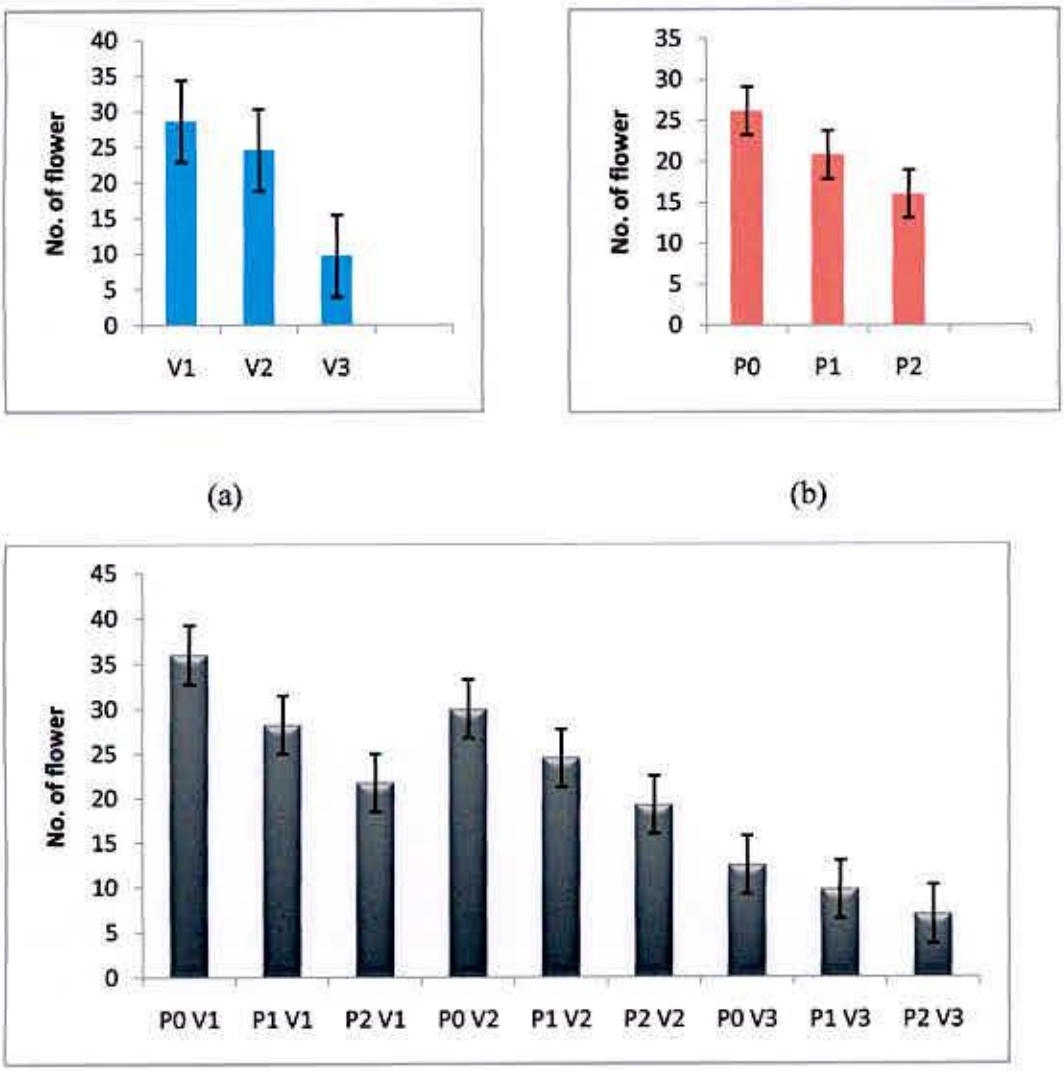


Fig 3 : Graph showing total number of flower as influenced by (a) genotypes, (b) shade and (c) genotypes × shade interactions (narrow vertical bars indicate SE value at alpha level 0.05). Here, V_1; RABI-3, V_2; Camarosa and V_3; Nohime and P_0; 100% sunlight, P_1; 20% shade, P_2; 35% shade

Under all three shade treatments the total number of flower plant^{-1} gave a significant variation. The maximum total number of flower plant^{-1} (26.17) was obtained under P_0 (100% sunlight) and then (20.83) under P_1 (20% shade). The minimum total number of flower plant^{-1} (16.00) was found under P_2 (35% shade).

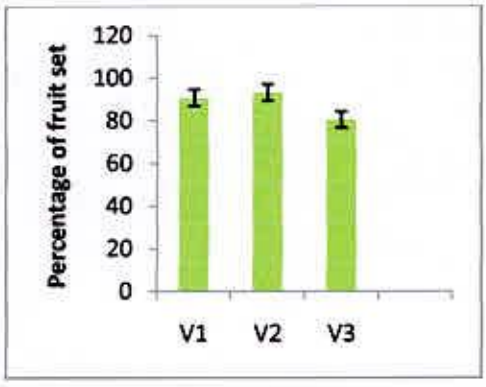
A significant variation in total number of flower plant^{-1} was also observed under different interaction effects of shade and genotypes. The maximum total number of flower plant^{-1} (36.00) was grown under P_0V_1 (100% sunlight × RABI-3), followed by P_0V_2 (100% sunlight × Camarosa), which was however statistically identical with P_1V_1 treatment combination. P_2V_3 (35% shade × Nohime) produced the minimum total number of flower plant^{-1} (7.00).

An important yield contributing character of strawberry plant is total number of flower plant^{-1}. The total number of fruit plant^{-1} is fully based on total number of flower plant^{-1}. It is predominantly a genetic character. As P_0V_1 treatment combination give the best performance so it is understood that RABI-3 under 100% sunlight produce more total number of flower plant^{-1}. Ozturk et al., (2004) and Demirsoy, (2007)found lowest flower number in constant shading. Awang & Atherton, (1995) found that shading have a strong inhibitory effect on floral development.

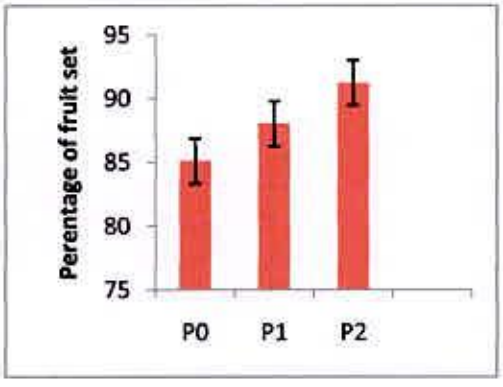
4.3.3 Percentage of fruit set plant^{-1}

The percentage of fruit set plant^{-1} is presented on Fig 4, which show that were a significant variation of percentage of fruit set plant^{-1} among the genotypes, shade treatments and the shade × genotype interactions.

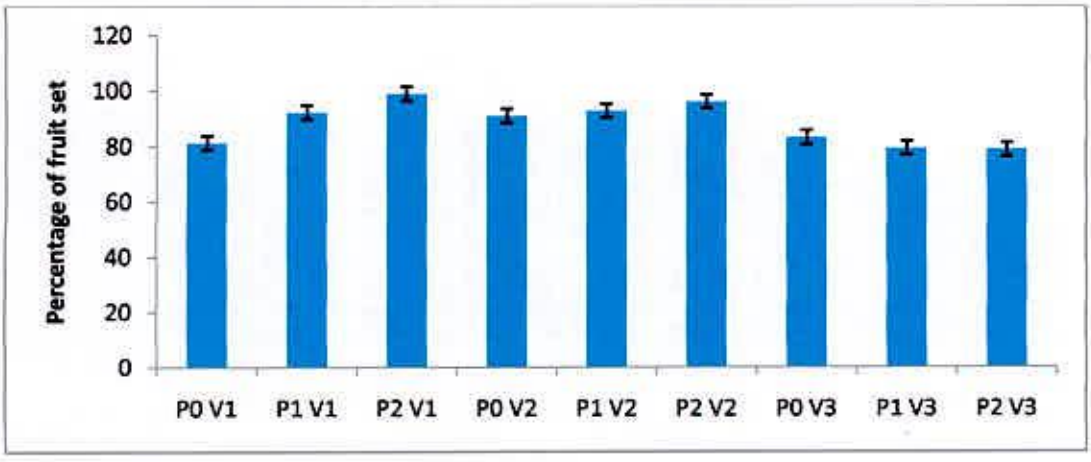
Percentage of fruit set of strawberry under different levels of shading



(a)



(b)



(c)

Fig 4: Graph showing percentage of fruit set as influenced by (a) genotypes, (b) shade and (c) genotypes × shade interactions (narrow vertical bars indicate SE value at alpha level 0.05)

Here, V_1; RABI-3, V_2; Camarosa and V_3; Nohime and P_0; 100% sunlight, P_1; 20% shade, P_2; 35% shade

A significant variation of percentage of fruit set plant^{-1} was found in different genotypes. 93.20% of fruit set in genotype V_2 (Camarosa), was statistically identical with V_1 (RABI-3). The genotype V_3 (Nohime) showed the minimum percentage of fruit set (80.48).

Though the maximum percentage of fruit set plant^{-1} (91.26) was obtained under P_2 (35% shade), there is no significant different among the shade treatments.

A significant variation was also observed under different interaction effects of shade and genotypes in percentage of fruit set plant^{-1}. The maximum percentage of fruit set plant^{-1} (98.91%) was produced under P_2V_1 (100% sunlight × RABI-3), which was however statistically identical with P_2V_2, P_1V_2, P_0V_2 treatment combination. The minimum percentage of fruit set plant^{-1} (78.87%) was found under P_2V_3 (35% shade × Nohime).

The total fruit weight is a function of number of flowers and the property of fruitset. From the interaction effect it is identified that P_2V_1, P_2V_2, P_1V_2, P_1V_1 treatment combination give the best performance. So it is clear that both RABI-3 and Camarosa treated with 35% shade and 20% shade increase the percentage of fruit set.

Table 4.3 Yield contributing characters of strawberry genotypes under different levels of shade[x]

Genotype[y]	Total no. of fruit plant^{-1}	Weight of each fruit (g)	Total fruit weight plant^{-1} (g)
V_1	25.58	8.703	221.8
V_2	22.83	10.01	227.3
V_3	7.917	2.024	16.25
$LSD_{0.05}$	4.837	2.151	25.38
Shade[z]			
P_0	22.33	7.032	184.0
P_1	18.83	6.860	154.8
P_2	15.17	6.846	126.6
$LSD_{0.05}$	3.501	0.8479	29.49
Interaction			
$P_0 V_1$	29.25 a	8.823 b	257.0 ab
$P_1 V_1$	26.00 ab	8.585 b	222.4 c
$P_2 V_1$	21.50 cd	8.700 b	186.1 d
$P_0 V_2$	27.25 a	9.955 a	270.9 a
$P_1 V_2$	22.75 bc	10.12 a	227.8 bc
$P_2 V_2$	18.50 d	9.955 a	183.3 d
$P_0 V_3$	10.50 e	2.318 c	24.00 e
$P_1 V_3$	7.750 ef	1.872 c	14.25 e
$P_2 V_3$	5.500 f	1.883 c	10.50 e
$LSD_{0.05}$	3.913	0.9477	32.97
CV (%)	10.61	6.99	10.82

[x] In a column means having similar letter(s) or without letterare statistically identical and those having dissimilar letter(s) differ significantly at $\alpha \leq 0.05$ level of significance by LSD range test

[y] V_1; RABI-3, V_2; Camarosa and V_3; Nohime

[z] P_0; 100% sunlight, P_1; 20% shade, P_2; 35% shade

4.3.4 Total number of fruit plant^{-1}

Table 4.3 is presenting a significant variation of total number of fruit plant^{-1} among the genotypes , shadeing treatment and the shadeing × genotype interactions.

Genotype V_1 (RABI-3) produced the maximum total number of fruit plant^{-1} (25.58). The second highest total number of fruit plant^{-1} (22.83) was found under genotype V_2 (Camarosa). The genotype V_3 (Nohime) produced the lowest total number of fruit plant^{-1} (7.917 plant^{-1}) which was significantly different from that under V_1 and V_2.

There was a variation in total number of fruit plant^{-1} under all the three shading treatments. The maximum total number of fruit plant^{-1} (29.25) was produced under P_0 (100% sunlight) and the minimum total number of fruit plant^{-1} (15.17) was found under P_2 (35% shade).

A significant variation was also observed under different interaction effects of shade and genotypes in total number of fruit plant^{-1}. The maximum total number of fruit plant^{-1} (29.25) was obtained under P_0V_1 (100% sunlight × RABI-3), which was statistically identical with P_0V_2 and P_1V_1 Treatment combination. The minimum total number of fruit plant^{-1} (5.500) was found under P_2V_3 (35% shade × Nohime).

The total number of fruit plant^{-1} is fully depending on total number of flower plant^{-1}. It is predominantly a genetic character. From the above result it is realized that RABI-

3 under 100% sunlight increase the total number of fruit plant^{-1}. Yahya et al., (1995) and Johannes (2008) observed that fruit number was reduced under shaded condition. Smeets (1976) observed that low light level for some days, resulted in stamen abortion those flower buds which were due to open in a few days. This is turn led to poor fruit set. Garrison et al., (1990) and Ibrahim et al., (1997) found that row cover reduced number of fruit.Watson et al., (2002); Rieger, (2005) observed that full sunlight exposure through the canopies is a key factor for maximizing fruit bearing.

4.3.5 Total fruit weight plant^{-1}

The total fruit weight plant^{-1} is presented on Table 4.3, which shows that there was a significant variation of total fruit weight plant^{-1} among the genotypes, shade treatments and the shade × genotype interactions.

Genotype V_2 (Camarosa) gave the maximum total fruit weight plant^{-1} (227.3 gm) which was however statistically identical with V_1 (RABI-3). The genotype V_3 (Nohime) produced the minimum yield (16.25 gm) and significantly different from V_1 and V_2 genotypes.

Variation in total fruit weight plant^{-1} under all the three shade treatments was observed. The maximum total fruit weight plant^{-1} (184 gm) was produced under P_0 (100% sunlight) and statistically identical with P_1 (20% shade). The minimum total fruit weight plant^{-1} (126.6 gm) was found under P_2 (35% shade).

A significant variation in total fruit weight plant^{-1} was also observed under different interaction effects of shade and genotypes. The maximum total fruit weight plant^{-1}

(270.9 gm plant^{-1}) was obtained under P_0V_2 (100% sunlight × Camarosa), which was however statistically identical with P_0V_1treatment combination. P_2V_3 (35% shade × Nohime) produced the minimum total fruit weight plant^{-1}(10.50 gm), which was statistically identical with P_1V_3 and P_0V_3.

An important yield contributing character of strawberry plant is total fruit weight plant^{-1}. It is predominantly a genetic character. It is fully depending on different growth parameters. Genotype V_3 (Nohime) shows the worst result under all shade treatments. Among all shade treatments P_0 (100% sunlight) performed the best and P_2 (35% shade) performed the worst with all genotypes. Garrison et al., (1990) ,Fletcher et al., (2002) and Ozturk et al.,(2004) found that the shading reduced fruit weight. According to Awang & Atherton (1995), Miura et al.,(1993), fruit under shaded condition can be lower. Durner (1999) found that shading can decrease 40 g yield plant^{-1}. El-Behairy et al., (2001) observed that hydroponic strawberry yields range between 300 and 1500 g plant^{-1}.

4.3.6 Weight of each fruit

The number of weight of each fruit is presented on Table 4.3 , showing that there was a significant variation of number of average fruit weight plant^{-1} among the genotypes, shade treatments and the shade × genotype interactions.

Variety V_2 (Camarosa) found the highest weight of each fruit (10.01 gm). The immediate after maximum weight of each fruit (8.703 gm) was found under V_1

(RABI-3). The genotype V_3 (Nohime) produced the minimum weight of each fruit (2.024 gm) and significantly different from V_1 and V_2 genotypes.

Although highest weight of each fruit (7.032 gm) was obtained under P_0 (100% sunlight) but there was no significant variation among the treatments.

Different interaction effects of shade and genotypes had a significant variation in weight of each fruit. The maximum weight of each fruit (10.12 gm) was grown under P_1V_2 (20% shade × Camarosa), statistically identical with P_0V_2 and P_2V_2 treatment combination. The next maximum weight of each fruit (8.823 gm) was found on P_0V_1 (100% sunlight × RABI-3), which was statistically identical with P_2V_1 and P_1V_1. P_1V_3 (20% shade × Nohime) produced the minimum weight of each fruit (1.872 gm).

Weight of each fruit has a great value on yield of strawberry plant. Different growth parameters regulate the weight of each fruit. It is predominantly a genetic character. Genotype V_2 (Camarosa) have the highest weight of each fruit treated with different shade and P_0 (100% sunlight) performed the best with all genotypes. From the interaction effect it is easily noticed that Camarosa give the maximum weight of each fruit in full sunlight

4.4 Quality contributing characters of strawberry genotypes under different levels of shading

Table 4.4: Quality contributing characters of strawberry genotype under different levels of shading[x]

Genotype[y]	pH	Soluble solid content (%)	Ascorbic acid (%)
V_1	4.713	3.375	4.383
V_2	4.558	4.733	4.717
V_3	5.467	1.000	2.417
$LSD_{0.05}$	0.5211	0.5385	0.652
Shade[z]			
P_0	4.742	3.183	3.350
P_1	4.967	4.550	4.067
P_2	5.030	1.375	4.100
$LSD_{0.05}$	0.3333	0.4647	0.388
Interaction			
$P_0 V_1$	4.55 d	3.75 c	3.900 c
$P_1 V_1$	4.77 d	4.75 b	4.650 a
$P_2 V_1$	4.81 cd	1.62 de	4.600 ab
$P_0 V_2$	4.50 d	4.75 b	4.200 bc
$P_1 V_2$	4.60 d	7.55 a	5.000 a
$P_2 V_2$	4.57 d	1.90 d	4.950 a
$P_0 V_3$	5.17 bc	1.05 fg	1.950 e
$P_1 V_3$	5.52 ab	1.35 ef	2.550 d
$P_2 V_3$	5.70 a	0.60 g	2.750 d
$LSD_{0.05}$	0.3725	0.5194	0.434
CV (%)	2.71	6.17	4.07

[x] In a column means having similar letter(s) or without letters are statistically identical and those having dissimilar letter(s) differ significantly at $\alpha \leq 0.05$ level of significance by LSD range test

[y] V_1; RABI-3, V_2; Camarosa and V_3; Nohime

[z] P_0; 100% sunlight, P_1; 20% shade, P_2; 35% shade

4.4.1 pH of the fruit

The pH of the fruit presented on Table 4.4, which show that there was a significant variation of pH of the fruit among the genotypes and the shade × genotype interactions.

Genotype V_3 (Nohime) found the maximum pH of the fruit (5.467 plant^{-1}). The second maximum pH of the fruit (4.713) was found under V_1 (RABI-3) and significant variation was observed with V_3.

There was no significant variation in pH of the fruit under all the three shade treatments.

A significant variation in pH of the fruit was observed under different interaction effects of shade and genotypes. The maximum pH of the fruit (5.700) was obtained under P_2V_3 (35% shade × Nohime), which was however statistically identical with P_1V_3 treatment combination. The lowest pH of the fruit (4.500) was found under P_0V_2 (100% sunlight × Camarosa), which was however statistically similar with P_0V_1, P_2V_2, P_1V_2 and P_1V_1 treatment combinations.

Acidity of fruits is generally determined by measuring the pH of the fruit. It is predominantly a genetic character. Genotype V_2 (Camarosa) have the lowest pH treated that's why the acidity of the Camarosa is highest. Besides this the V_3

(Nohime) has a higher pH which is mostly alkaline. From the interaction effect it is identified that P_0V_1 treatment combination give the best performance. So it is clear that Nohime treated with 35% shade give the highest alkalinity of the fruit. Morgan, (2006) observed that acid levels in the fruit seem to be less affected by low light condition. Spayd & Morris (1981) reported that the pH of strawberry fruit remain at about 3.5 during fruit development.

4.4.2 Soluble Solid Content (SSC) of the fruit

The percentage of Soluble Solid Content (S.S.C.) of the fruits presented on Table 4.4 showing that there was a significant variation of percentage of Soluble Solid Content (SSC) of the fruit among the genotypes, shade treatments and the shade × genotype interactions.

Genotype V_2 (Camarosa) found the maximum Soluble Solid Content (SSC) of the fruit (4.733 gm). The second maximum Soluble Solid Content (S.S.C.) of the fruit (3.375 gm) was found under V_1 (RABI-3). The genotype V_3 (Nohime) produced the minimum Soluble Solid Content (SSC) of the fruit (1.000 gm) which was significantly different from V_1 and V_2 genotypes.

There was a variation in Soluble Solid Content (S.S.C.) of the fruit under all the three shade treatments. The maximum Soluble Solid Content (S.S.C.) of the fruit (4.55%) was obtained underP_1 (20% shade). The next maximum Soluble Solid Content (SSC)

of the fruit (3.183%) was found under P_0 (100% sunlight). The lowest Soluble Solid Content (SSC) of the fruit (0.4647 gm) was obtained under P_2 (35% shade).

A significant variation in Soluble Solid Content (S.S.C.) of the fruit was also observed under different interaction effects of shade and genotypes. The maximum Soluble Solid Content (SSC) of the fruit (7.550 gm) was obtained under P_1V_2 (20% shade × Camarosa). P_0V_2 (100% sunlight× Camarosa) produced the next highest Soluble Solid Content (SSC) of the fruit (4.750), which was statistically identical with P_1V_1 (20% shade × RABI-3). The miimum Soluble Solid Content (SSC) of the fruit (0.6000 gm) was found under P_2V_3 (35% shade × Nohime).

By measuring the SSC sweetness of the fruit is determined. It is predominantly a genetic character. Genotype V_2 (Camarosa) have the maximum SSC, so the sweetness of the Camarosa is highest. Among all shade treatments P_1 (20% shade) caused the highest SSC to all genotypes. In interaction effect it is clarified that P_1V_2 treatment combination give the best performance. So it is clear that Camarosa when treated to 20% shade increase the SSC of fruits.

4.4.3 Ascorbic acid percentage of fruit

Table 4.4 is presenting that Ascorbic acid percentages of fruits have significant variation among the genotypes, shade treatments and the shade × genotype interactions.

Genotype V_2 (Camarosa) produced the maximum Ascorbic acid percentage of fruit (4.717%) and then the V_1 (RABI-3). The genotype V_3 (Nohime) produced the minimum Ascorbic acid percentage of fruit (2.417%) which was significantly different from that under V_1 and V_2.

There was a variation in Ascorbic acid percentage of fruit under all the three shade treatments. The maximum Ascorbic acid percentage of fruit (4.10%) was occured under P_2 (35% shade), which was however statistically identical with P_1 (20% shade). The minimum Ascorbic acid percentage of fruit (3.35%) was found under P_0 (100% sunlight).

A significant variation in Ascorbic acid percentage of fruit was also observed under different interaction effects of shade and genotypes. The maximum Ascorbic acid percentage of fruit (5.00%) was obtained under P_1V_2 (20% shade × Camarosa), which was however statistically identical with P_2V_2, P_2V_1 and P_1V_1 treatment combination. The immediate after highest Ascorbic acid percentage of fruit (4.20%) was found in P_0V_2 (100% sunlight × Camarosa). The minimum Ascorbic acid percentage of fruit (2.55%) was found under P_1V_3 (20% shade × Nohime), which was statistically similar with P_2V_3 (35% shade × Nohime).

Ascorbic acid regulate the sourness and taste of the fruit. It is predominantly a genetic character. Genotype V_2 (Camarosa) and shade treatment P_2 (35% shade) produce the maximum ascorbic acid percentage. In case of interaction effect P_1V_2, P_2V_2, P_1V_1

treatment combination gives the best performance. So it can be concluded that Camarosa treated with 20% shade increase the ascorbic acid percentage of the fruit.

CHAPTER V

SUMMARY AND CONCLUSION

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This experiment was conducted at Horticulture Research Farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November 2010 to March 2011. Runners were planted on 4th November, 2010. Two factorial experiments were laid out in split plot design with four replications. Size of each pot was 25 cm × 20 cm. Three genotypes namely, RABI-3, Camarosa, and Nohime & three shade treatments namely, 100% sunlight, 20% shade and 35% shade. The Objective of the study was to determine shading effect on three different genotypes of strawberry on the growth, yield and fruit quality attributes.

From the experiment it is transparent that Camarosa performed the best. It gave the best yield and fruit quality is good. RABI-3 also gave better result in terms of the parameters of the experiment. The genotype Nohime showed the least performance as it required longer periods in all the cases, gave the lowest yield and produced poor fruit quality attributes. In case of shade treatment, 100% sunlight acted well, 20% shade did moderately in case of yield but better for fruit quality. It is proved from the results that 35% shade was unsuitable for strawberry cultivation as it gave the poorest growth, yield and quality. Nohime beneath 35% shade reached to all these parameter using a huge time and gave the least yield but Camarosa cultivated with 100% sunlight performed the best for growth and RABI-3 was nearest to it.

It is pointed out from the experiment that Camarosa required minimum time for attaining floral bud (79.33 days), flower (93.08 days), fruit set (100.3 days), fruit

ripening (112.7 days) and larger LAI at 25 DAT (7.91) and LAI at 50 DAT (9.45) than RABI-3 and Nohime. Under 100% sunlight floral bud initiation (71.08 days), flowering (83.50 days), fruit setting (100.3 days), fruit ripening (108.3 days) happened in a limited time, whereas 35% shade took longer duration for all the parameters mentioned. So, it was logical that Camarosa under 100% sunlight showed the best performance.

Because of producing small number of bud (11.92), flower (9.75), fruit (7.917); minimum percentage of fruit set (80.48%) and lowest total fruit weight (16.25 gm) it was easily determined that the Nohime resulted the worst in case of yield comparing with Camarosa and RABI-3. All the genotypes cultivated under 35% shade could not give better yield, only (17.67) bud, (16) flower and (15.17) fruit was produced. In case of interaction, RABI-3 and Camarosa performed better beneath 100% sunlight and the worst yield was obtained from Nohime cultivated under 35% shade.

Not only the yield performance but also the fruit quality is essential for measuring the fruit value. That is why the pH, SSC percentage and ascorbic acid percentage of the fruit of all genotypes were measured. Among them Camarosa acted better as for low pH, highest SSC (4.733%) and ascorbic acid (4.717%). RABI-3 was next to Camarosa and Nohime showed the poorest performance. The highest pH (5.030) and the lowest SSC (0.464) were obtained under 35% shade. Camarosa cultivated under 20% shade showed the best performance in all the cases by producing low pH (4.50); higher SSC (7.55%) and ascorbic acid percentage (5.00%).

CONCLUSION

Light intensity is an important factor in strawberry production. Therefore, shading can affect on growth, yield and quality of strawberry.

Three strawberry genotypes were grown under three different levels of shade treatment. Among them Camarosa showed best vegetative growth. Total number of flower bud, flower and fruits were also better in those and required minimum days for flower bud initiation, flowering, fruiting and for fruit ripening. And next to it was RABI-3. Fruit weight and average fruit weight and % of fruit weight were also found maximum in Camarosa under 100% sunlight. Maximum number of flower bud, flower, and fruit was recorded under 100% sunlight. No significant variation was observed in pH among different shade treatments but a moderate good result was found in Camarosa under 100% sunlight and 20% shade. SSC and ascorbic acid percentage was good in camarosa under 20% shade. Nohime and 35% shade treatment showed worst performance. Considering the above study, it may conclude that marketable yield is high in Camarosa. Among the shade application 100% sunlight give the best result for yield but quality attributes give better performance at 20% shade.

As per the findings of above experiment, further studies can be conducted to determine how yield can be increased under shade neither decreasing fruit quality or different parameters like storability, thickness, aroma and color of many more strawberry genotypes.

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APPENDICES

APPENDICES

Appendix I. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from November 2010 to March, 2011

Month	*Air temperature (°C)		*Relative humidity (%)	*Rainfall (mm) (total)
	Maximum	Minimum		
October, 2010	29.18	18.26	81	39
November, 2010	25.82	16.04	78	0
December, 2010	22.4	13.5	74	0
January, 2011	24.5	12.4	68	0
February, 2011	27.1	16.7	67	30
March, 2011	31.4	19.6	54	11

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargaon, Dhaka – 1207.

Appendix II. Analysis of variance of the data on leaf area index at different days after transplanting (DAT) of strawberry

Source of variation	Degrees of freedom	Mean square	
		Leaf Area Index (LAI) at	
		25 DAT	50 DAT
Replication	3		
Factor A (Genotype)	2	4.988*	0.761*
Error	6	1.420	0.377
Factor B (Shading)	2	8.694*	29.08*
Interaction (A×B)	4	0.525*	2.091*
Error	18	0.923	0.697

*: Total Significant at 0.05 level of probability 35

Appendix III. Analysis of variance of the data on days to 1st bud initiation, flowering, fruit setting and ripening after transplanting (DAT) of strawberry

Source of variation	Degrees of freedom	Mean square			
		Days to 1st			
		floral bud initiation	flowering	fruit setting	fruit ripening
Factor A (Genotype)	2	1196.778*	1066.778*	1140.194*	537.528*
Error	6	23.519	5.889	3.306	7.935
Factor B (Shading)	2	2706.028*	2825.614*	2426.264*	1138.694*
Interaction (A×B)	4	51.444*	51.9*	52.5*	68.278*
Error	18	16.898	17.093	17.00	22.046

*: Significant at $\alpha \leq 0.05$ level of probability

Appendix IV. Analysis of variance of the data on bearing habit of strawberry

Source of variation	Degrees of freedom	Mean square		
		Bearing habit at		
		Total no.bud plant^{-1}	Total no. of flower plant^{-1}	Percentage of fruit set plant^{-1}
Factor A (Genotype)	2	1242.333*	1189.083*	546.658*
Error	6	6.519	3.009	55.514
Factor B (Shading)	2	385.583*	310.333*	112.911^{NS}
Interaction (A×B)	4	33.917*	19.542*	127.104*
Error	18	6.139	3.213	35.234

*: Significant at $\alpha \leq 0.05$ level of probability

Appendix V. Analysis of variance of the data on related to fruit yield of strawberry

Source of variation	Degrees of freedom	Mean square		
		Fruit yield at		
		Total no. of fruits plant^{-1}	Total fruit weight plant^{-1} (g)	Weight of each fruit (g)
Factor A (Genotype)	2	1084.361*	173709.033*	220.197*
Error	6	7.583	208.690	1.5000
Factor B (Shading)	2	145.58*	9860.379*	0.1174^{NS}
Interaction (A×B)	4	12.6*	1516.664*	0.8576*
Error	18	3.972	281.947	0.233

NS: Non Significant *: Significant at $\alpha \leq 0.05$ level of probability

Appendix VI. Analysis of variance of the data on related to fruit quality of strawberry

Source of variation	Degrees of freedom	Mean square		
		Fruit quality at		
		pH of the fruit	Soluble Solid Content (S.S.C.) (%)	Ascorbic acid (%)
Factor A (Genotype)	2	1.417*	21.423*	926.88*
Error	2	0.044	0.047	6.889
Factor B (Shading)	2	0.047^{NS}	15.218*	92.975*
Interaction (A×B)	4	0.117*	3.061*	15.886*
Error	6	0.018	0.035	2.444

*: Significant at $\alpha \leq 0.05$ level of probability