EFFECT OF DIFFERENT LEVELS OF LIGHT INTENSITY ON MORPHO-PHYSIOLOGY AND YIELD OF BRINJAL (*Solanum melongena* L.)

MAHMUDUL KABIR

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENTAL SCIENCE
SHER-E-BANGLA AGRICULURAL UNIVERSITY
DHAKA-1207

JUNE, 2020

EFFECT OF DIFFERENT LEVELS OF LIGHT INTENSITY ON MORPHO-PHYSIOLOGY AND YIELD OF BRINJAL (*Solanum melongena* L.)

BY

MAHMUDUL KABIR

REGISTRATION NO.: 13-05547

A Thesis Submitted to
Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
IN
AGROFORESTRY AND ENVIRONMENTAL SCIENCE
SEMESTER: JANUARY- JUNE, 2020

APPROVED BY:

Dr. Jubayer-Al-Mahmud
Associate Professor
Supervisor

Dr. Md. Forhad Hossain
Professor
Co-supervisor

Dr. Jubayer-Al-Mahmud
Chairman
Examination committee

Dr. Jubayer-Al-Mahmud
Associate Professor
Department of Agroforestry and Environmental Science
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh
Mobile: 01771-606735
E-mail: jamahmud_bd@yahoo.com

CERTIFICATE

*This is to certify that thesis entitled, **"Effect of different levels of light intensity on morpho-physiology and yield of brinjal (Solanum melongena L.)"** submitted to the faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **AGROFORESTRY AND ENVIRRONMENTAL SCIENCE**, embodies the result of a piece of bona fide research work carried out by **Mahmudul Kabir**, Registration No.: **13-05547** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has been fully acknowledged by him.

Dated: June, 2020
Place: Dhaka, Bangladesh

(Dr. Jubayer-Al-Mahmud)
Associate Professor
Supervisor

DEDICATED

TO

MY BELOVED

PARENTS

ACKNOWLEDGEMENT

Firstly, the author is prostrated before Almighty Allah, most merciful and beneficent, for giving the strength and courage to successfully complete the research work.

This thesis owes its existence to the help, support and motivation of several people. Firstly, I would like to express my sincere appreciation and gratitude to my supervisor, ***Associate Prof. Dr. Jubayer-Al-Mahmud*** *for his guidance and constant encouragement during my research. His support and inspiring suggestions have been precious for the development of this thesis content.*

I am also indebted to my co-supervisor ***Prof. Dr. Md Forhad Hossain*** *and all my other teachers of* ***Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University****, who have been a constant source of encouragement and enthusiasm, not only during this thesis work but also during the two years of my M.S. program.*

My deepest gratitude goes to my family for their unflagging love and unconditional support throughout my life and my studies. You made me live the most unique, magic and carefree childhood that have made me who I am now.

Finally, I wish to thank all my fellow lab mates for being there in all the hard work and sharing my joys and sorrows. To them I say, "You make the bad times into good and the good times unforgettable".

- Author

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT.)

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

EFFECT OF DIFFERENT LEVELS OF LIGHT INTENSITY ON MORPHO-PHYSIOLOGY AND YIELD OF BRINJAL (*Solanum melongena* L.)

ABSTRACT

Low light stress is a limiting factor for crop production especially in agroforestry system. A pot experiment was conducted in the Field Laboratory of the Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka- 1207, during the months of October 2019 to mid April 2020. Three brinjal varieties viz. V1 (BARI Begun-1), V2 (BARI Begun-4), V3 (BARI Begun-9) were exposed to four light intensity treatments, (100, 75, 50 and 25% PAR which indicate control (S0), S1, S2 and S3, respectively) to evaluate their performances. Light stress (mainly S2 and S3) substantially hampered the plant growth, development as well as yield. Low light stress primarily reduced the photosynthetic performance (lower SPAD value) of plants which contribute in reduction of plant height, number of primary branches and leaves of all brinjal plants. Moreover low light intensity negatively affects the fresh and dry weight. It can also decrease number of fruits, fruit length, fruit diameter and individual fruit weight in all variety. As a result plant wise brinjal production hampered seriously with low yield. In comparison with control (100% PAR) treatment, 75% PAR condition (S1) decreased fruit weight by 16.8, 13.5 and 19.7% in V1, V2 and V3, respectively. In 50% PAR condition, yield per plant were decreased by 36.4, 33.5 and 42.4% in V1, V2 and V3, respectively. Lastly severe stress (S3) declined fruit weight per plant by 55.0, 61.5 and 67.0% in V1, V2 and V3, respectively. From this result it is very clear that under severe stress (S3) V1 cultivar perform well but V2 perform well against S1 and S2 treatments. But before suggesting variety for any agroforestry system more research work should be performed in different soil condition.

CHAPTER 1

INTRODUCTION

Currently low light irradiance is one of the most important environmental stresses throughout the world due to drastic climate change, which hamper crop growth and productivity (Hatamian *et al*. 2015). Moreover now-a-days agroforestry is becoming familiar practice around Asia. In agroforestry system agricultural crops suffer from proper light. Generally, vegetables are grown in different agroforestry system including homestead and its surroundings beneath the fruit and timber trees. There are about 19.4 million homesteads in Bangladesh which comprises about 0.45 million hectares of land (BBS, 2009). Most of the vegetables produced and consumed in this country are coming from these homesteads. These areas are also increasing due to the construction of new houses for the ever increasing population. In this situation, vegetables cultivation needs to be increased in homestead areas. To serve this purpose, higher yielding and partial shade tolerant vegetables should be introduced. Vegetables are one of the essential food items of daily requirement. Improvement of daily dietary value depends largely on the vegetables consumption. The per capita consumption of vegetables in Bangladesh is only 53 g, which is far behind the daily requirement of 200 g/head (Rashid, 1999). This figure is lower than that of some other Asian countries like India (167 g), Pakistan (69 g), Sri Lanka (120 g), China (280 g) and Japan (248 g); the world average consumption being 250 g/head/day (Rampal and Gill, 2002). So, vegetable production and consumption need to be increased in Bangladesh. Vegetables are not produced evenly throughout the year in Bangladesh. About 35% of the vegetables are produced in summer season and the rest in the winter season (Rashid, 1999). Due to climate change some area of the world facing low light intensity stress. On the other hand for increasing production, introduction of agroforestry system is very urgent. In agroforestry system crops should struggle low light stress. The development or identification of low light tolerant vegetables could be one of the achievable attempts to solve such problems. Secondly, Bangladesh is an over populated and agro-based country. Demographic consumption and declining per capita land availability make it clear that Bangladesh will have to produce more farm products from less land plus other resources in the future. It is now a prime need to improve system-based productivity and emphasis should be given on homestead vegetables production.

Brinjal is a major vegetable crop of Bangladesh and grown all over the world in outdoor fields, greenhouses and net houses. It is popular for its taste and various types of uses.Furthermore brinjal is a great source of vitamins and minerals. They're a great source of vitamin C, vitamin K, vitamin B6, thiamine, niacin, magnesium, manganese, phosphorus, copper, fiber, folic acid, potassium, and more. It is low in calories and sodium, and is a great source of dietary fiber,

So, in Bangladesh, among the potential summer vegetables, brinjal (*Solanum melongena* L.) is a very popular vegetable. Lack of knowledge or research to find the low light resistant cultivars are the central problems for brinjal cultivation in agroforestry system. Low light stress hampers photosynthesis and occurs flower abortion and fruits drop frequently, which causes very poor yield of most of the vegetables grows in homestead (Haque *et al*. 2009; Dong *et al*. 2014). It can also alter photosynthetic activity of plant (Shao *et al*. 2014). For this reason, farmers are not interested in cultivating brinjal, especially in the homestead or along with other agroforestry practices. Recently, BARI has released different brinjal varieties which can grow both in summer and winter. Unfortunately, screnning to find out reduced light and partial shade tolerance of this crop has not been studied in different homestead conditions. So, it is very important to observe the changes in terms of growth and yield in response to low light to evaluate the performances of different BARI brijal varieties. Considering the above mentioned facts three popular brinjal varieties are selected in this study for evaluating their performance under low light conditions targeting following objectives:

a. To evaluate the changes of growth and physiological attributes of different brinjal varieties under different low light stress

b. To assess the yield and yield contributing characters of different brinjal varieties under low light stress

c. To recognize the most suitable and adaptive variety on yield basis under low light condition.

CHAPTER 2

REVIEW OF LITERATURE

Brinjal is very common vegetables throughout the world. In Bangladesh it is very familiar and widely acceptable due to its nutrition and testiness. It is cultivated year round in Bangladesh but winter season is perfect for maximum production. Other than open field production of brinjal, many family cultivate it in homestead or any other agroforestry system. The available recommended cultivars of this vegetable are not available in respect of optimum growth and development under reduced light condition. Very few research works related to growth, physiology and yield of different vegetables including brinjal production under reduced light have been carried out to date. However, some of the important and informative works and research findings related to the production of different vegetables under low light stress, so far been done at home and abroad, have been reviewed in this chapter.

Thakur *et al*. (2019) conducted a field experiment at the experimental farm of CSIR-Institute of Himalayan Bioresource Technology, Palampur, India for two consecutive years (2015–16 and 2016–17). The aim of the study was to test the hypothesis whether different shade level and mulch type would influence the growth, flower yield and essential oil profile of R. damascena. Yield attributes viz., numbers of flowers plant^{-1}, fresh flower weight plant^{-1}, flower yield, and essential oil yield were significantly higher under open sunny conditions as compared to 25% and 50% shade levels. However, plants grown under 50% shade level recorded significantly higher plant height (cm), plant spread (cm) and the lowest numbers of branches as compared to control. Among mulches, black polyethylene mulch recorded significantly higher growth, and yield attributes of damask rose as compared to other mulches. Black polyethylene mulch recorded 74.5 and 39.2% higher fresh flower yield as compared to without mulch, during 2015–16 and 2016–17, respectively. Correlation studies showed a positively significant correlation between quality and quantity traits. A total of twenty-six essential oil compounds were identified which accounted for a total of 88.8 to 95.3%. Plants grown under open sunny conditions along with the applications of black polyethylene mulch produced a higher concentration of citronellol and trans-geraniol. Damask rose planted in open sunny conditions and mulched with black polyethylene sheet recorded significantly higher flower yield.

Rezai *et al*. (2018) conducted an experiment with sage (*Salvia officinalis* L.). plants under different light intensity. They reported that different level of light intensity contributes in significant changes on diverse plant parameters including on leaf morphology, photosynthetic capacity, and chlorophyll content.

Minimizing energy consumption and maximizing crop productivity are major challenges to growing plants in Bioregenerative Life Support System (BLSS) for future long-term space mission. As a primary source of energy, light is one of the most important environmental factors for plant growth. Dong *et al*. (2014) conducted experiment to investigate the effects of low light intensity at different stages on growth, pigment composition, photosynthetic efficiency, biological production and antioxidant defense systems of wheat (*Triticum aestivum* L.) cultivars during ontogenesis. Experiments were divided into 3 intensity-controlled stages according to growth period (a total of 65 days): seedling stage (first 20 days), heading and flowering stage (middle 30 days) and grain filling stage (last 15 days). Initial light condition of the control was 420 lmol $m^{-2}s^{-1}$ and the light intensity increased with the growth of wheat plants. The light intensities of group I and II at the first stage and the last stage were adjusted to the half level of the control respectively. For group III, the first and the last stage were both adjusted to half level of the control. During the middle 30 days, all treatments were kept the same intensity. The results indicated that low-light treatment at seedling stage, biomass, nutritional contents, components of inedible biomass and healthy index (including peroxidase (POD) activity, malondialdehyde (MDA) and proline content) of wheat plants have no significant difference to the control. Furthermore, unit kilojoule yield of group I reached 0.591×10^{-3} g/kJ and induced the highest energy efficiency. However, low-light treatment at grain filling stage affected the final production significantly.

Venkateswarlu *et al*. (2011) carried out an experiment to examine effects of low light intensity on different growth phases in rice (*Oryza sativa* L.). They reported that low light intensity negatively affect plant growth and development which ultimately decreased rice production.

An experiment was performed at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, by Haque *et al*. (2009). In order to investigate the morpho-physiological changes and yield output under four different light levels (100, 75, 50 and 25 % PAR), Bottle gourd cv. high-green (hybrid) was grown. Some morphological characteristics such as main stem length, internode length and individual leaf area have been observed to increase, while main stem diameter and leaf numbers per plant have decreased due to decreased light levels. In bottle gourd, the number of leaves per plant did not decrease significantly at 50% PAR. The leaf weight ratio (LWR) remained more or less similar, reducing PAR by up to 50 %. With the decrease in PAR amount, i.e. partial shading, induced chlorophyll synthesis in leaves, the SPAD value increased. Compared to 100% PAR, there was no decrease in overall dry matter. The highest yield (41.53 t ha^{-1}) was provided by Bottle gourd at 75 % PAR level and there was no substantial reduction in fruit yield at 25 % PAR level compared to full sunlight. However, for reduced light conditions (up to 50 %

PAR), considering Total Dry Matter (TDM) and fruit yield of bottle gourd and cucumber, it was considered acceptable.

Gregoriou *et al*. (2007) carried out a study using olive (*Olea europaea* L.) plant to know the effects of reduced irradiance on leaf morphology, photosynthetic capacity, and fruit yield. They reported that reduced level of light intensity contributes in significant changes on different plant activities including growth, photosynthesis and total yield.

Wang *et al*. (2007) produced red, blue, UV-A and UV-B light to enhance the light composition in the solar greenhouse, and investigated the effects of different light qualities on cucumber growth characteristics. The germination rate, fresh and dry weight, plant height and flower differentiation number were decreased when the stoma conduction, transpiration rate, and CO_2 concentration between cells as well as the photosynthesis rate were decreased under UV-B light; while the stoma density and thickness of cucumber leaves were greatly increased.

In Srilanka, Pathiratna and Perera (2005) investigated the possibility of intercropping cinnamon (*C. verum*) with rubber (*H. brasiliensis* clone RRIC 100) planted with the normal inter-row spacing of 8.1 m. By the eighth year, PAR transmission from the rubber canopy into the center of the inter-row was reduced to 20.6%. Cinnamon length per stick, weight, and bark yield have also declined. By the eighth year, the reduction in the bark yield of cinnamon per bush was 70.5 %. When the light level was around 60%, the dry matter content of bark was highest (9.36 %). At this spacing by the fifth year, adverse effects of low light availability and rubber competition on cinnamon were apparent.

Wang *et al*. (2003) conducted a study to investigate the effect of illumination and its effects on the growth of some medicinal plants in an intercropping system with *Populus tomentosa* at different row spacing. The average daily light intensity between rows decreased as the spacing of the rows decreased. When intercropped with *Populus tomentosa*, the height growth of *Glycyrrhiz auralensis*, *Platycodon grandiflorus* and *Pinellia pedatisecta* was different.

Shikata *et al*. (2003) conducted field experiments in Japan in 1999 to examine the effect of maize intercropping on cowpea growth and light environment and to determine the photosynthetic rate of the canopy in relation to the leaf area index (LAI), light interception, and photosynthetic rate of the leaf net. Superior light interception obtained by intercropping with maize led to an increase in LAI with a decrease in the coefficient of light extinction and a high photosynthetic rate of canopy.

It is very important to grow species and cultivars suitable for low light and artificial lighting, as stated by Sevelius (2003), in Nordic winter conditions with a lack of natural light. The conducted experiment to determine whether the leaf net exchange of CO_2, the fluorescence of chlorophyll, the evolution of oxygen, the content of chlorophyll *a* and *b*, In evaluating gerbera (*Gerbera cantabrigensis*) growth in low light, leaf morphology would be useful. Lynx had the lowest accumulation of biomass and flower production.

In the summer season of 1999, at the Faculty of Agriculture Research Station, University of Mutah, South Jordan, a field experiment was carried out by Sharaiha and Battikhi (2002). In particular, under the 2:2 intercropping row arrangements, maize and potato yields have increased. The increase in potato yield could be attributed to a decrease in air heat units (by 210 and 28), soil heat units (by 80 and 88) and light interception units (by 350 and 344 micro mol m^{-2} $second^{-1}$) for Friesland and Berca compared to their single crops, respectively. In addition, in contrast to sole cropping, the values of soil moisture conservation and evapo-transpiration for Frisia continued to decline under intercropping.

During the summer in Southern Spain, cucumber plants were grown by Peil and Lopez (2002) under greenhouse and shading screen-inducing conditions of diffuse light, with two fruit removal intensities, viz., one fruit remaining per leaf axil and two fruits remaining per three leaf axils. In terms of vegetative rather than total fruit growth and in terms of dry rather than fresh weight, the effects of fruit removal on biomass production were greater. Increasing fruit removal rate increased the allocation of dry matter to the vegetative organs and the overall production of dry matter aboveground. While, with the fruit removal rate, dry matter development of the vegetative sections of the shoot increased dramatically, the allocation of dry matter between stems and leaves was not affected.

During two growth cycles (spring and summer), light interception of a cucumber row crop was investigated by Peil *et al*. (2002) under greenhouse conditions. Photosynthetic active radiation (PAR) tests have been carried out. At the top (PARo) and at the bottom (PARt) of the crop during all the growth cycles. In summer, shading screen-inducing diffuse light conditions were used, resulting in a decrease of 33 (1036 and 691 mol m-2 in spring and summer, respectively) of the integral incoming PAR (Sigma PARo). An current model of canopy light interception (M1) by a row crop was used to estimate the intercepted light by the crop, along with a basic estimation method based on Lambert-Beer's rule. Model validation was performed using experimental results, assuming that all PARo was diffuse in summer.

Intercropping provides an significant way not only to increase the productivity and land use efficiency of smallholder rubber lands, but also to generate revenue during the unproductive immature rubber tree process stated by Rodrigo *et al*. (2001). In the rubber-based treatments, the production of dry matter was directly related to the planting density, being lower in the sole rubber and larger in the intercrop. Dry matter was derived from an improvement not only in light capture (270 %) but also radiation-use efficiency (RUE, 230 %) through treatments. Neither R nor BR care, which is currently recommended in Srilanka for intercropping, achieved maximum ground cover with fractional interception remaining below 40 % and 50% respectively. In BBBR treatment, fractional interception was maximum, and by the end of the measurement period, overall intercepted radiation was 23 and 73 % higher than in BBR and BR intercrops, respectively.

Roodagi, *et al*. (2001) performed a field experiment in Karnataka , India, to evaluate the impact of sowing and intercropping methods on the leaf area index (LAI), light transmission ratio (LTR) and cane yield of sugarcane during 1997-98. Standard sowing (ridge and furrow, 90 cm) and paired row methods (60-120-60 cm) were the methods of sowing. The cane+sunnhemp intercropping system had the highest cane and sugar yields, while *Gerbera jamesonii*cv had the lowest cane+maize intercropping system. Illusion, cv. *Rosa Hybrida*. *Kalanchoe blossfeldiana* cv.

Ficus and *Tenorio benjamina* cv. Exotica was grown by Buwalda *et al*. (2000) under laboratory conditions and exposed to 3 different patterns of temperature variation over a 72-day growing period at 2 mean temperature levels (18 and 22^0C) and 2 light levels (2.5 and 5.5 mol PAR m^{-2} d^{-1}). The experiments were conducted on 16 15 m^2 phytotrons, each with 2.5 and 5.5 mol PAR m-2 d-1 light levels and 4 (14, 18, 22 and

26^0C) temperature levels. At the higher level of light, *F. benjamina* final fresh weight, shoot length, and number of side shoots were superior.

Between November and April 1994-97, three experiments were performed between Bodson and Verhoyen (2000) to research the effects of photoperiod, supplementary light intensity and regular supplementary light integral on gerbera (*Gerbera cantabrigensis* cultivars Estelle and Ximena) flowering under poor natural light conditions. The plants were subjected to various photoperiods (12, 18 and 24 h), light photoperiods (12, 18 and 24 h). Intensities (75, 112.5, 150 and 300 micro mol / m^{-2} s^{-1} PAR) and additional cycles of illumination (12, 18 and 24 h). In all experiments, if the same regular supplementary light integral was used, the 12-h photoperiod produced the highest number of inflorescences. Since the amount of gerbera flower yield has been strongly influenced by the additional lighting regimes, the grower must be conscious of the various distributions of the same light energy over one day, which can contribute to a shift in the number of inflorescences of approximately 45 %.

Labeke and Dambre (1999) performed a greenhouse study in Belgium to investigate the effects of supplementary light on Gerbera cv. Tiffany (small flowers). and cv Optima (large flowers). Gerbera (6 m^{-2} for cv. Tiffany and 4 m^{-2} for cv. Optima) was planted on rockwool mats on 11 August 1998. When natural light reached 150 W m^{-2}, supplementary light (approx. 3000 lux) was used. Data on the number of flowers/ plant, stem length, weight and flower diameter were collected weekly. The number of flowers m^{-2} of cv was increased by supplementary light. Optima significantly (slightly (by 6 %) increased flower development in cv. Tiffany by supplementary light). However, for flower diameter (between October and December), stem length (between December and April) and stem weight (between October and May), substantial increases were calculated.

During the 1992-93 rabi season in Gazipur, Bangladesh, Ahmed and Jahan (1998) conducted a field experiment in order to evaluate the effect of intercropping wheat (cv. Sonalika) with potato (cv. Cardinal) on light interception, leaf area index and development of dry matter. Here proper light was limiting factor for plant. The treatments included 100% potato + 100% wheat in 1 or 2 rows, 100% potato + 50% wheat in 1 or 2 rows, and 100% potato + 25% wheat in 1 or 2 rows. Due to intercropping, leaf area indexes (LAI) and dry matter output by the component crops were reduced.

CHAPTER 3

MATERIALS AND METHODS

This chapter discuses the procedures of performing the experiment to find out the results of low light induced alterations on growth morpho-physiology and yield of different brinjal (*Solanum melongena* L.) varieties. A short explanation of locations of the study area, planting materials, climate and soil, seedling establishment, layout and design of the experiment, pot preparation, fertilization, transplanting of seedlings, intercultural operations, harvesting, data recording procedure, statistical analysis etc have been discussed in this section. They are as follows:

3.1 Experimental site and geographical location

The experiment was carried out in the Field laboratory of Agroforestry and Environmental Science Department, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the period from October 2019 to Mid April 2020. Location of the site was 23°74'N latitude and 90°35'E longitude with an elevation of 8 meter from sea level (Islam, 2014; Laylin, 2014) in Agro-ecological zone of "Madhupur Tract" (AEZ-28) (Anonymous, 1988). The experimental site is shown in the map of AEZ of Bangladesh in (Appendix 1).

3.2 Climate and soil

The climate of experimental site was under subtropical climatic zone. The experimental period [during October to Mid April (Rabi season)] maintain plenty of sunshine and moderately low temperature which was highly suitable for brinjal production in Bangladesh. Physiochemical properties of the soil used in plastic pot experiment are listed in Appendix 2.

3.3 Planting materials

Three popular varieties of brinjal were collected from PGRC, BARI, Gazipur on September 2019. The list of 3 (three) selected brinjal genotypes are presented below:

1. BARI Begun-1 (V1)
2. BARI Begun-4 (V2)
3. BARI Begun-9 (V3)

3.4 Treatments of the experiment

The experiment was conducted to evaluate the performance of 3 brinjal varieties [BARI Begun-1 (V1), BARI Begun-4 (V3), BARI Begun-9 (V3),) under 4 level of light intensity.

The following four PAR levels were maintained in this study for each variety for creating low light stress by using white net.

S0-Control, 100% Photosynthetically Active Radiation (PAR) / full sunlight

S1-75% PAR

S2-50% PAR

S3-25% PAR

So, total number of treatment was 12. They are listed following:

1. V1S0
2. V1S1
3. V1S2
4. V1S3
5. V2S0
6. V2S1
7. V2S2
8. V2S3
9. V3S0
10. V3S1
11. V3S2 and
12. V3S3

3.5 Design and layout of the experiment

The experiment was laid out following completely randomized design (CRD) in Rabi season, 2019-20 having two factors where Factor A included 3 brinjal varieties and Factor B included 4 light (PAR) treatments. The experiment was carried out with 3 replications and total 36 plastic pots were used for growing plant.

3.6 Pot preparation

Pots were filled with soil after mixing appropriate doses of cowdung on October 29, 2019. Prior to pot filling, weeds and stubbles were completely removed from soil to ensure proper plant growth. The soil was treated with Formaldehyde (45%) for 48 hours before filling the plastic pots to keep soil free from pathogen. Each plastic pot was filled with 10 kg of soil. The height of pot was 35 cm, top diameter was 30 cm and bottom diameter was 20 cm.

3.7 Raising of seedlings and crop establishment

Seed sowing was done on November 01, 2019 in the separate plastic pots. Before sowing, seeds were treated with 70% ethanol for five minutes. Seedlings were raised in the pots using regular nursery practices. Recommended cultural practices were undertaken before and after sowing the seeds. When the seedlings become 25 days old (on November 25, 2019) then homogenous two seedlings were transferred to each main plastic for further growing. But after establishment one plant was removed and one was grown for performing experiment.

3.8 Manure and fertilizers application

Before transplanting of seedlings soils of plastic pots were dried in the sun after well pulverization. Then well decomposed cow dung was mixed with the soil. After transplantation different chemical fertilizers were added according to the recommendation guide BARI, 2010. The required amount of fertilizer was calculated for each pot considering the dose required for 1 ha land. On an average, each plastic pot was filled with soil containing 100gm decomposed cow dung (10 tons/ha). Fertilizers (urea, TSP, MP) were applied in each pot following recommended dose.

3.9 Establishment of shading treatments

After transplantation to main pot nylon nets of different sieve size will be hanged with the help of bamboo sticks at a height of 2.3 meters to create low light treatments. Low light treatments will be consisted of 75% PAR, 50% PAR and 25% PAR. The control treatment will be consisted of full sunlight or 100% PAR (Plate 1).

3.10 Intercultural operations

Different intercultural operations along with irrigation were provided as per necessity. Weeding was performed in all pots at regular interval to keep plants free from unwanted plants. Diseases and pest attack is a limiting factor to brinjal growth and development which seriously hamper overall production. Brinjal plants were treated with Bavistin DF and Cupravit 50WP to prevent undesired diseases @1g/L and 2g/L respectively. Leaf miner and aphid were controlled by using Malathion 250EC @ 0.5ml/L. Tracer-45 SC (Spinosad) @ 0.4 ml/L was used against brinjal fruit and shoot borer. Almost all fungicide and pesticide were sprayed in two intervals, first dose at vegetative growth stage and another is during early flowering stage to manage pest and diseases except Tracer-45 SC (Spinosad). This insecticide was sprayed five more time. After full establishment of plant, stalking was done for each plant by bamboo stick between 25-30 days after transplanting to keep the plants erect always and to avoid breakage of plants due to heavy fruit weights during fruiting stage. Proper tagging and labeling were done for each plant using thin sticks.

3.11 Harvesting

As there were three varieties in the experiment flowering as well as fruiting time varied significantly. Fruit harvesting for all varieties was done at the edible stage. Marketable mature fruits were harvested time to time upto Mid April.

3.12 Data collection

Different growth, physiological and yield contributing parameters were recorded from each pot throughout the experiment. Data were recorded in respect of the following parameters:

3.12.1 Growth and physiological parameters

3.12.1.1 Plant height

Plant height of each plant was recorded with SI unit (cm) using meter scale after 2, 4 and 6 weeks.

3.12.1.2 Number of primary (1°) branches per plant

Primary branch of each plant was measured at 6 w of age after seedling transplantation to main pot.

3.12.1.3 Girth of main stem

Girth of main stem of each plant was measured using Digital Caliper-515 (DC-515) in millimeter (mm) unit. Later it was converted to centimeter (cm) unit. This parameter was taken at 6 w of age after seedling transplantation.

3.12.1.4 Number of leaves per plant

Total leaf numbers per plant were recorded at 6 w DAT by counting all leaves from each plant.

3.12.1.5 SPAD value of leaf

SPAD (soil plant analysis development) values of leaf was recorded at 6 w aged plant using a portable SPAD 502 Plus meter (Konica-Minolta, Tokyo, Japan) to get assumption about chlorophyll (chl) content under different treatment condition. In every measurement, the SPAD reading was repeated 5 times from the leaf tip to base, and the average was used for statistical analysis.

3.12.1.6 Plant fresh weight

Plant fresh weight (FW) excluding fruits was recorded at the time of last harvest. After uprooting each plant were weighed using electrical balance machine which was expressed as gram (g).

3.12.1.7 Plant dry weight

Plant dry weight (DW) excluding fruits was counted after oven drying at 70° C temperature. Then the uprooted plant samples were weighed using electrical balance machine and mean was calculated.

3.12.2 Yield and yield contributing components

3.12.2.1 First flowering days

Days to first flowering were recorded the days from the date of brinjal seedling transplanting.

3.12.2.2 Number of fruits per plant

Fruits were harvested several times. The number of total edible and healthy fruits harvested in several days from each plant was recorded.

3.12.2.3 Fruit length

Length of fruit was calculated using meter scale and expressed as cm. Then mean was calculated for each treatment from three replications.

3.12.2.4 Fruit diameter

Diameter of fruit was measured using Digital Caliper-515 (DC-515) in millimeter (mm) unit. Afterward it was converted to centimeter (cm) unit. Subsequently mean was calculated from three replications.

3.12.2.5 Individual fruit weight per plant

Five fruits were collected from each plant indiscriminately and then their weight was measured by using electrical balance machine. Finally mean of individual fruit weight was calculated.

3.12.2.6 Yield per plant

Fruits were harvested many times. Yield per plant was recorded from all harvests of each plant and expressed as kilogram (kg) per plant. It was also calculated from number of total Brinjal by multiplying individual fruit weight.

3.13 Statistical analysis

All the values of measured parameters are the means of three replications. One way analysis of variance (ANOVA) was undertaken using XLSTAT v.2018 software (Addinsoft 2018) and the mean differences were compared by Fisher’s LSD test. Differences at $P \leq 0.05$ were considered as significant.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Growth and physiological parameters

4.1.1 Plant height

Stress potentially hampers plant growth in dose dependant manner which primarily observed from the height reduction. Similarly in current experiment plant height is decreased in all varieties due to low light stress (Figure 1-3).

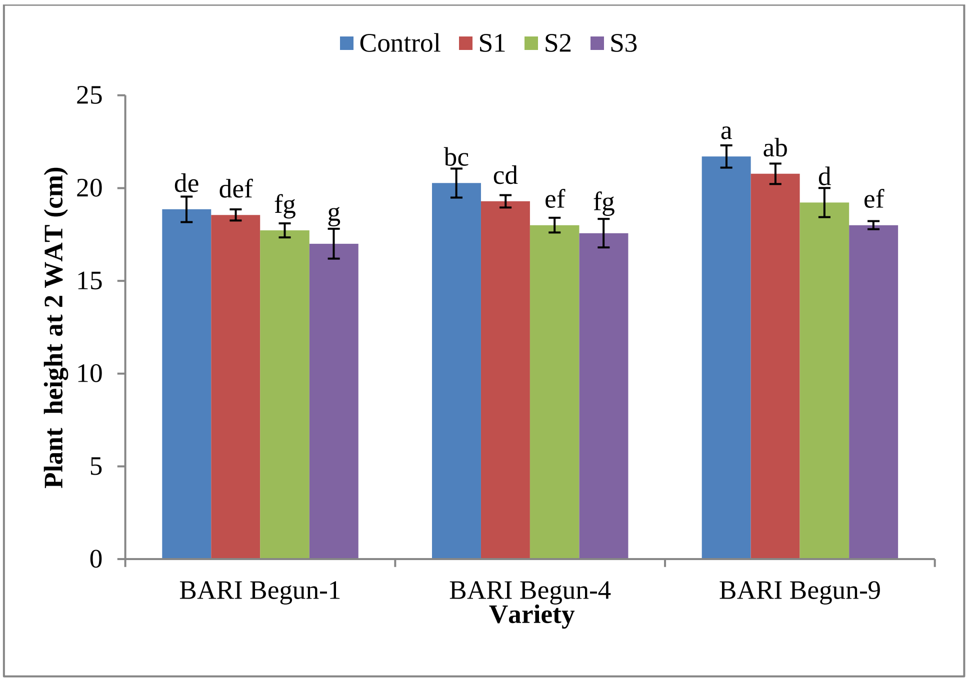


Figure 1. Effect of different light intensity on plant height at 2 weeks after transplanting of different brinjal varieties. Control, S1, S2 and S3 indicate 100%, 75%, 50% and 25% Photosynthetically Active Radiation (PAR), respectively. Means (±SD) were calculated from three replications (n = 3) for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ applying Fisher's LSD test

In contrast to control (100% PAR), at 2 weeks after transplanting (WAT), 75% PAR condition (S1) decreased plant height by 1.6, 4.9 and 4.3% in V1 (BARI Begun-1), V2 (BARI Begun-4) and V3 (BARI Begun-9), respectively. In 50% PAR condition, plant heights were decreased by 6.0, 11.2 and 11.4% in V1, V2 and V3, respectively. Finally severe stress (25% PAR condition, S3) reduced plant height by 9.8, 15.4 and

20.6% in V1, V2 and V3, respectively. Similar findings were observed at 4 and 6 WAT.

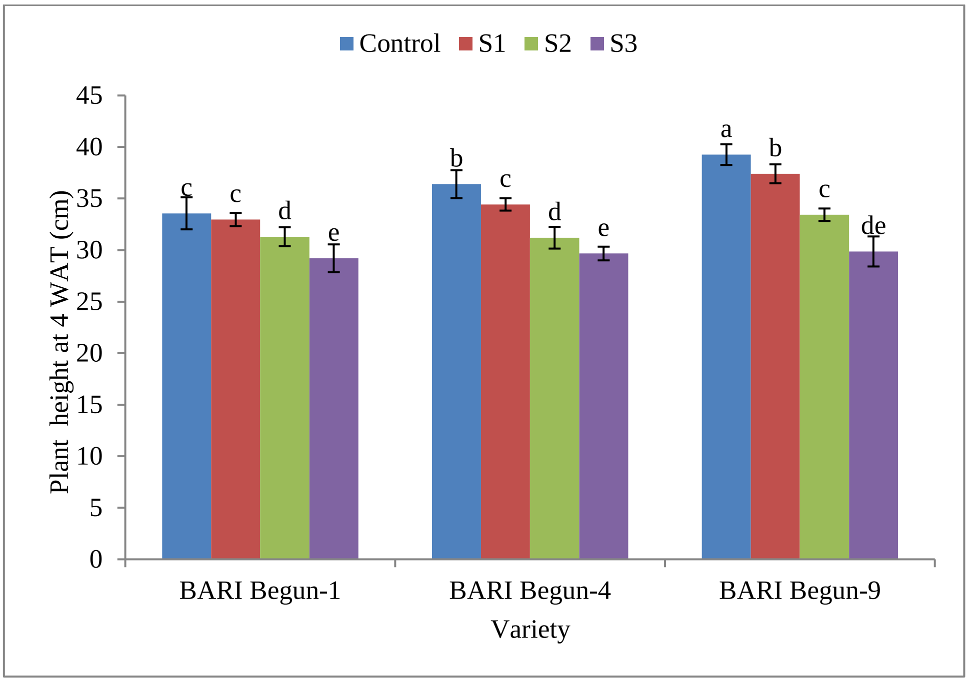


Figure 2. Effect of different light intensity on plant height at 4 weeks after transplanting of different brinjal varieties. Control, S1, S2 and S3 indicate 100%, 75%, 50% and 25% Photosynthetically Active Radiation (PAR), respectively. Means (±SD) were calculated from three replications (n = 3) for each treatment. Bars with different letters are significantly different at P≤0.05 applying Fisher's LSD test

So, it is very clear that maximum height reduction was observed under S3 treatment in all varieties and in variety wise performance, lowest reduction was recorded in V1 and highest reduction was observed in V3. The findings my study is supported by Dong *et al*. (2014) who confirmed that low light intensity effects on the growth specially decreased the straw length of wheat of (*Triticum aestivum* L.) at different growth stages. Similar results were also obtained by Thakur *et al*. (2019) in damask rose (*Rosa damascena* Mill.). Haque *et al*. (2009) also observed low light intensity severely hampered plant height of bottle gourd.

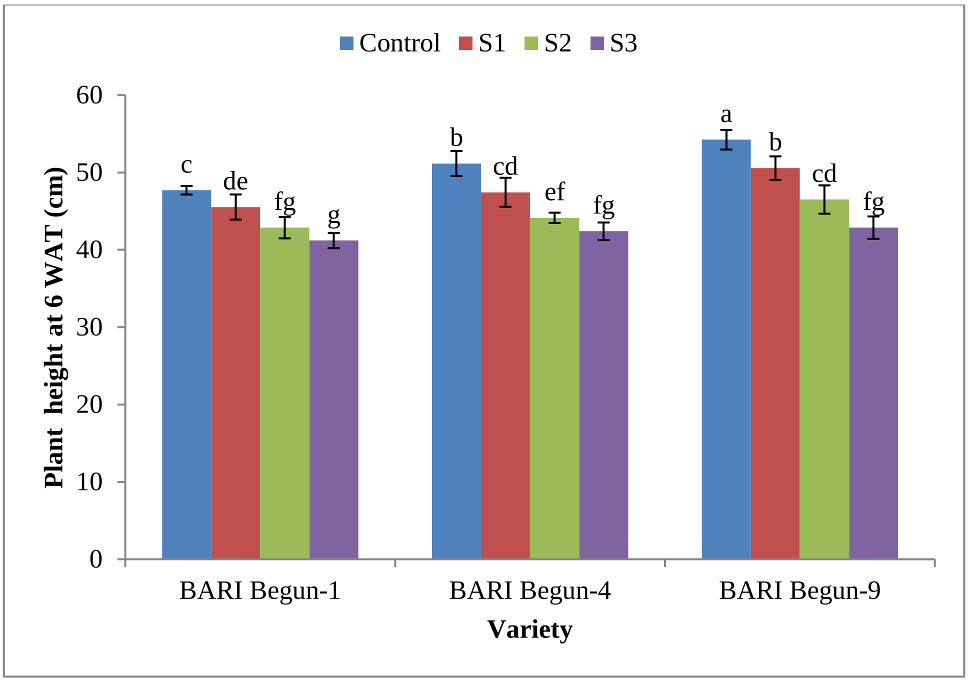


Figure 3. Effect of different light intensity on plant height at 6 weeks after transplanting of different brinjal varieties. Control, S1, S2 and S3 indicate 100%, 75%, 50% and 25% Photosynthetically Active Radiation (PAR), respectively. Means (±SD) were calculated from three replications (n = 3) for each treatment. Bars with different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.1.2 Number of primary (1°) branches per plant

Number of primary (1°) branches differs variety to variety (Tripathy et al. 2017). In present study the number of 1° branches per plant was 9.7 in V1, 10.0 in V2 and 11.7 in V3. These findings has close relation with the findings of Deotale et al. (1998) and Rai et al. (1998) who reported significant variation among the cultivars of brinjal for the number of branches per plant. Light stress decrease formation of primary (1°) branches in plant which. Under S1 light treatment, number of 1° branches decreased and it became 9.0, 9.7 and 11.0 in V1, V2 and V3, respectively. The S2 treatment further reduced 1° branches which are 8.7, 9.3 and 10.3 in V1, V2 and V3 respectively. Lastly Under S3 light treatment, number of 1° branches decreased and it became 8.0, 8.0 and 9.7 in V1, V2 and V3, respectively. Thakur *et al*. (2019) demonstrated that 25 and 50% shading significantly decreased number of branches in damask rose (*Rosa damascena* Mill.).

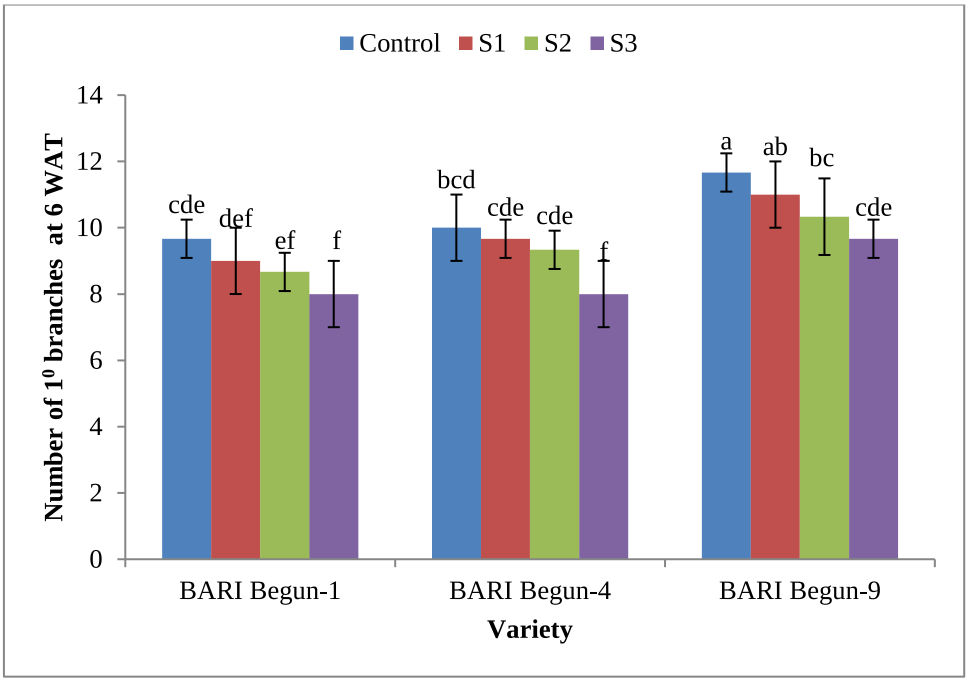


Figure 4. Effect of different light intensity on primary branches (1^0) at 6 weeks after transplanting of different brinjal varieties. Control, S1, S2 and S3 indicate 100%, 75%, 50% and 25% Photosynthetically Active Radiation (PAR), respectively. Means (±SD) were calculated from three replications (n = 3) for each treatment. Bars with different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.1.3 Girth of main stem

Main stem girth is also an important parameter to judge growth pattern during stress condition. In this experiment light stress significantly decrease the girth of main stem. Compare with control (100% PAR) treatment, 75% PAR condition (S1) decreased main stem girth by 7.3, 1.2 and 7.1% in V1, V2 and V3, respectively. In 50% PAR condition, stem girth were decreased by 13.8, 4.1 and 9.7% in V1, V2 and V3, respectively. Lastly severe stress (S3) declined main stem girth by 17.4, 13.6 and 19.0% in V1, V2 and V3, respectively. Haque *et al*. (2009) reported that in contrast to control (100%) different levels of low light (75, 50 and 25% PAR) slightly or significantly decreased the stem diameter of bottle gourd which confirmed reduced girth.

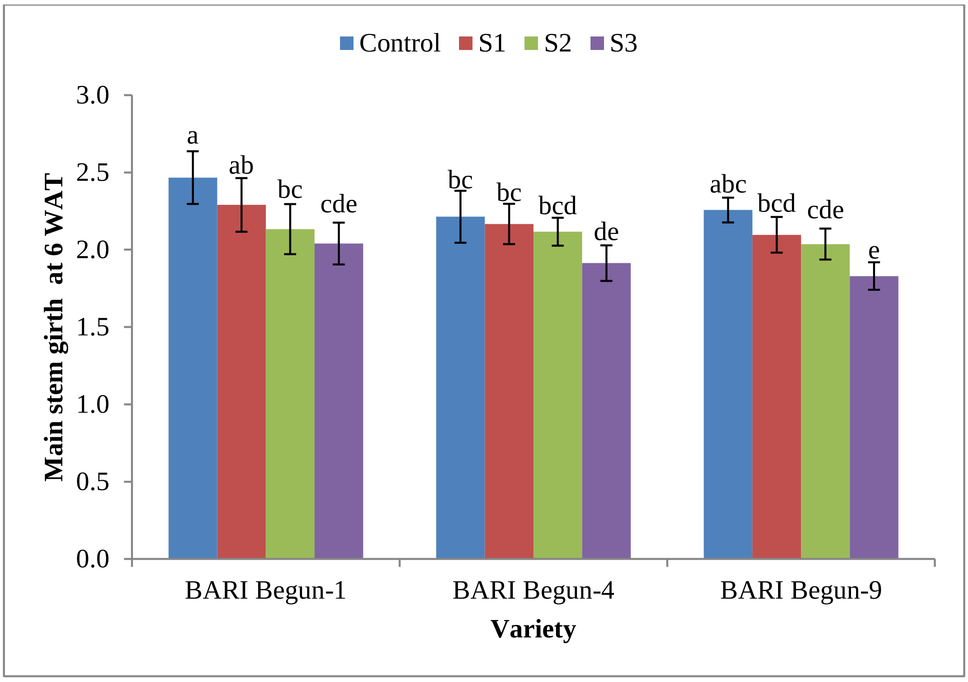


Figure 5. Effect of different light intensity on main stem girth at 6 weeks after transplanting of different brinjal varieties. Control, S1, S2 and S3 indicate 100%, 75%, 50% and 25% Photosynthetically Active Radiation (PAR), respectively. Means (±SD) were calculated from three replications (n = 3) for each treatment. Bars with different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.1.4 Number of leaves per plant

Leaves are the important organ for energy production of plant. Stress significantly hamper leaf number and their growth. In my experiment increases of light stress decreased the leaves number in similar fashion. Noteworthy discrepancy was recorded from number of leaves per plant with different light intensity and cultivars and their interaction effect.

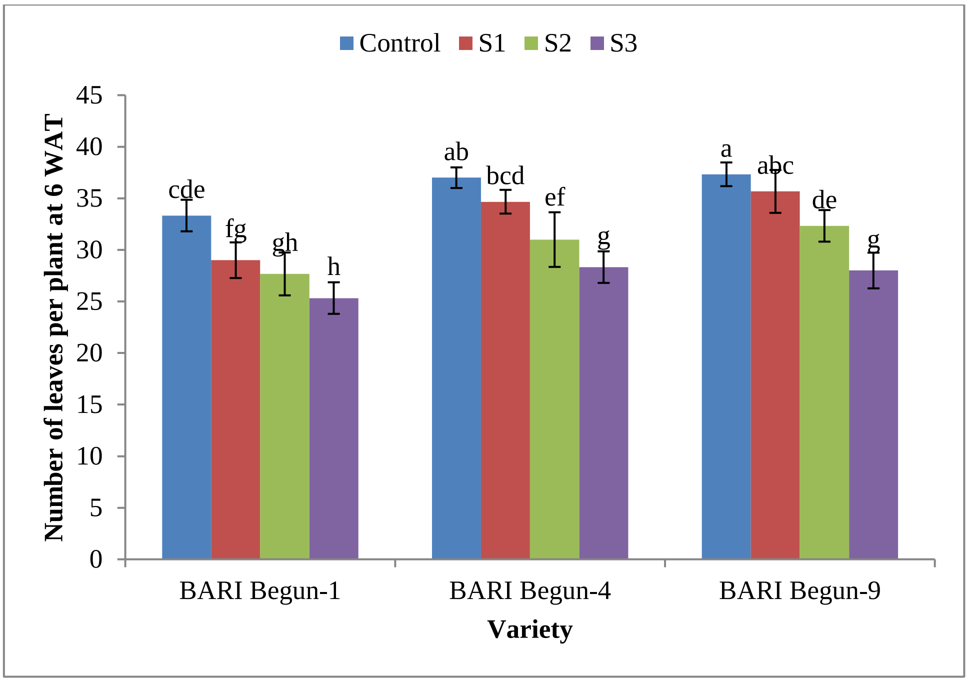


Figure 6. Effect of different light intensity on total number of leaves at 6 weeks after transplanting of different brinjal varieties. Control, S1, S2 and S3 indicate 100%, 75%, 50% and 25% Photosynthetically Active Radiation (PAR), respectively. Means (±SD) were calculated from three replications (n = 3) for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ applying Fisher's LSD test

Under S1 light treatment, number of leaves decreased slightly but under S2 and S3 treatment leaves number decreased significantly in all varieties. The number of leaves under control condition was 33.3, 37.0 and 37.3 in V1, V2 and V3, respectively. The S1 treatment decreased number of leaves which were 29.0, 34.7 and 35.7 in V1, V2 and V3, respectively. Under S2 light treatment, number of leaves decreased and it became 27.7, 31.0, 32.3 in V1, V2 and V3, respectively. Lastly, in severe stress (S3) number of leaves recorded as 25.3, 28.3, 28.0 in V1, V2 and V3, respectively. Similar findings was also recorded by Kubota and Hamid (1992) who reported that under low light condition, plant expense more energy to structural development compare to the plant grown under full sunlight. Haque *et al*. (2009) and Pathiratna and Perera (2005) also found that numbers of leaves per plant decreased due to the reduced light levels in different plants.

4.1.5 SPAD value of leaf

SPAD value gives an idea about photosynthetic performance of a plant. In this experiment light stress significantly decrease SPAD value of leaves. In comparison with control (100% PAR) treatment, 75% PAR condition (S1) decreased SPAD value by 7.9, 5.3 and 1.7% in V1, V2 and V3, respectively. In 50% PAR condition, stem girth were decreased by 15, 14 and 10% in V1, V2 and V3, respectively. Lastly severe stress (S3) declined SPAD value by 20.6, 24.6 and 18.0% in V1, V2 and V3, respectively. So, it clear that light stress in this study significantly decreased photosynthetic activity of brinjal as SPAD value indicate the concentration of chlorophyll content of leaves. Gregoriou *et al*. (2017) reduced irradiance on olive (*Olea europaea* L.) on notably decreased SPAD value. Rezai *et al*. (2018) found similar result in sage (*Salvia officinalis* L.) under low light condition.

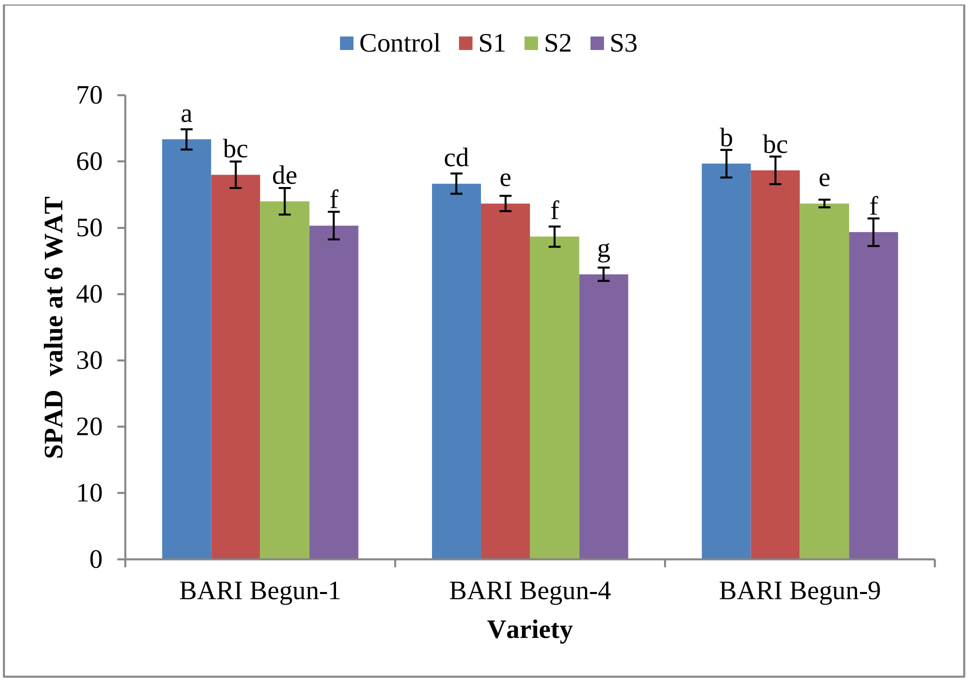


Figure 7. Effect of different light intensity on leaf SPAD value at 6 weeks after transplanting of different brinjal varieties. Control, S1, S2 and S3 indicate 100%, 75%, 50% and 25% Photosynthetically Active Radiation (PAR), respectively. Means (±SD) were calculated from three replications (n = 3) for each treatment. Bars with different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.1.6 Plant fresh weight

Plant fresh weight is a vital parameter that negatively influenced by any sort of stress. In current experiment, S1 light treatment decreased plant fresh weight slightly but under S2 and S3 treatment fresh weight decreased significantly in all varieties. The amount of fresh weight under control condition was 118.7, 126.7 and 136.3 g in V1, V2 and V3, respectively. The S1 treatment the amount of fresh weight decreased which were 29.0, 34.7 and 35.7 g in V1, V2 and V3, respectively. Under S2 light treatment, the amount of fresh weight further decreased and it became 27.7, 31.0, 32.3 g in V1, V2 and V3, respectively. Lastly, in severe stress (S3) amount of fresh weight were recorded as 25.3, 28.3, 28.0 g in V1, V2 and V3, respectively. Reduction of plant weight under stress condition indicate the damages towards growth of brinjal plant which corroborate others findings (Haque *et al*. 2009; Dong *et al*. 2014).

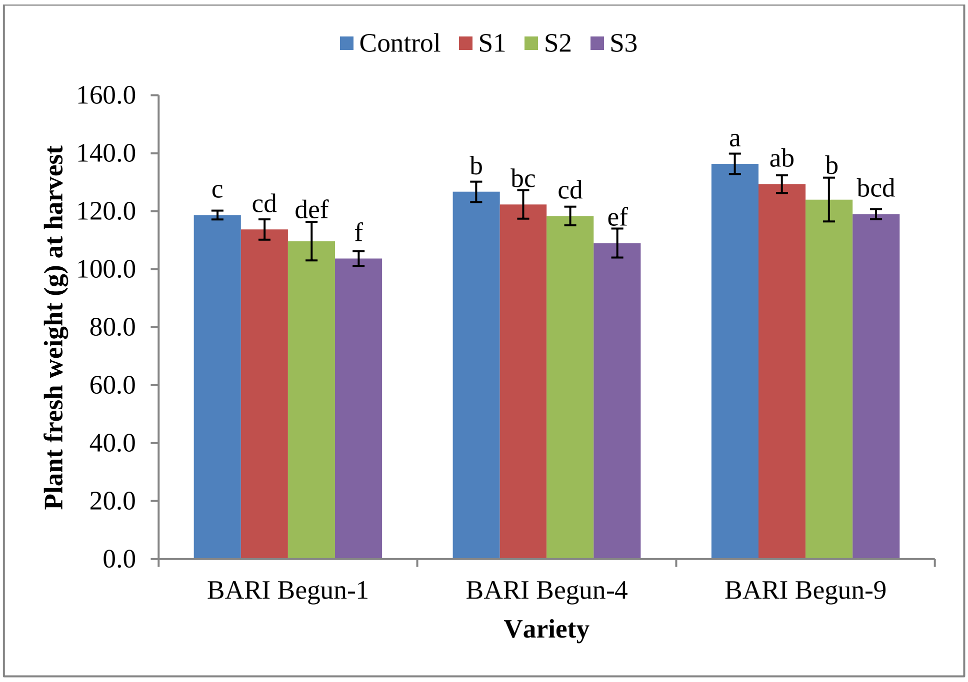


Figure 8. Effect of different light intensity on plant fresh weight at final harvest after transplanting of different brinjal varieties. Control, S1, S2 and S3 indicate 100%, 75%, 50% and 25% Photosynthetically Active Radiation (PAR), respectively. Means (±SD) were calculated from three replications (n = 3) for each treatment. Bars with different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.1.7 Plant dry weight

Like as plant fresh weight dry weight also followed similar pattern under light stress condition. The amount of fresh weight under control condition was 13.2, 14.1 and 15.2 g in V1, V2 and V3, respectively. The S1 treatment the amount of fresh weight decreased which were 12.6, 13.6 and 14.4 g in V1, V2 and V3, respectively. Under S2 light treatment, the amount of fresh weight further decreased and it became 12.2, 13.2, 14.1 g in V1, V2 and V3, respectively. Lastly, in severe stress (S3) amount of fresh weight were recorded as 11.9, 12.4, 13.9 g in V1, V2 and V3, respectively. Thakur *et al*. (2019) also found similar growth reduction in damask rose (*Rosa damascena* Mill.). Dong *et al*. (2014) found similar result in whet plant.

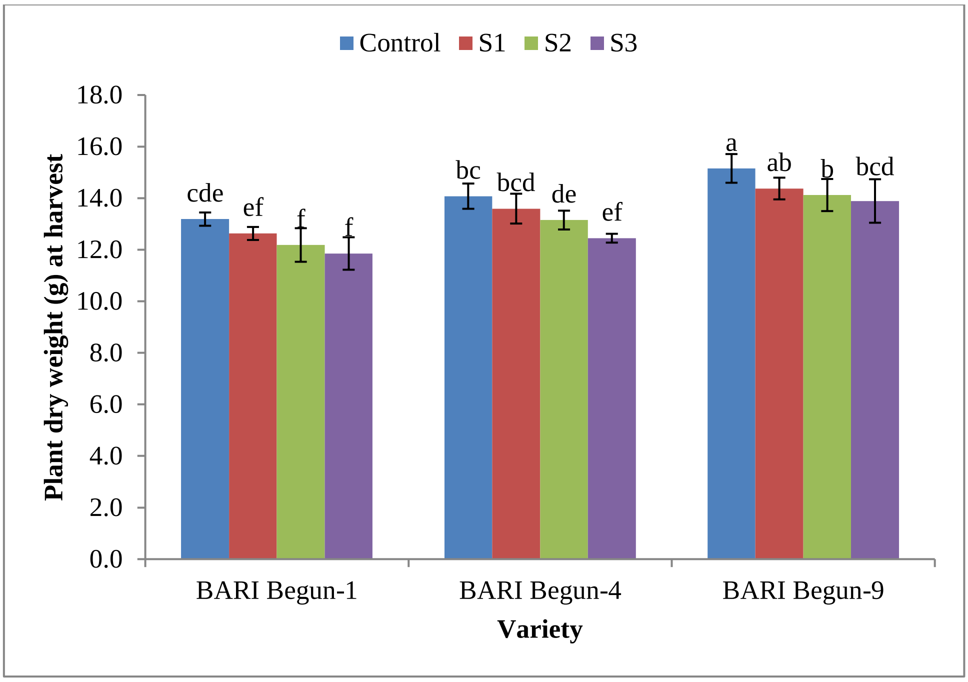


Figure 9. Effect of different light intensity on plant dry weight at final harvest after transplanting of different brinjal varieties. Control, S1, S2 and S3 indicate 100%, 75%, 50% and 25% Photosynthetically Active Radiation (PAR), respectively. Means (±SD) were calculated from three replications (n = 3) for each treatment. Bars with different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.2 Yield and yield contributing components

4.2.1 First flowering days

First flowering days after transplanting indicate the level of stress because in stress condition every organism wants to complete their life cycle in shortest possible time. In my study S1 and S2 treatment decreased first flowering days slightly but under severe stress (S3 treatment) condition first flowering days decreased significantly. The time of first flowering for control treatment was 30.3, 31.0 and 33.7 days in V1, V2 and V3, respectively but for S3 treatment they were 26.3, 27.3 and 29.3 days in V1, V2 and V3, respectively.

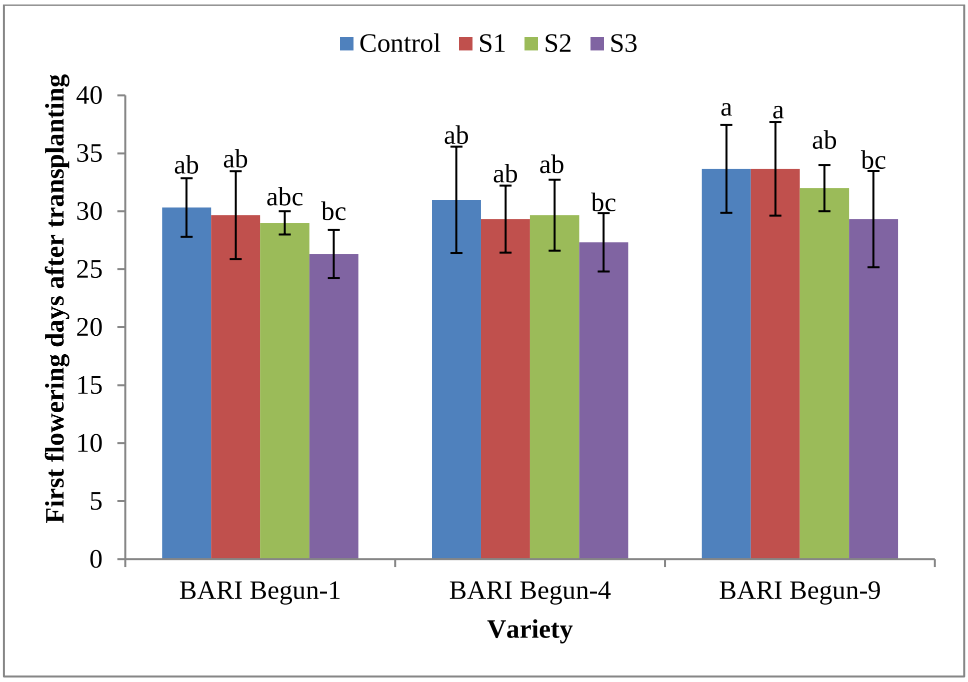


Figure 10. Effect of different light intensity on plant first flowering days after transplanting of different brinjal varieties. Control, S1, S2 and S3 indicate 100%, 75%, 50% and 25% Photosynthetically Active Radiation (PAR), respectively. Means (±SD) were calculated from three replications (n = 3) for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ applying Fisher's LSD test

4.2.2 Number of fruits per plant

Fruit number is hampered by any kind of stress. The reduction of fruit number increases with the increase of stress intensity and duration. In comparison with control (100% PAR) treatment, 75% PAR condition (S1) decreased number of fruit per plant by 7.5, 5.3 and 8.1% in V1, V2 and V3, respectively. In 50% PAR condition, stem girth were decreased by 16.9, 14.2 and 18.8% in V1, V2 and V3, respectively. Lastly severe stress (S3) declined SPAD value by 33.1, 35.3 and 39.4% in V1, V2 and V3, respectively. Reduction of fruit number decreases the total production of plant. Kumar *et al*. (2013) and Gregoriou *et al*. (2017) also carried out experiments under shade condition with clary sage and olive. Both research findings support my experimental findings.

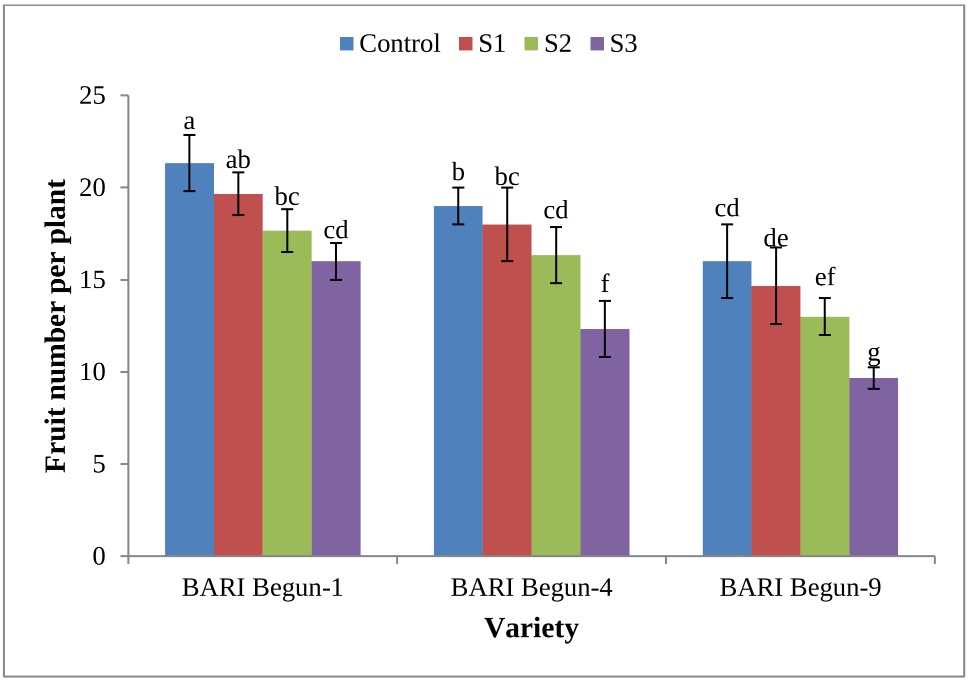


Figure 11. Effect of different light intensity on fruit number per plant of different brinjal varieties. Control, S1, S2 and S3 indicate 100%, 75%, 50% and 25% Photosynthetically Active Radiation (PAR), respectively. Means (±SD) were calculated from three replications (n = 3) for each treatment. Bars with different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.2.3 Fruit length

Fruit length of brinjal can directly affect on total production. In present study fruit length drastically decreased in S3 treatment (under severe stress) in comparison with control. The fruit lengths for control treatment were 18.67, 19.67 and 8.67 cm in V1, V2 and V3, respectively but for S3 treatment they were 13.33, 14.33 and 5.67 cm in V1, V2 and V3, respectively. On the other hand fruit length for S1 treatment were 18.33, 18.67 and 8.33 cm and for S2 treatment they were 16.67, 16.33 and 6.67 cm. But, Haque *et al*. (2009) conducted an experiment with bottle gourd and found reverse result. They confirmed that under 50% and 75% PAR condition fruit length increased and no significant variation was observed under 25% PAR, compared to control treatment.

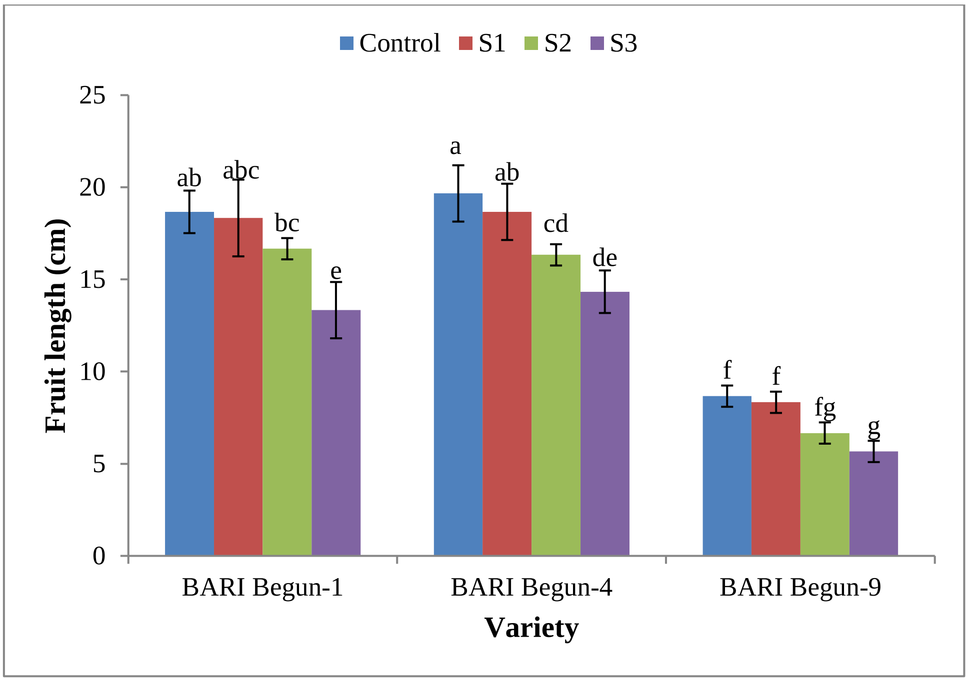


Figure 12. Effect of different light intensity on fruit length of different brinjal varieties. Control, S1, S2 and S3 indicate 100%, 75%, 50% and 25% Photosynthetically Active Radiation (PAR), respectively. Means (±SD) were calculated from three replications (n = 3) for each treatment. Bars with different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.2.4 Fruit diameter

Like fruit length fruit diameter of brinjal can directly affect on total production. In this experiment S1 treatment slightly decreased fruit diameter in V1 and V2 but significantly in V3treatment. But under S2 and S3 treatment all varieties showed notable decrease of fruit length. The fruit diameter of brijal under control condition was 2.23, 2.17 and 5.80 cm in V1, V2 and V3, respectively. The S1 treatment the fruit diameter decreased which were 2.20, 2.10 and 5.30 cm in V1, V2 and V3, respectively. Under S2 light treatment, the amount of fresh weight further decreased and it became 1.93, 1.90 and 4.47 cm in V1, V2 and V3, respectively. Lastly, in severe stress (S3) fruit diameter were recorded as 1.80, 1.70 and 3.87 in V1, V2 and V3, respectively. Hoque *et al*. (2009) got reverse result under similar stress treatment.

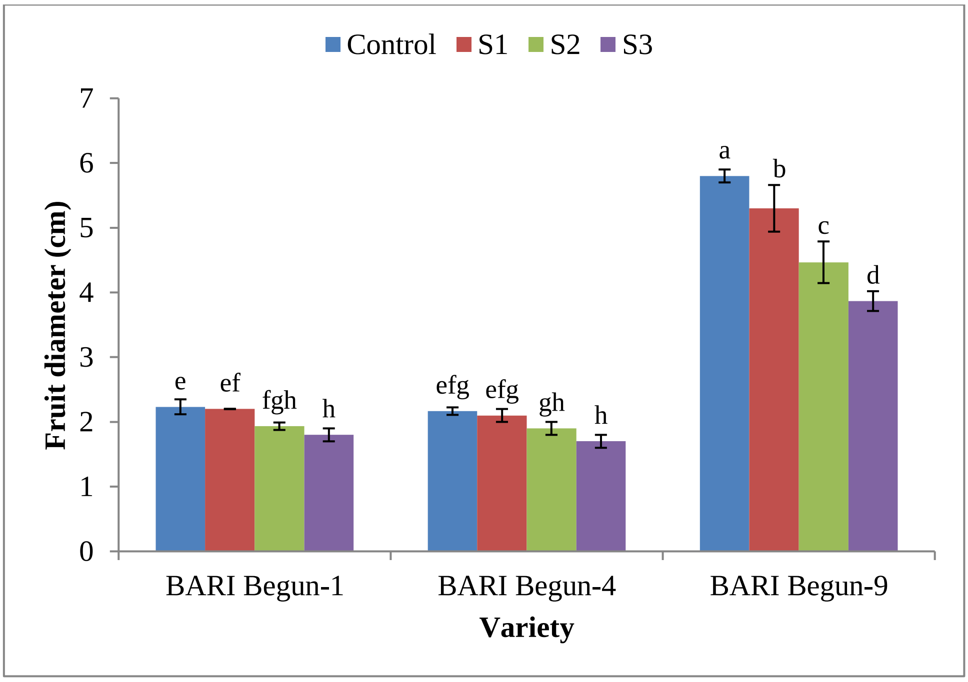


Figure 13. Effect of different light intensity on fruit diameter of different brinjal varieties. Control, S1, S2 and S3 indicate 100%, 75%, 50% and 25% Photosynthetically Active Radiation (PAR), respectively. Means (±SD) were calculated from three replications (n = 3) for each treatment. Bars with different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.2.5 Individual fruit weight per plant

Individual fruit weight depends on fruit length and diameter. As both fruit length and diameter decreased significantly under light stress (in most of the cases), so fruit weight also decreased substantially. In comparison with control (100% PAR) treatment, 75% PAR condition (S1) decreased fruit weight by 9.1, 9.4 and 11.2% in V1, V2 and V3, respectively. In 50% PAR condition, stem girth were decreased by 22.4, 24.5 and 28.8% in V1, V2 and V3, respectively. Lastly severe stress (S3) declined SPAD value by 39.6, 40.4 and 45.3% in V1, V2 and V3, respectively. Reductions of fruit weight ultimately decrease production which corroborates other findings (Kumar *et al.* 2013 and Gregoriou *et al*. 2017).

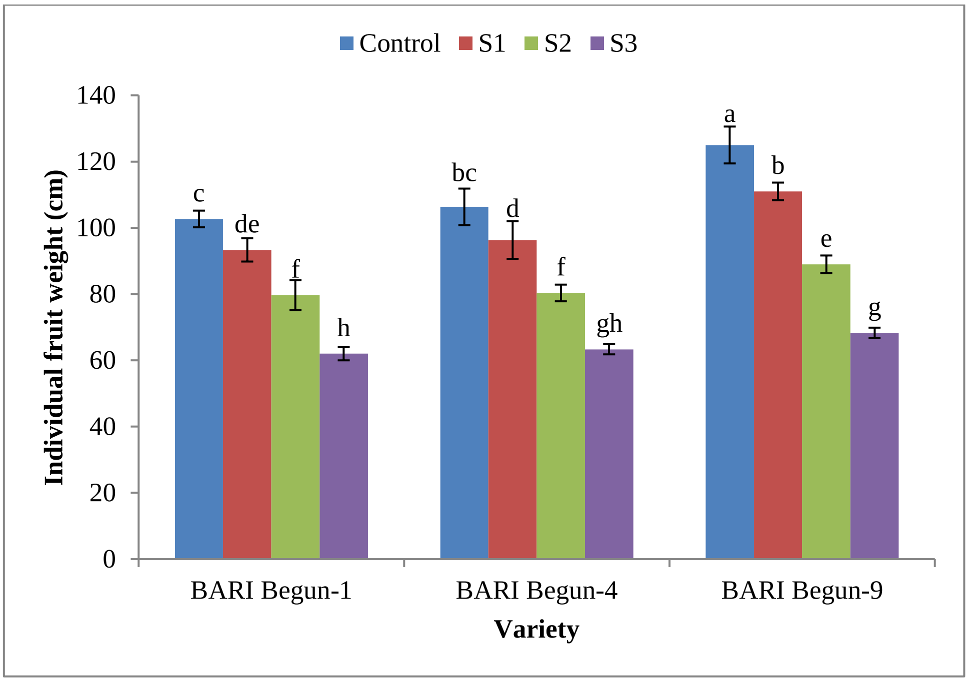


Figure 14. Effect of different light intensity on individual fruit weight of different brinjal varieties. Control, S1, S2 and S3 indicate 100%, 75%, 50% and 25% Photosynthetically Active Radiation (PAR), respectively. Means (±SD) were calculated from three replications (n = 3) for each treatment. Bars with different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.2.6 Yield per plant

Almost all yield attributes of brinjal were significantly affected by shade level. As a result yield per plant also decreased notably under stress condition. The fruit weight per plant of brijal under control condition were 2.20, 2.00 and 2.03 kg in V1, V2 and V3, respectively. The S1 treatment the fruit diameter decreased which were 1.83, 1.73 and 1.63 kg in V1, V2 and V3, respectively. Under S2 light treatment, the amount of fresh weight further decreased and it became 1.40, 1.33 and 1.17 kg in V1, V2 and V3, respectively. Lastly, in severe stress (S3) fruit diameter were recorded as 0.99, 0.77 and 0.67 kg in V1, V2 and V3, respectively. In comparison with control (100% PAR) treatment, 75% PAR condition (S1) decreased fruit weight by 16.8, 13.5 and 19.7% in V1, V2 and V3, respectively. In 50% PAR condition, yield per plant were decreased by 36.4, 33.5 and 42.4% in V1, V2 and V3, respectively. Lastly severe stress (S3) declined fruit weight per plant by 55.0, 61.5 and 67.0% in V1, V2 and V3, respectively. Here lower yield reduction was observed in V1 under severe stress (S3) and V2 under S1 and S2 treatment condition. Haque *et al.* (2009), Dong *et al*. (2014) and Thakur *et al.* (2019) confirmed similar yield reduction in different plants.

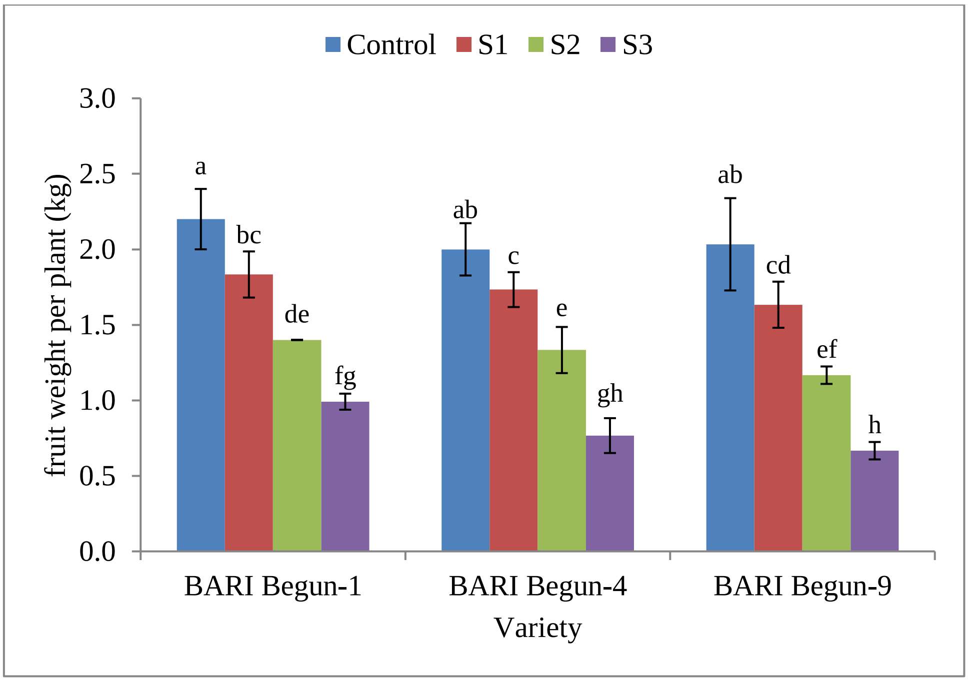


Figure 15. Effect of different light intensity on fruit weight per plant of different brinjal varieties. Control, S1, S2 and S3 indicate 100%, 75%, 50% and 25% Photosynthetically Active Radiation (PAR), respectively. Means (±SD) were calculated from three replications (n = 3) for each treatment. Bars with different letters are significantly different at P≤0.05 applying Fisher’s LSD test

CHAPTER 5

SUMMARY AND CONCLUSION

Summary

Low light stress is one of the important limiting factors for crops in agroforestry system. Brinjal (*Solanum melongena* L.) belongs to the Solanaceae family is one of the important vegetable crops of Bangladesh. Brinjal plant is moderately tolerant to low light stress as they are cultivated at agroforestry system for a long time but exact low light tolerance level may depend on variety sensitivity. Evaluation followed by screening can be an easier method to determine low light adaptive varieties.

A pot experiment was carried out to monitor the performances of three Brinjal genotypes under four different light intensity treatments. The experiment was conducted at the Field Laboratory of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during the months of October 2019 to mid April 2019. The experiment had two factors: 1. Three varieties including BARI Begun-1 (V1), BARI Begun-4 (V3), BARI Begun-9 (V3) and 4 levels of light intensity eg. S1-100% Photosynthetically Active Radiation (PAR) / full sunlight as control, S2-75% PAR, S3-50% PAR and S4-25% PAR.

Several growth and yield attributes were recorded and statistically analyzed for the evaluation of brinjal varieties under different low light stress treatments to achieve the objectives of the study.

Plant height of all varieties decreased significantly under S2 and S3 treatment at all 2, 4 and 6 w after transplanting. But, V1 showed minimum reduction than the other variety and V3 showed maximum reduction. In control condition, maximum primary branches were recorded in V3 variety but %age of declining was higher in this variety under stress condition. Lowest reduction was recorded in V1. In case of stem girth length minimum reduction under stress condition was observed in V2. Though in contrast to V1, total number of leaves was higher in V2 and V3 even under stress condition but lower reduction %age was observed under V1. Interestingly in term of SPAD value V3 perform better performance than V1 and V2 under low light stress condition. Both fresh and dry weights of plant are very important parameter under stress condition. In both cases low light stress was more destructive for V2 and V3 than the V1. In case of first flowering no significant variation was observed under control, S1 and S2 treatment but significant changes occurred under S3 treatment where stress shortened the days of first flowering. Hence no varietal differences were obtained under S3 treatment. Fruit length, diameter and fruit number per plant of all varieties were not significantly changed under S1 treatment but S2 and S3 treatment changed them significantly. The most prominent parameter was individual fruit weight which was significantly declined under any sort of stress and directly contributes in yield reduction. Maximum yield reduction (67%) was observed in V3S3 treatment.

Conclusion

Taking into consideration the yield performance, BARI Begun-4 variety was the best brinjal variety under 75% and 50% PAR level while BARI Begun-1 was the best variety under severe low light condition (25% PAR). But before recommendation the variety for agroforestry system this research work should be evaluated in different agro-climatic zone in Bangladesh. Also more new released variety should be included such type of varietal screening research.

REFERENCES

Addinsoft. (2018). XLSTAT v. 2018: Data analysis and statistics software for Microsoft Excel. Addinsoft, Paris, France.

Ahmed, F. and Jahan, M. A. (1998). Effect of potato/wheat intercropping on light interception, leaf area index and dry mattcr production. *Bangladesh Agric*. **8**(1): 67-70.

Baumann. D. T., Bastiaans, L., Goudriaan. J.. Laar, H. H. and Kropff. M. J. (2002). Analyzing crop yield and plant quality in an intereropping system using an ceo-physiological model for inter-plants competition. *Agric. Syst*. **73**(2): 173-203.

BBS (Bangladesh Bureau of Statistics). (2009). Statistical yearbook of Bangladesh, Ministry of Planning, Government of People's Republic of Bangladesh,

Bodson, M. and Verhoyen. M. N. J. (2000). Supplementary lighting regimes strongly affect the quantity of gerbera flower yield. *Acta. Hort*. **515**: 91-98.

Buwalda. F.. Eveleens, B. and Wertwijn, R. (2000). Ornamental crops tolerate large temperature fluctuations: a potential for more efficient greenhouse heating strategies. *Acta Hort*. **515**: 14 1-149.

Dong, C., Fu, Y., Liu, G., and Liu, H. (2014). Low light intensity effects on the growth, photosynthetic characteristics, antioxidant capacity, yield and quality of wheat (*Triticum aestivum* L.) at different growth stages in BLSS. *Adv. Space Res.* **53**(11), 1557–1566. doi:10.1016/j.asr.2014.02.004

Fujita, K.K. Matsamoto,G.K Buda.O. and Ogato,S. (1993) Effect of Shading on growth and Di-nitrogen fixation of kudzce and tropical pasture legumes. *Soil Sci. Plant Nutr.* **39**(1); 43-54.

Gregoriou, K., Pontikis, K., Vemmos, S.N. (2007). Effects of reduced irradiance on leaf morphology, photosynthetic capacity, and fruit yield in olive (*Olea europaea* L.). *Photosynthetica*, **45**(2):172–181.

Haque, M. M., Hasanuzzaman M. and Rahman. M. L. (2009). Effect of light intensity on the morpho-physiology and yield of bottle gourd (*Lagenaria vulgar* L). *Academic J. Plant Sd*, **2**(3): 158-161.

Hatamian, M,, Arab, M., Roozban, M.R. (2015). Stomatal behavior of two rose cultivar under different light intensities. *J. Crop Journal*. **17**(1):1–11.

Kubota. F. and Hamid. A. (1992). Comparative analysis of dry matter production and photosynthesis between mungbean (*Vigna radiate* I,.) and blackgram (*V. mungo* L.) in different light intensities. *J. Fac. Agric. Kyushu Univ*. **37**(1-2): 71-80..

Kumar R, Sharma S, Pathania V. (2013). Effect of shading and plant density on growth, yield and oil composition of clary sage (*Salvia sclarea* L.) in North Western Himalaya. *J. Essent. Oil Res.* **25**(1): 23–32.

Kumar, V., Swamy, K.N., Vardhin,i B.V., Rao, S. S. R. (2014). Effect of light curtailment on growth, biochemical response and essential oil content of rose scented geranium. *Int. J. Multidiscip. Curr. Res*. **2**:322–326.

Morgan, D.C., Stanley, C. J. and Warrington, I. J. (1985). The effect of shading on fruitfulness and yield in sultana. *J. Hort. Sci.* **60**: 473-484.

Pathiratna, L. S. S. and Perera, M. K. P. (2005). Rubber (*Hevea brasiliensis*) cinnamon (*Cinnamomum verum*) intercropping system: performance under standard inter row spacings of rubber. *Natural Rubber Res*. **18**(2): 105-112.

Peil, R. M. and Lopez, G. J. (2002). Effect of fruit removal on growth and biomass partitioning in cucumber. *Acta Hort.* **588**: 69-74.

Peil, R. M., Gonzalez, M. M. and Lopez, G. J. (2002). Light interception of a greenhouse cucumber crop: measurements and modelling results. *Acta Hort*. **588**: 81-87.

Rao. L. J. and Mitra, B. N. (1998). Growth and yield of peanut as influenced by degree and duration of shading..! *Agron. Crop Sc.* **160**: 260-265.

Rashid, M. (1999). Shobji Biggan. Rashid publishing house, 94 Puraton DOHS, Dhaka, Bangladesh. pp. 243-285.

Rezai, S., Etemadi, N., Nikbakht, A., Yousefi, M., Majidi, M. M. (2018). Effect of light intensity on leaf morphology, photosynthetic capacity, and chlorophyll content in sage (*Salvia officinalis* L.). *Hortic Sci Technol*. **36**(1): 46–57.

Rodrigo. V. H. L., Stirling, C. M., Tekiehaimanot.. Z. and Nugawela. A. (2001). Intercropping with banana to improve fractional interception and radiationuse efficiency of immature rubber plantations. *Field Crops Res*. **69**(3): 237-249.

Sevelius, N. (2003). Photosynthetic features of three gerbera cultivars in low light. *Acta Hort*. **624**: 297-302.

Shao, Q., Wang, H., Guo, H., Zhou, A., Huang, Y., Sun, Y., et al. (2014) Effects of shade treatments on photosynthetic characteristics, chloroplast ultrastructure, and physiology of *Anoectochilus roxburghii*. *PLOS ONE*, **9**(2):1–10.

Sharaiha. R. K. and Battikhi, A. (2002). A study on potato/corn inter cropping microclimate modification and yield advantages. *Dirasat Agril Sci*. **29**(2): A-97-108.

Shikata, K., Matsushita, Y.. Nawata, E. and Sakuratani. T. (2003). Effect of intereropping with maize on the growth and light environment of cowpea, *Japanese. Trop. Agric*. **47**(1): 17-26.

Thakur, M., Bhatt, V., Kumar, R. (2019). Effect of shade level and mulch type on growth, yield and essential oil composition of damask rose (*Rosa damascena* Mill.) under mid hill conditions of Western Himalayas. *PLOS ONE*, **14**(4): e0214672. doi: 10.1371/journal.pone.0214672

Venkateswarlu, B., Prasad, V.V.S.S., Rao, A.V. (1977) Effects of low light intensity on different growth phases in rice (*Oryza sativa* L.). *Plant Soil* **47**:37–47 (1977). doi: 10.1007/BF00010366

Wang, J. Y., Wang, W. Q., Wu, H. X. (2003). Illumination domino effect and its influence on height growth of medicinal plant in intercropping system of *Populus tomentosa* and medicinal plants. *J. Zhejiang Univ. Sci. B*. **20**(1): 17-22.

Wang, S. I. L., Fan, S. X., Kong, Y. and Qingjun, C. (2007). Effect of light quality on the growth and photosynthetic characteristics of cucumber *Cucutnis sazivus* L. under solar greenhouse. *Acta Hort*. **731**: 243-249.

Plate 1: Leveling of soil to set pot

Plate 2: Transferring pot

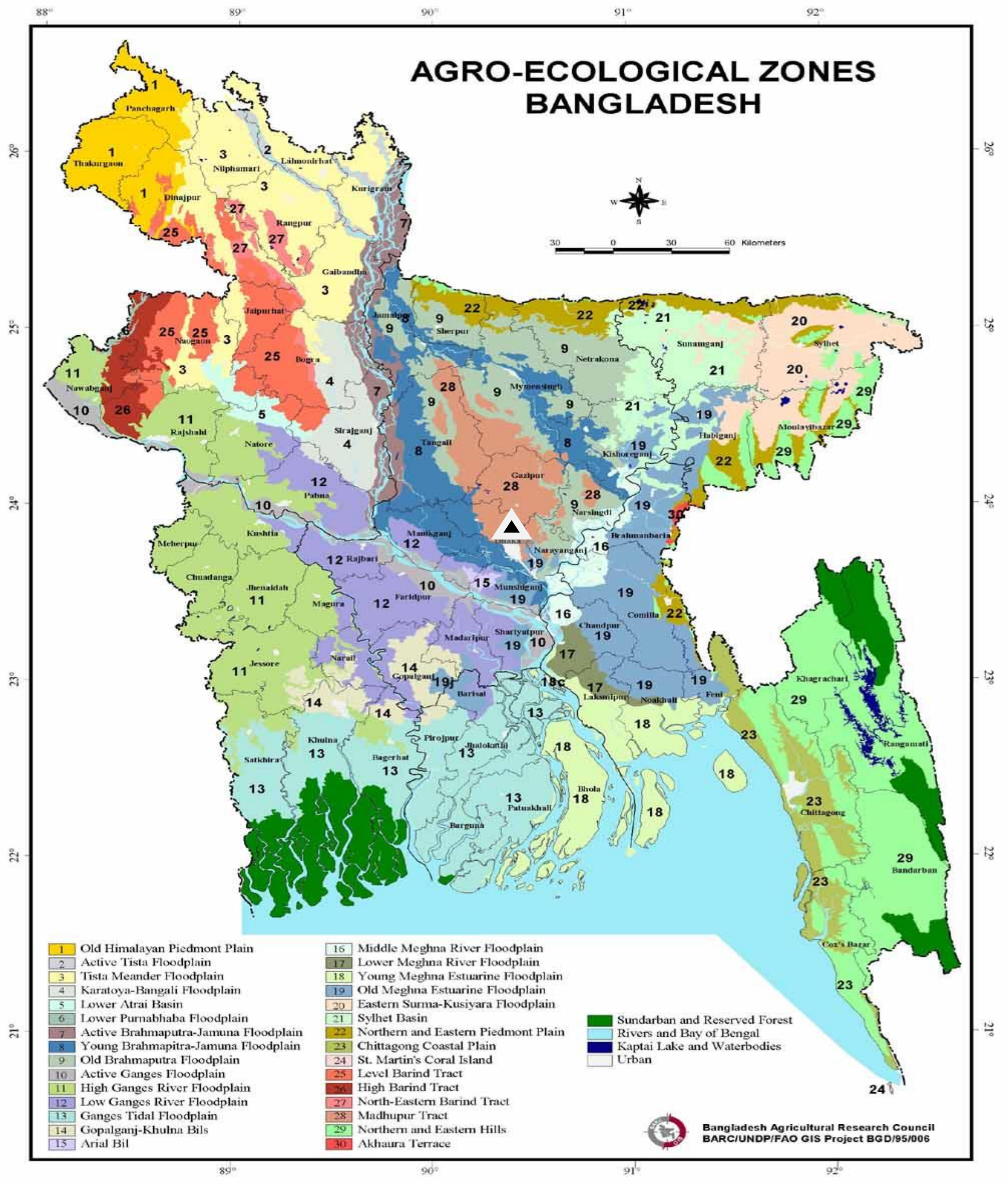
Plate 3: Total 36 pots before placing under net

Plate 4: Different low light treatments

Plate 5: Irrigation

APPENDICES

Appendix 1. Map showing the experimental site under the study



▲ The experimental site under study

Appendix 2. The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0 -15 cm depth).

Mechanical composition:

Particle size	Constitution
Texture	Loamy
Sand	40%
Silt	40%
Clay	20%

Chemical composition:

Soil characters	Value
Organic matter	1.44 %
Potassium	0.15 meq/100 g soil
Calcium	1.00 meq/100 g soil
Magnesium	1.00 meq/100 g soil
Total nitrogen	0.072
Phosphorus	22.08 μg/g soil
Sulphur	25.98 μg/g soil
Boron	0.48 μg/g soi
Copper	3.54 μg/g soil
Iron	262.6 μg/g soil
Manganese	164 μg/g soil
Zinc	3.32 μg/g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka

Appendix 3. All values of different growth and yield contributing traits of three brinjal varieties under control and low light stress treatment with mean and SD

Plant height (cm) 2 w					
	R_1	R_2	R_3	Mean	SD
V_1S_1	18.7	18.25	19.6	18.85	0.69
V_1S_2	18.25	18.55	18.85	18.55	0.30
V_1S_3	17.55	17.45	18.15	17.72	0.38
V_1S_4	17.65	16.1	17.25	17.00	0.80
V_2S_1	19.55	21.1	20.15	20.27	0.78
V_2S_2	18.9	19.45	19.5	19.28	0.33
V_2S_3	17.55	18.3	18.15	18.00	0.40
V_2S_4	18.45	17.2	17.05	17.57	0.77
V_3S_1	21.1	22.3	21.7	21.70	0.60
V_3S_2	20.2	21.3	20.8	20.77	0.55
V_3S_3	18.6	18.95	20.1	19.22	0.78
V_3S_4	18.25	17.9	17.85	18.00	0.22
Plant height (cm) 4 w					
	R_1	R_2	R_3	Mean	SD
V_1S_1	33.4	32.1	35.2	33.57	1.56
V_1S_2	32.5	32.7	33.7	32.97	0.64
V_1S_3	31.1	30.5	32.3	31.30	0.92
V_1S_4	29.3	27.8	30.5	29.20	1.35
V_2S_1	35.1	37.8	36.3	36.40	1.35
V_2S_2	33.8	34.5	35	34.43	0.60
V_2S_3	31.1	30.2	32.3	31.20	1.05
V_2S_4	28.9	30	30.1	29.67	0.67
V_3S_1	38.2	40.2	39.4	39.27	1.01
V_3S_2	36.4	38.2	37.6	37.40	0.92
V_3S_3	32.8	33.5	34	33.43	0.60
V_3S_4	28.5	31.4	29.7	29.87	1.46

Plant height (cm) 6 w					
	R_1	R_2	R_3		
V_1S_1	47.1	48.2	47.8	47.70	0.56
V_1S_2	45.2	44.1	47.3	45.53	1.63
V_1S_3	43.4	41.3	43.9	42.87	1.38
V_1S_4	42	41.5	40.1	41.20	0.98
V_2S_1	52.9	49.7	50.9	51.17	1.62
V_2S_2	46.4	46.3	49.6	47.43	1.88
V_2S_3	43.7	43.8	44.9	44.13	0.67
V_2S_4	41.6	41.9	43.7	42.40	1.14
V_3S_1	55.6	53.1	54	54.23	1.27
V_3S_2	49.2	50.3	52.2	50.57	1.52
V_3S_3	45.2	45.7	48.6	46.50	1.84
V_3S_4	41.4	42.9	44.3	42.87	1.45
Number of primary branches per plant at 6 w					
	R_1	R_2	R_3	Mean	SD
V_1S_1	9	10	10	9.67	0.58
V_1S_2	8	9	10	9.00	1.00
V_1S_3	8	9	9	8.67	0.58
V_1S_4	8	7	9	8.00	1.00
V_2S_1	10	9	11	10.00	1.00
V_2S_2	10	9	10	9.67	0.58
V_2S_3	10	9	9	9.33	0.58
V_2S_4	8	9	7	8.00	1.00
V_3S_1	12	11	12	11.67	0.58
V_3S_2	12	10	11	11.00	1.00
V_3S_3	11	9	11	10.33	1.15
V_3S_4	10	9	10	9.67	0.58

Main stem girth (cm) at 6 w					
	R_1	R_2	R_3	Mean	SD
V_1S_1	2.63	2.48	2.29	2.47	0.17
V_1S_2	2.48	2.25	2.14	2.29	0.17
V_1S_3	2.32	2.03	2.05	2.13	0.16
V_1S_4	2.18	2.03	1.91	2.04	0.14
V_2S_1	2.25	2.03	2.36	2.21	0.17
V_2S_2	2.18	2.03	2.29	2.17	0.13
V_2S_3	2.11	2.03	2.21	2.12	0.09
V_2S_4	1.8	2.03	1.91	1.91	0.12
V_3S_1	2.18	2.25	2.34	2.26	0.08
V_3S_2	2.03	2.03	2.23	2.10	0.12
V_3S_3	1.94	2.03	2.14	2.04	0.10
V_3S_4	1.8	1.76	1.93	1.83	0.09
Number of leaves per plant					
	R_1	R_2	R_3	Mean	SD
V_1S_1	35	32	33	33.33	1.53
V_1S_2	30	27	30	29.00	1.73
V_1S_3	26	27	30	27.67	2.08
V_1S_4	25	24	27	25.33	1.53
V_2S_1	37	38	36	37.00	1.00
V_2S_2	36	34	34	34.67	1.15
V_2S_3	30	29	34	31.00	2.65
V_2S_4	28	27	30	28.33	1.53
V_3S_1	38	36	38	37.33	1.15
V_3S_2	38	34	35	35.67	2.08
V_3S_3	32	31	34	32.33	1.53
V_3S_4	30	27	27	28.00	1.73

SPAD value of leaf					
	R_1	R_2	R_3	Mean	SD
V_1S_1	63	62	65	63.33	1.53
V_1S_2	58	56	60	58.00	2.00
V_1S_3	54	52	56	54.00	2.00
V_1S_4	48	51	52	50.33	2.08
V_2S_1	55	58	57	56.67	1.53
V_2S_2	53	53	55	53.67	1.15
V_2S_3	49	50	47	48.67	1.53
V_2S_4	44	42	43	43.00	1.00
V_3S_1	58	59	62	59.67	2.08
V_3S_2	58	61	57	58.67	2.08
V_3S_3	53	54	54	53.67	0.58
V_3S_4	50	47	51	49.33	2.08
First flowering time (days after transplanting)					
	R_1	R_2	R_3	Mean	SD
V_1S_1	28	30	33	30.33	2.52
V_1S_2	27	34	28	29.67	3.79
V_1S_3	28	29	30	29.00	1.00
V_1S_4	28	27	24	26.33	2.08
V_2S_1	27	30	36	31.00	4.58
V_2S_2	26	31	31	29.33	2.89
V_2S_3	29	27	33	29.67	3.06
V_2S_4	25	30	27	27.33	2.52
V_3S_1	38	32	31	33.67	3.79
V_3S_2	33	38	30	33.67	4.04
V_3S_3	32	30	34	32.00	2.00
V_3S_4	28	26	34	29.33	4.16

Plant fresh weight (g) at harvest					
	R_1	R_2	R_3	Mean	SD
V_1S_1	13	13.08	13.48	13.19	0.26
V_1S_2	12.67	12.86	12.36	12.63	0.25
V_1S_3	11.56	12.86	12.13	12.18	0.65
V_1S_4	12.56	11.65	11.35	11.85	0.63
V_2S_1	14.44	13.52	14.27	14.08	0.49
V_2S_2	14.22	13.08	13.48	13.59	0.58
V_2S_3	13.56	12.86	13.03	13.15	0.37
V_2S_4	12.56	12.53	12.25	12.45	0.17
V_3S_1	15.11	14.62	15.73	15.15	0.56
V_3S_2	14	14.29	14.83	14.37	0.42
V_3S_3	13.67	13.86	14.83	14.12	0.62
V_3S_4	13.33	14.86	13.48	13.89	0.84
Plant dry weight (g) at harvest					
	R_1	R_2	R_3	Mean	SD
V_1S_1	18	18	20	18.67	1.15
V_1S_2	22	22	15	19.67	4.04
V_1S_3	12	12	17	13.67	2.89
V_1S_4	23	23	29	25.00	3.46
V_2S_1	28	28	26	27.33	1.15
V_2S_2	25	25	21	23.67	2.31
V_2S_3	28	28	26	27.33	1.15
V_2S_4	27	27	26	26.67	0.58
V_3S_1	15	15	18	16.00	1.73
V_3S_2	36	36	30	34.00	3.46
V_3S_3	34	34	30	32.67	2.31
V_3S_4	18	18	17	17.67	0.58

Fruit number per plant					
	R_1	R_2	R_3	Mean	SD
V_1S_1	20	23	21	21.33	1.53
V_1S_2	19	21	19	19.67	1.15
V_1S_3	17	19	17	17.67	1.15
V_1S_4	17	16	15	16.00	1.00
V_2S_1	20	18	19	19.00	1.00
V_2S_2	16	18	20	18.00	2.00
V_2S_3	16	18	15	16.33	1.53
V_2S_4	14	12	11	12.33	1.53
V_3S_1	16	18	14	16.00	2.00
V_3S_2	14	17	13	14.67	2.08
V_3S_3	12	13	14	13.00	1.00
V_3S_4	10	9	10	9.67	0.58
Fruit diameter (cm)					
	R_1	R_2	R_3	Mean	SD
V_1S_1	2.3	2.3	2.1	2.23	0.12
V_1S_2	2.2	2.2	2.2	2.20	0.00
V_1S_3	1.9	1.9	2	1.93	0.06
V_1S_4	1.8	1.7	1.9	1.80	0.10
V_2S_1	2.2	2.1	2.2	2.17	0.06
V_2S_2	2.2	2.1	2	2.10	0.10
V_2S_3	2	1.9	1.8	1.90	0.10
V_2S_4	1.6	1.8	1.7	1.70	0.10
V_3S_1	5.8	5.7	5.9	5.80	0.10
V_3S_2	5.2	5	5.7	5.30	0.36
V_3S_3	4.7	4.1	4.6	4.47	0.32
V_3S_4	3.7	3.9	4	3.87	0.15

Fruit length (cm)					
	R_1	R_2	R_3	Mean	SD
V_1S_1	18	20	18	18.67	1.15
V_1S_2	20	19	16	18.33	2.08
V_1S_3	16	17	17	16.67	0.58
V_1S_4	12	13	15	13.33	1.53
V_2S_1	21	20	18	19.67	1.53
V_2S_2	20	17	19	18.67	1.53
V_2S_3	17	16	16	16.33	0.58
V_2S_4	15	13	15	14.33	1.15
V_3S_1	9	8	9	8.67	0.58
V_3S_2	9	8	8	8.33	0.58
V_3S_3	6	7	7	6.67	0.58
V_3S_4	5	6	6	5.67	0.58
Individual fruit weight (g)					
	R_1	R_2	R_3	Mean	SD
V_1S_1	100	105	103	102.67	2.52
V_1S_2	93	97	90	93.33	3.51
V_1S_3	80	75	84	79.67	4.51
V_1S_4	60	64	62	62.00	2.00
V_2S_1	112	106	101	106.33	5.51
V_2S_2	98	101	90	96.33	5.69
V_2S_3	80	83	78	80.33	2.52
V_2S_4	63	62	65	63.33	1.53
V_3S_1	130	126	119	125.00	5.57
V_3S_2	113	108	112	111.00	2.65
V_3S_3	88	92	87	89.00	2.65
V_3S_4	68	70	67	68.33	1.53

Fruit weight per plant (kg)					
	R_1	R_2	R_3	Mean	SD
V_1S_1	2	2.4	2.2	2.20	0.20
V_1S_2	1.8	2	1.7	1.83	0.15
V_1S_3	1.4	1.4	1.4	1.40	0.00
V_1S_4	1.02	1.02	0.93	0.99	0.05
V_2S_1	2.2	1.9	1.9	2.00	0.17
V_2S_2	1.6	1.8	1.8	1.73	0.12
V_2S_3	1.3	1.5	1.2	1.33	0.15
V_2S_4	0.9	0.7	0.7	0.77	0.12
V_3S_1	2.1	2.3	1.7	2.03	0.31
V_3S_2	1.6	1.8	1.5	1.63	0.15
V_3S_3	1.1	1.2	1.2	1.17	0.06
V_3S_4	0.7	0.6	0.7	0.67	0.06