Yield Response of Drip Irrigated Cucumber to Mulch and Irrigation Regimes under Different Shading Nets

A Thesis submitted to the

Mahatma Phule Krishi Vidyapeeth, Rahuri - 413 722,
Dist. Ahmednagar, Maharashtra, (India)

by
Miss. Poornima.
B. Tech. (Agril. Engg.)
(Reg. No. 2014/14)

In partial fulfillment of the requirements for the degree

of

Master of Technology
(Agricultural Engineering)

in

Irrigation and Drainage Engineering

Department of Irrigation and Drainage Engineering
Dr Annasaheb Shinde College of Agricultural Engineering
Mahatma Phule Krishi Vidyapeeth,
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June
2016

Candidate's Declaration

I hereby declare that this thesis entitled**, "Yield Response of Drip Irrigated Cucumber to Mulch and Irrigation Regimes under Different Shading Nets"** or any part thereof has not been previously submitted by me or any other person to any other University or Institute for a degree or diploma.

Place: M.P.K.V., Rahuri.

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This is to certify that the thesis entitled **“Yield Response of Drip Irrigated Cucumber to Mulch and Irrigation Regimes under Different Shading Nets”** submitted to the Faculty of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.) in the partial fulfillment of the requirement for the award of degree of **Master of Technology (Agricultural Engineering)** in **Irrigation and Drainage Engineering,** embodies the results of a piece bonafide research work carried out by **Miss. Poornima** under my guidance and supervision and no part of thesis has been submitted to any other University or Institute for Degree or Diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

(S. B. Gadge)

Place: M.P.K.V., Rahuri.

Date: / /2016

Dedication

Affectionately dedicated to

My beloved parents, respected teachers and friends….

Certificate

This is to certify that the thesis entitled **"Yield Response of Drip Irrigated Cucumber to Mulch and Irrigation Regimes under Different Shading Nets"** submitted by **Miss. Poornima** has been checked by us and we found it to be of sufficient standard for submission for the degree of **Master of Technology (Agricultural Engineering)** in **Irrigation and Drainage Engineering,** of Mahatma Phule Krishi Vidyapeeth, Rahuri.

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Place: M.P.K.V., Rahuri.

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List of Abbreviations

@	:	at the rate
am	:	Ante meridiem
%	:	Per cent
B: C ratio	:	Benefit cost ratio
C. D.	:	Critical difference
cm	:	Centimeter
CO_2	:	Carbon di-oxide
CWPF	:	Crop water production function
Dept.	:	Department
DAS	:	Days after Sowing
dSm^{-1}	:	Deci – Siemens per meter
EC	:	Electrical conductivity
Eq.	:	Equation
ETc	:	Crop evapotranspiration
ETo	:	Reference evapotranspiration
EU	:	Emission uniformity
et al.	:	And another
Etc.	:	Etcetera
Fig.	:	Figure
FUE	:	Fertilizer use efficiency
g	:	Gram
GWP	:	Ground Water Project
ha	:	Hectare
HP	:	Horse power
H	:	Hour
IDE	:	Irrigation and Drainage Engineering
i.e.	:	That is
K	:	Potassium (Kelium)
Kc	:	Crop coefficient

Kg	:	Kilogram
Kg/ha	:	Kilogram per hectare
Km/hr	:	Kilometer per hour
Kg/m^3	:	Kilogram per cubic meter
lph	:	Liter per hour
m	:	Meter
Mha	:	Million hectares
μm	:	Micrometer
M. S.	:	Maharashtra state
mm	:	Millimeter
MPKV	:	Mahatma Phule Krishi Vidyapeeth
MT	:	Million Tonnes
N	:	Nitrogen
NDVI	:	Normalized vegetative index
nm	:	Nanometer
P	:	Phosphorus
PAR	:	Photosynthetically Active Radiations
PFDC	:	Precision Farming Development Center
pH	:	Negative logarithm of hydrogen ion
PVC	:	Polyvinyl chloride
q/ha	:	Quintal per hectare
R	:	Replication
Rs./ha	:	Rupees per hectare
RDF	:	Recommended dose of fertilizer
S. E.	:	Standard error
SPI	:	Standardized Precipitation Index
t/ha	:	Tonnes per hectare
T.S.S	:	Total soluble sugar
Var.	:	Variety
viz.	:	Namely

WSF	:	Water soluble fertilizer
WUE	:	Water use efficiency

Abstract

Yield response of drip irrigated cucumber to mulch and irrigation regimes under different shading nets

by

Miss.Poornima

Master of Technology
(Agricultural Engineering)
in

Irrigation and Drainage Engineering

Mahatma Phule Krishi Vidyapeeth, Rahuri,

Dist – Ahmednagar (Maharashtra)

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Department : Irrigation and Drainage Engineering

Cucumber (*Cucumis sativus*.L.) is an important and commercially popular vegetable belonging to the family cucurbitaceae. Cucumber is grown for its immature fruits that are used as salad vegetable and pickles. They are good source of iron, calcium, vitamin A, C and it contain carbohydrates, protein and dietary fiber. They are preferably consumed by the health conscious peoples, as its fruits are fat-free and low in sodium. The crop is sensitive to temperature and light and the adverse climatic condition are known to reduce the yield drastically.

An experiment on cucumber crop was conducted at the Instructional Farm, Department of Irrigation and Drainage Engineering, Dr. A. S. C. A. E., Mahatma Phule Krishi Vidyapeeth, Rahuri during the period 06th February, 2015 to 05th June, 2015. The experiment was designed in a split plot design with five main treatments (Green-white

shade nets with 35, 50, 75 % shading, red shade net with 50% shading and open field) and eight irrigation sub-treatments. The sub main treatments comprised of four levels of irrigation. The irrigation level treatment had (120, 100, 80 and 60 % ETc) either a silver black plastic mulch or without mulch. Each sub treatment was replicated thrice in the individual shade net house and open field in a 16 m X 18 m plot size. Irrigation was scheduled on the basis of reference crop evapotranspiration calculated by Penman-Monteith's equation. The water soluble fertilizers *viz.* 19:19:19, urea, 13:00:45 were used for fertigation through drip irrigation system @ 125:62.5:62.50. Each shade net house had a specially prepared media (Red soil, sand, wheat husk and FYM in 3:3:3:1 proportion) , consisting of 190.12 kg ha^{-1} of N, 43.12 kg ha^{-1} of P and 200.12 kg ha^{-1} of K, respectively. The open field had clay soil consisting of 150.13 kg ha^{-1} of N, 60.12 kg ha^{-1} of P and 380 kg ha^{-1} of K, respectively. The EC and pH of the media were 0.57 dSm^{-1} and 7.15, respectively and that for soil in open field were 0.76 dSm^{-1} and 8.6, respectively. The EC, pH and SAR value of irrigation water was 0.57 dS m^{-1}, 7.15 and 1.12, respectively.

The seasonal water requirement of cucumber under drip irrigation was estimated to be 602.80 mm for 120% ETc, 493.89 mm for 100%, 400.16 mm for 80% ETc and 310.10 mm for 60% Etc during the season respectively. The red shade net with 50 % shading gave highest yield (52.25 t ha^{-1}), followed by green-white shade net with 75 % shading. Application of drip irrigation @ 80% of ETc with silver black plastic mulch resulted in highest yield (47.68 t ha^{-1}) as compared to all other irrigation treatments. The mulch treatments exhibited higher yields as compared to the non-mulch treatment. The minimum yield was obtained in open field condition due to adverse climatic conditions during growing period of crop.

Water use among the Green-white shade net with 35% shading percentage ranged from 129.55 to 43.87 kg/ha-mm and maximum WUE observed in treatment T_7. WUE in Green-white shade net with 50 % shading ranges from 60.16 to 128.27 kg/ha-mm and maximum WUE observed in treatment T_7. WUE in Green-white shade net with 75 % shading ranges from 192.09 to 84.01 kg/ha-mm and maximum WUE observed from treatment T_7. Further, WUE in Red shade net with 50 % shading ranges from 204.78 to

92.53 kg/ha-mm and maximum WUE observed from treatment T_7. Lowest WUE was observed in the control treatment.

Comparison of the average values of WUE among the green-white and red shade net, reveals that the highest average WUE was observed in red shade net with 50 % shading (204.78 kg/ha-mm) followed by green white shade net with 75 % (192.090 kg/ha-mm), green-white shade net with 35 % (129.5 kg/ha-mm) and green-white shade net with 50 % (128.27 kg/ha-mm) The lowest average WUE was observed in open field i.e. in control treatment (105.12 kg/ha-mm).Fertilizer use efficiency among the green-white shade net, the FUE was observed to vary in 35 % shading, FUE ranges from 53.10 to 106.95 and maximum FUE recorded in treatment T_5. In green-white shade net with 50 % shading, FUE ranges from 70.01 to 101.10 and maximum FUE recorded from treatment T_3. In green-white shade net with 75 % shading, FUE ranges from 95.03 to 149.42 and maximum FUE recorded from treatment T_5. Further, FUE in red shade net with 50 % shading ranges from 111.98 to 168.10 and maximum FUE observed from treatment T_5. Lowest FUE was observed in the control treatments.

Comparison of the average values of FUE among the green-white and red shade net, reveals that the highest average FUE was observed in red shade net with 50 % shading (168.10) followed by green-white shade net with 75 % (149.42), green-white shade net with 35 % (106.95) and green-white shade net with 50 % (101.10). The lowest average FUE was observed in open field i.e. in control treatment (76.33). This reveals that shading net conserve fertilizer and hence enhances the FUE.

The highest benefit cost ratio (2.85) was obtained in S_4T_5 (i.e. Red shade net with 50 % shading and application of drip irrigation @ 80% of ETc with plastic mulch) . The maximum net income was obtained from same treatment combination S_4T_5 (Rs. 110481.56/1008 m^2).

The overall results revealed that, maximum yield of cucumber, gynocious hybrid Gypsy, can be obtained under Red shade net with 50 % shading with application of drip irrigation @ 80% of ETc under silver black plastic mulch, during summer season under semi-arid condition of Rahuri, district Ahmednagar of Maharashtra State.

1. Introduction

India is an agricultural country. The Indian economy is basically agrarian. In spite of economic development and industrialization, agriculture is the backbone of the Indian economy. As Mahatma Gandhi said, “India lives in villages and agriculture is the soul of Indian economy”. Nearly two-thirds of its population depends directly on agriculture for its livelihood. Agriculture is the main backbone of India’s economy. It contributes about 26 percent of the gross domestic product. Agriculture meets food requirements of the people and produces several raw materials for industries.

India is a unique country with vast expanse of level land, rich soils, wild climatic variations suited for various types of crops, ample sunshine and a long growing season. The net sown area in India today is about 143 million hectares. India has the highest percentage of land under cultivation in the world. In spite of the fact that large areas in India, after independence, have been brought under irrigation, only one-third of the cropped area is actually irrigated. The productivity of agriculture is very low. Farming depends mainly upon monsoon rain. Most of the production comprises food crops. About one-third of the land holdings are small, less than one hectare in size. Farmers own their own small piece of land and grow crops primarily for consumption. Even storage facilities for crops are inadequate. Now with use of new technology, large areas have been brought under high yielding variety. This led to green revolution in several parts of India. This has helped in increasing yields per hectare as well as total production of different crops.

India has total geographical area of 329 Mha which is 2.45 % of the global land area. The total arable land is 165.3 Mha contributing to about 50.2 % of the total geographical area against the corresponding global figure of 10.2 %. The average annual rainfall in India is about 1190 mm with 4% of the total average runoff in the river. Population of India is expected to reach from 1027 million (2001, AD) to 1930 million by 2025. Food grain requirement will have to be raised to 350 million tonnes by 2025 to meet the requirement of population. As water and land are becoming limiting resource, there is no scope to increase irrigation potential by using additional water. Further study reports that India will be a highly water stressed country 2020 onward Hence, only way to increase agriculture production is by increasing water use efficiency and adopting protected cultivation techniques which can improves continuously the productivity, profitability and sustainability of farming systems. Further for the purpose of water saving and increased yield, micro-irrigation methods is the recommended technique. At present, the net irrigated area in India is 57.11 Mha and the area under drip irrigation is 1.114 Mha and in Maharashtra it is about 6,04,440 ha (Anonymous, 2014).

Cucumber (*Cucumis sativu*s L.) is an important and commercially popular vegetable belonging to the family cucurbitaceae. The cucumber is one of the oldest of the cultivated vegetables probably a native of India and an important vegetable crop of India where it is produced in a large scale for shipment and pickling. Like most cucurbits the cucumber is a warm season crop and has little or no frost tolerance

It is preferably grown for its edible tender fruits in almost all parts of the world. The crop is one of the most nutritive vegetables rich in vitamins and minerals such as phosphorus, potassium, calcium and iron. In India, cucumber is cultivated in an area of 44.12 Mha with a production of 673.74 MT and in Maharashtra it is cultivated in an area of 0.21 Mha with a production of 2.95 MT (Anonymous, 2014). Cucumber is very sensitive to fluctuations of light and temperature. Temperature affects the rate of plant development, fruit length, color and the balance between vegetative growth and fruit development under unfavorable climatic conditions, several problems may occur, such as the reduction of female flowers, delay in fruit growth and mineral disorders etc.

Controlled environment agriculture, an emerging technique, is not only highly productive, but also helps in water and land conservation and is a positive step towards environment protection. It is gaining popularity as the most intense and rewarding forms of all agricultural endeavours. Such techniques including shade house technology provide environment favorable for better crop growth and yields higher produce with good quality. These require comparatively less land area for production resulting in increased land productivity and facilitate year round production of crops. The increase in air temperature and intensity of solar radiation caused due to climate changes during the last decade, resulted in increasing area of crops grown under shading materials of various types. The different types of netting is used to protect agricultural crops from adverse climatic conditions such as wind, cold, precipitation, excessive radiation, extreme temperature, insects and diseases. Such shading of crops results in number of changes on both local microclimate and crop activity. These changes on local microclimate modify CO_2 assimilation and consequently crop growth and development (Kittas *et al.*, 2009). Smith *et al.* (1984) observed that under shading nets the air temperature is lower than that of the ambient air and it's depending on the shading intensity. Shade netting not only decreases light quantity but also alters light quality to a varying extent and might also change other environmental conditions.

Photo-selective shade netting is an emerging approach in protected cultivation. The photo selective net products are based on the introduction of various chromatic additives, light dispersive and reflective elements into the netting materials. They are designed to selectively screen various spectral components of solar radiation (UV, PAR and beyond), and/or transform direct light into scattered light. The spectral manipulation is aimed to specifically promote desired physiological responses, while the scattering improves the penetration of the modified light into the inner plant canopy. Studies of ornamental crops, grown in shade-net houses, revealed distinct responses to the red, yellow, blue, grey and pearl nets, compared with common black nets of the same shading factor. These include stimulated vegetative vigour, dwarfing, branching, leaf variegation and timing of flowering. The photo selective netting has also been tested in vegetable cultivation in either net-houses, or in combination with insect-proof nets or greenhouse plastic film covers. The nets are reported to increase the productivity of leafy crops, bell peppers and ornamentals, compared with each crop's standard cover. Although the shade-net holes allow free passage of small pests, the rates of pest infestations and vector-borne viral diseases are affected by the colour and reflectivity of the nets. The photo selective, light-dispersive shade nets provide a unique tool that can be further implemented within protected cultivation practices. However, very limited studies have been carried out under local climatic conditions.

Mulching, a practice of covering the soil/ground to make more favourable conditions for plant growth, development and efficient crop production, is known to effectively modify soil temperature. Black or clear mulch intercept sunlight which warms the soil. White or aluminium mulch reflects the sun's heat and keeps the soil cooler. Black mulch applied to the planting bed prior to planting warms the soil and promotes faster growth in early season, which generally leads to earlier harvest. The different types of mulch affect the vegetative growth and soil moisture regulation. The silver/black and black plastic mulch controls weeds by 95 to 98%. The plastic mulch is being adopted by the farmers on account of earliness and the highest early yield. The increase in yield of mulched plots is probably associated with the conservation of moisture, improved microclimate both beneath and above the soil surface, light reflection and great weed control, especially in silver/black plastic mulch. (Rajablariani *et al.* 2012).

Very limited work has been done to study the composite effects of drip irrigation and plastic mulch on crop response under net house for the local climatic conditions. Problems such as suitable cultivars for open field production, optimum climatic conditions like soils, temperature, insect pests and diseases could limit cucumber production in the open field and may significantly reduce growth and yield. Hence, the present study has been undertaken with an aim to evaluate the influence of shade net color, shading percentage and irrigation scheduling together with the mulch on growth and yield of cucumber crop.

Keeping all these points in view, the present study entitled "Yield Response of Drip Irrigated Cucumber to Mulch and Irrigation Regimes under Different Shading Net" was undertaken with the following specific objectives

1. To work out the water requirement of cucumber crop under shade net house.
2. To study yield response of cucumber to irrigation under different shade net.
3. To study and compare the microclimatic variation due to shading nets during the crop growth Period.
4. To compute the water use efficiency and fertilizer use efficiency of cucumber grown in shade net house.
5. To work out the economics of cucumber cultivation under shade net house.

2. Review of Literature

Now a days, water scarcity and energy crisis are the burning problems in Indian agriculture. In water scarcity areas, crop needs frequent irrigation for good growth and yield. Proper irrigation scheduling has to be planed to provide water when plants need them. Protected cultivation is one of the farming system widely used to provide and maintain the a controlled environment suitable for optimum crop production leading to maximum profits. Research work reported the Yield Response of Drip Irrigated Cucumber to Mulch and Irrigation Regimes under Different Shading Net. Hence, the present study has been undertaken. Objectives of the of study is to work out water requirement of cucumber under different to shade net house, yield response of cucumber to irrigation under different shade net, compare the microclimate variation due to shading nets and water use efficiency and fertilizer use efficiency of cucumber grown under shade net.

This chapter provides the brief reviews on the topics related to the objectives of the study.

2.1 Crop response to irrigation scheduling

2.1 Crop response to shading nets

Sumathi *et al.*, (2008) have conducted studies through their four field experiments (two summer and two winter crops conducted during 2005 and 2007) and tried to find out the effect of shade and fertigation on the production of cucumber. Cucumber (Cucumis sativus L.) hybrid 'NS 404" obtained from Namdhari hybrid seeds, a high yielding popular hybrid among the growers, was considered for this investigation. The shade and fertigation showed positive influence on growth and yield parameters in cucumber hybrid. The highest root shoot ratio, dry matter accumulation was also observed with the application of 100 per cent water soluble fertilizer plus calcium chloride spray under shade net condition. Microtome study was undertaken to study the influence of shade and fertigation in leaves and root anatomy.

Naraghi and Lotfi (2009) conducted an experiment to study the effect of different levels of shading on yield and fruit quality of cucumber (Cucumis sativus). One month cucumber seedlings were transplanted under curtains making different levels of shading (15, 35 and 60 per cent of solar radiation) and full sunlight, as control. The experimental design was completely randomized with four replicates and each experimental unit included 10 plants. The results showed that increasing shading density up to 35 per cent led to an increase in the number of fruits per plant. However, the number of fruits tended to decrease as shading density increased to 60 per cent. Shading density was observed to greatly influence the physiological disorders like sun-scald of cucumber fruits. The result also suggested that plants subjected to 35 per cent shading showed the highest yield.

Callejon-Ferre *et al. (2009)* carried out an experiment to identify the effects of using aluminised screens offering different degrees of shading on the production and quality of tomato crop grown under greenhouse conditions. The study was performed in an Almería-type "*raspa and amagado*" commercial greenhouse with an area of 10,000 m^2. The covering material was heat-insulating polyethylene (200 μm thick). The passive ventilation area of the green house was 14%. Transplantation of the plantlets into the sandy mulch soil of the greenhouse was performed to leave a density of 1.78 plants m^{-2}. Plants were grown under extendable aluminised screens offering 40% (T40), 50% (T50) and 60% (T60) shading, as well as under traditional whitewashing conditions (control). The screens were used during the middle hours of the day in summer with a view to reducing radiation, and at night in autumn and winter to prevent the loss of heat via outgoing long-wave infrared radiation. Shading provided by aluminised screens (T60, T50 and T40) inside a *raspa and amagado* greenhouse with a sand-mulch soil, did not improve the marketable production of tomatoes compared to traditional whitewashing (T0). Compared to the whitewashing treatment, the fruits of the T60 treatment showed significantly lower Brix but higher fruit firmness values; this was seen in over both growing seasons.

Zoran *et al.* (2011) conducted three-year trial to evaluate the influence of different colored shade nets (photoselective) on the plant development, yield and quality of bell pepper (*Capsicum annuum* L.). Pepper was grown under four different colored shade-nets (pearl, red, blue and black) with different relative shading (40% and 50%). Exposure to full sunlight was used as a control. Use of color-shade nets improved productivity by moderating climatic extremes. Depending on the year, the total fruit yields (t ha^{-1}) under the colored shade nets were higher by 113 to 131% relative to the open field.

Patil (2012) carried out experiment on yield response of cucumber (*Cucumis sativus* L.) to shading percentage of shade net and fertigation. The investigation was planned and executed on the instructional farm of department of irrigation and drainage engineering, Dr. A. S. C. A. E., Mahatma Phule Krishi Vidyapeeth, Rahuri during the period 31st Jan, 2012 to 30th May, 2012. The main treatments comprised of four growing environments viz. Green White shade net with 35, 50, 75 per cent shading and open field (control) condition. The sub main treatments comprised with six levels of fertigation. The maximum yield (31.33 t ha^{-1}) was obtained from shade net with 75 % shading and application of 125 % NPK through drip system. The yield in open field was minimum on account of adverse climatic conditions. In shade net with 75 % shading (treatment S3), FUE varied from 37.07 to 68.73 kg/kg and maximum FUE recorded from treatment T_4 (Drip irrigation with application of 100 % NPK through drip system) i. e. 68.73 kg/kg. Lowest FUE were observed from control treatment as compared to other.

The above reviewed studies shows that there is definite influence of shade net color on the and percentage growth parameter and yield parameter of different crops and microclimate of growth conditions. It was also found that favorable environmental is created under shade net by modification in the climate situation required for the plant depending on color and shade net house. Overall the better crop response is observed in the shade net house as compare to open field condition.

2.2 Crop response to irrigation scheduling

Kashypa (2008) studied that irrigation scheduling of capsicum (capsicum annum var.grossum) under scarcity condition at the college of forestry and hill agriculture, hill campus, Ranchi, Uttarakhand with five irrigation treatments 10 % (T1), 30% (T2), 45%(T3),60%(T4), and 75% (T5) based on maximum allowable depletion (MAD) of available soil water. No stress was maintain at initial stages of tile crop development in order to allow the plant healthy growth. Field experiment revealed that the irrigation with 45% maximum allowable depletion of available soil water gave maximum water use efficiency for capsicum crop. They found that the irrigation of capsicum crop for 0-30 cm soil profile to be considered, as most of the water was found to be extracted from this layer by the plants.

Ayas *et al,*. (2011) determined the effect of deficit irrigation on yield for broccoli grown under the unheated greenhouse condition at the agricultural research station of Yenisehir high school of Uludag University in Bursa, Turkey, in 2007. In research, they have applied water to broccoli as 1.00, 0.75, 0.50, 0.25, and 0.00% (as control) of evaporation from a Class-A Pan evaporimeter corresponponding to 2 day irrigation frequency. Irrigation water applied ranged from 70 to 522 mm, and water consumption ranged from 88 to 542 mm. they found the significant result for effect of irrigation level on the yield, head height, head diameter, head weight, and dry matter. The highest yield was 29.2 t/ha and the highest values for water use efficiency (WUE) and irrigation water use efficiency (IWUE) were found to be 6.71 and 6.50 kg/m^3 for water application level 0.75. Authors found that the for scare water resources conditions, 0.75 water application level is the most suitable for broccoli irrigation by drip irrigation under unheated greenhouse conditions.

Ghogare *et al.,* (2001) carried out comparative study on yield and water use efficiency of cucumber grown under polyhouse, shade net and open cultivation. There were five treatments. Two were in polyhouse. These were irrigated by drip irrigation methods applying water equivalent to pan evaporation (T1) and 70 per cent of pan evaporation (T2), respectively. Two treatments were laid in open field, irrigated by drip irrigation applying water equivalent to pan evaporation (T3) and 70 per cent of pan evaporation (T5). One treatment was in shade net (T4) irrigated by drip irrigation applying water equivalent to pan evaporation. The yield in polyhouse was seven to eight times more than open cultivation and four to five times more than shade net cultivation. The average water use efficiency in polyhouse (T1 and T2) was highest (8.71 q/ha-cm and 9.14 q/ha-cm), followed by 1.59 q/ha-cm in shade net (T4) and (0.9, 0.97 q/ha-cm) in open cultivation (T3 and T5).

It is observed that the above studies yield of different crop and growing parameters are influenced by the different levels of water deficit.

2.3 Microclimatic variation due to shading nets during the crop growth period.

Hashem *et al., (*2011) found that moderate decrease in temperatures associated with the use of nets at the spring season. Black net provides better ventilation and water permeability because of its open lockstitch design which reduced wind speed and heat build up in structures and reduced soil moisture loss evaporation**.**

Meena *et al,*. (2015) have investigated the effects of microenvironment under different colour shade nets on the growth and development of the spinach (Spinacia oleracea) at IARI New Delhi. Spinach crop were sown under four different color shade nets namely white, black, red and green with 40% mesh size along with control (without shade nets).Results showed that the microenvironment was changed under different color shade nets in both the season but the difference was more in summer than rainy season. The air temperature, wind speed, soil temperature, canopy temperature, light intensity, radiation was found to be lower under different color shade as compared to the corresponding value under control. However the relative humidity and soil moisture had higher value under color shade nets than corresponding value in control. The percentage reflectance as well as value of NDVI and VI was found to be more in green followed by red, black, control and white. The heat use efficiency had higher value under green shade nets followed by red, white, black and control. Biomass, leaf area, chlorophyll content, yield as well as radiation use efficiency and water use efficiency was found to be higher in the colour shade net as compared to corresponding value in the control. The yield was found highest under green as well as red followed by white, black and control.

2.4 Influence of silver black plastic mulch on growth, yield and quality of crops under shade net house

Mady *et al., (2007)* carried out a field experiment during 2005 and 2006 under protected cultivation at Sakha Greenhouse Station, Kafr El-Sheikh to find out increasing WUE of cucumber crop as affected by water stress (irrigation at 40, 60, 80 and 100 % of field capacity). Compost levels were (control, 0.68, 1.36, 2.05, 2.73 and 3.41 kg /m^2). The main results of this study indicated that these were significant differences in the cucumber yield, quality (T.S.S), and its water relations e.g. (Water consumptive use (m) and water use efficacy (kg /m^3)). It could be concluded that in other to produce higher yield, high quality of cucumber water saving, water consumptive use and water use efficiency at 80% from field capacity irrigation with 2.05 kg/m^2 of compost under trickle irrigation system and plastic house in both seasons.

Yaghi *et al*., (2015) studied the effect of two types of plastic mulch (transparent and black) with drip irrigation on water requirement and Cucumber (*Cucumis sativus, L*.) yield, in addition to their effect on maturity time. Trials were carried out at Teezen Research Station, Hama Agricultural Research Center, GCSAR, Syria, during 2009–2010 growing seasons using complete randomized block design with three replicates. Soil characteristics were followed too because they reflect the effects of plastic mulch. Treatments were transparent mulched drip irrigation (DI + TM), black mulched drip irrigation (DI + BM), drip irrigation without mulching (DI) and surface furrow irrigation (SI). The results of the study indicated that (DI + TM) treatment excelled all other treatments at yield and water use efficiency (WUE), where its yield was 63.9 t ha−1, and (WUE) was 0.262 t ha^{-1} mm^{-1}, while (DI + BM) treatment produced 57.9 t/ ha, with a (WUE) of 0.238 t ha^{-1} mm^{-1}. However cucumber yield and WUE declined in the remaining treatments of no mulch (DI) and (SI) to reach 44.1 t/ ha with 0.153 t ha^{-1} mm^{-1} and 37.7 t/ ha with 0.056 t ha^{-1} mm^{-1}, respectively. The results showed that (DI + TM) treatment gave the highest soil temperature and moisture during both of the seasons in comparison to (DI + BM). This enhanced its vegetative growth and almost doubled its productivity compared to the SI treatment.

Halapa *et al*., (2015) have studied the effect of different mulches and two biodegradable mulches on yield of field grown cucumber. This study were conducted during two different climatically growing season 2011 and 2012 in southern Finland. All the mulches increased the yield as compare to bare ground. In 2012 average temperature was lower as compare to 2011 there were no difference in yield between two different types of mulches. Soil temperature of the experimental crop is monitored throughout the growing period of cucumber. Mulches with dark color with upper surface increases soil temperature more then with the light color upper surface. The soil warming effect of mulch was greater during early season and diminished when plant grew more leaves cover the mulch surface. From this study concluded that during both the year compare to dark colored paper mulch comparable with biodegradable in yield production and could replace it with mulch as material for cucumber production.

2.5 Economics of cucumber cultivation under shade net house

Singh *et al.,* (2007) conducted an experiment to evaluate the techno-economic feasibility of year round parthenocarpic cucumber cultivation under naturally ventilated greenhouse in northern India. Trials were conducted at the Indo-Israel project of Indian Agricultural Research Institute, New Delhi under which an indigenously designed naturally ventilated greenhouse was evaluated for its techno-economic feasibility for year-round cucumber cultivation. The cost-benefit ratio of cucumber cultivation under greenhouse was worked out as 1:2.29 under Delhi conditions of India. It was concluded that the low-cost naturally ventilated greenhouses are more suitable.

2.6 Concluding remarks

The above reviews shows that the use of shade net modifies the growth environment by changing the radiant flux, air temperature etc. near the crop canopy. Its adoption can provide optimum environmental medium for better crop growth to achieve higher yield and high quality product. The use of mulch has advantages such as better crop growth, high yield, conservation of moisture, prevents erosion, and controls the weed. Similarly, the adoption drip irrigation facilities fertigation along with irrigation integrated approach toward. It also influences crop growth and development and also directly affects the benefit- cost ratio. However, the results need adoption of such technique uses not only influences the crop growth and development but also affects the benefits-cost ratio. However result need to be verified under local condition. Hence, the experiment was undertaken to study the response of cucumber to mulch and irrigation levels under different shading nets under local climatic condition.

As the shading percentage, color, and irrigation level influence the yield and quality of different crops as observed from selected reviews. The experiment was proposed to know the influence of these parameter on yield of cucumber and conducted accordingly.

3. Material and Methods

The present investigation is entitled “Yield Response of Drip Irrigated Cucumber to Mulch and Irrigation Regimes under Different Shading Nets” was carried out during summer season of 2015. The details of materials and methods adopted during the investigation to fulfill the objectives are described in this chapter.

3.1 Experimental details

This section describes the details of the experiment performed to satisfy the objectives of the study. The experiment was conducted under four different shade net houses and an open field.

3.1.1 Study area - geographical location

The present investigation was conducted at the Instructional Farm of Department of Irrigation and Drainage Engineering, Dr. Annasaheb Shinde College of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri during the period from February 2015 to June 2015. Geographically, the farm lies at 74^0 38’ 00” E longitudes and 19^0 20’00” N latitude at 557 m above the mean sea level in the central campus of Mahatma Phule Krishi Vidyapeeth, Rahuri

3.1.2 Climatic condition of study area

3.1.2.1 General climatic conditions

Climatically, the region falls under the semi-arid and sub-tropical zone with average annual rainfall of 560 mm. The rainfall is erratic, coupled with frequent dry spells. The distribution of rain is uneven and is distributed over 15 to 37 rainy days. During the crop period, generally the maximum temperature ranges between 25.6 to 41.6 ^{0}C and the minimum temperature ranges between 10.4 to 26.4 ^{0}C, respectively. The pan evaporation ranges from 1.57 to 8.69 mm day^{-1}. The wind speed ranges from 0.2 to 9.5 km hr^{-1} and the maximum and minimum relative humidity ranges from 22 to 98 per cent and 8 to 86 percent, respectively.

3.1.2.2 Climatological data

The actual meteorological data on important weather parameter during the crop growth period (06th February, 2015 to 06th June, 2015) were collected on daily basis from the meteorological observatory situated at the Instructional Farm of Department of Irrigation and Drainage Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri.

The data includes maximum and minimum temperature, minimum and maximum relative humidity, actual sunshine hour, daily wind speed and rainfall etc.

The climatological data inside the shade net house and the open field during crop growth period were noted daily in the morning (7.30 am) and in the afternoon (2.30 pm) from the Stevenson's screen installed in shade net and the open field. The data includes maximum and minimum temperature, dry bulb temperature and wet bulb temperature. The Stevenson's screen installed in shade net house is shown in Plate 3.1.

Plate 3.1 Stevenson's screen

Plate 3.2 Stevenson's screen internal view

3.1.3 Experimental setup

The experimental set up consisted of different treatments in shade net house and open field. The topography of the experimental field was uniform and leveled. The soil was well drained with 45 cm depth.

3.1.3.1 Media in shade net house

The soil media in shade net house consisted of red soil, farm yard manure (FYM) and sand mixed with wheat husk in the proportion of 3:3:3:1. Urea and single super phosphate were added and thoroughly mixed in media. The media was then sterilized (fumigated) by using formalin in the proportion of 1:10 in water.

3.1.3.2 Soil in open field

The open field had black cotton soil with textural class "clay". The open field was considered to be the control treatment for the experiment.

3.1.3.3 Soil analysis

The physio-chemical properties of the soil for the study area were determined by adopting the standard methods given in Tables 3.1 and 3.2. The representative samples of soil were collected from the four corners and one sample from the center of the field. The samples were mixed thoroughly and air dried in the shed. The stones, roots and other debris were separated out from the soil samples. A composite sample weighing 1 kg was obtained and powdered in wooden mortar and pestle, sieved through 2 mm sieve and analyzed for its physical and chemical properties by using standard methods.

Table 3.1 Methods to determine physical properties of soil

Details	Methods
Soil texture a) Sand (%) b) Silt (%) c) Clay (%)	Sieve analysis
Textural class	Triangular diagram
Bulk density (gm/cc)	Core cutter method
Field capacity (%)	Pressure plate apparatus
Permanent wilting point (%)	Pressure plate apparatus

Table 3.2 Methods to determine chemical properties of soil

Details	Methods
pH	Potentiometric method
EC (dSm^{-1})	Conductometric method
Available N	Alkaline permanganate
Available P	Modified Olsen
Available K	Neutral N ammonium acetate of flame photometer
Organic carbon	Wet oxidation method

3.1.4 Water source

The water was pumped for the experiment from an open dug well situated at corner of the Instructional Farm of Department of Irrigation and Drainage Engineering.

The water analysis was done and chemical properties were determined to know the quality of water. The chemical properties of irrigation water were determined by adopting standard procedure shown in Table 3.3.

Table 3.3 Methods to determine chemical properties of irrigation water

Sr. No.	Chemical properties	Method adopted
1.	pH	Potentiometric
2.	EC	Conductometric
3.	SAR	Calculated

3.1.5 Planting

As per the crop spacing, marking was done on raised beds. The seeds were sown at marked spacing under both shade net house and open field.

3.1.6 Irrigation system

Drip irrigation system was adopted to fulfill the irrigation requirement of the crop. The plants were watered daily before 12 noon or late in the evening. The drip control head consist of a suction pipe, screen filter, sand filter with back flush assembly, electric power source, control valves and by-pass assembly. The system was operated by electric motor pump-set. The filter unit assembly of the drip system is shown in Plate 3.6.

3.1.6.1 Details of pump-set

An electrical pump set was used for pumping water into the drip irrigation system. The details of the pump set used were as under:

Type of pump	: Induction motor
HP	: 2
Head	: 26 m
Rpm	: 2800

The operating pressure of drip irrigation system was maintained at 1 kg cm^{-2}.

3.1.6.2 Details of drip irrigation system

The details of drip irrigation system installed for application of water to the experiment field was as under:

Main and sub main pipe	: PVC
Size of main pipe	: 63 mm diameter (OD)
Size of sub main/manifold pipe	: 20 mm diameter

Lateral pipe	: LLDPE material
Size of lateral	: 12 mm (OD)
Type of dripper	: Non- pressure compensating
Discharge of emitter	: 2 lph (On line drippers)
Spacing between lateral	: 1.3 m
Spacing between emitter	: 30 cm
Operating pressure	: 1 kg cm^{-2}
No. of laterals per treatment	: 3
No. of drippers per treatment	: 18

3.1.7 Fogging system

The fogging system had automatic controller (Plate 3.3) to operate the system for 30 second ('ON' period) after the interval of 'OFF' period about 8 minute during the afternoon period.

3.1.7.1 Details of fogging system

The details of fogger system are as under:

Type of foggers	: Four way fogger
Distance between two lateral	: 3 m
Distance between two fogger	: 3 m
Discharge of single fogger	: 4 lph
Droplet size	: 70 – 130 µ
Operating pressure	: 2 – 2.5 kg cm^{-2}

3.1.8 Experimental treatment details

The experiment was carried out in split plot design with five main treatments (shading percentage and color) and eight sub treatments (irrigation levels) with three replications. The area of each shade net was 288 m^2. The treatment details are given below:

a) Main Treatments: Growing environment (Shading percentage and net color)

S_1: – 35 % shading (Green-white shade net)

S_2: – 50 % shading (Green-white shade net)

S_3: – 75 % shading (Green-white shade net)

S_4: – 50 % shading (Red shade net)

S_5: – 0 % of shading (Open field)

Layout of 35 % experiment

Layout of 50% experiment

75% layout

50% red experiment layout

Open field layout

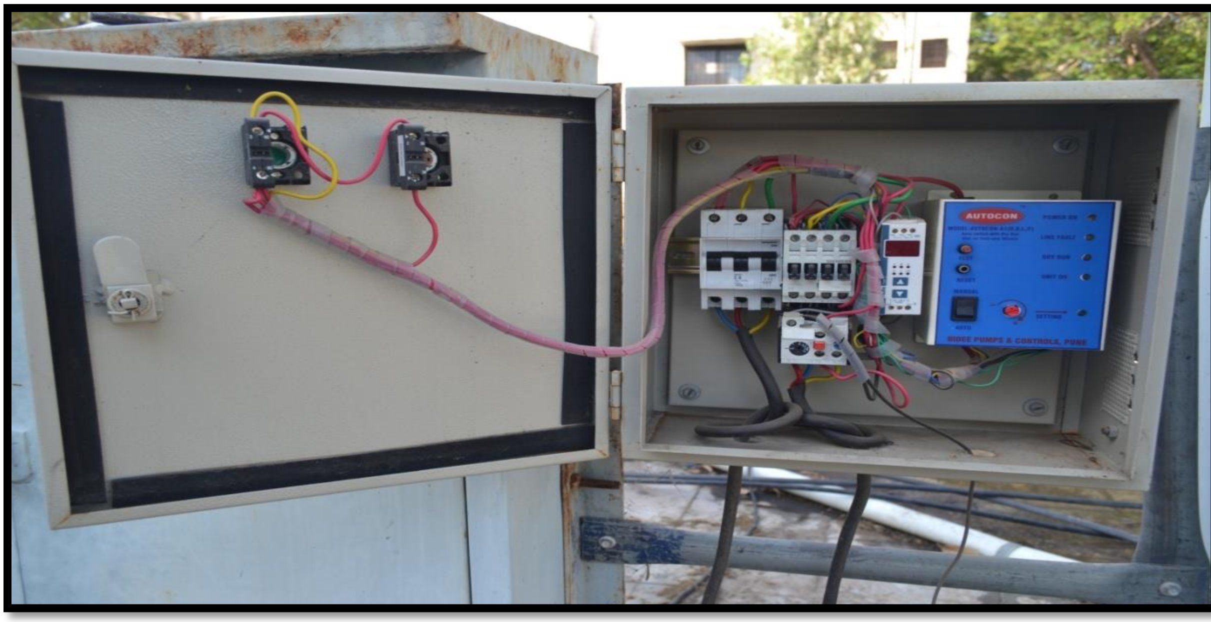

Plate 3.3 Automatic controller for operating fogging system

Plate 3.4 Pump set used for irrigation

Plate 3.5 Filter unit assembly of the drip irrigation system

b) Sub – Treatments: Agro technique (Irrigation regimes and plastic mulch) treatments

T_1 = Drip irrigation @ 120 % of ETc with plastic mulch.

T_2 = Drip irrigation @ 120 % of ETc without plastic mulch.

T_3 = Drip irrigation @ 100 % of ETc with plastic mulch.

T_4 = Drip irrigation @ 100 % of ETc without plastic mulch.

T_5 = Drip irrigation @ 80 % of ETc with plastic mulch.

T_6 = Drip irrigation @ 80 % of ETc without plastic mulch.

T_7= Drip rrigation @ 60% of ETc with plastic mulch.

T_8 = Drip irrigation @ 60% of ETc without plastic mulch.

Replications **:** 3 (In each shade net house)

Size of shade net **:** 16 m X 18 m.

Bed system **:** Raised bed system.

3.1.8.1 Layout of the experiment

The experiment was carried out in four shade net houses with different shading per cent of shade net and an open field. The size of each shade net and the open field was 18 m X 16 m. The experiment was laid out in split plot design with five main treatments, eight sub-treatments and three replications. The size of each plot was 2 m × 3.9 m. A 0.5 m buffer strip was provided between two beds to avoid lateral movement of water from one bed to another and enable easy cultural operations like weeding, spraying, fertigation and harvesting etc. The schematic layout of an experimental set-up is shown in Figure 3.1 to 3.5. Plate 3.6 shows the top view of study area.

3.1.9 Agronomical details of the crop

The agronomical details of the crop are given below:

Local name	:	*Kakadi*, Cucumber
Common name	:	*Khira*
Botanical name	:	*Cucumis sativus* L.
Variety	:	Gypsy/Hybrid
Crop duration	:	120 days
Crop spacing	:	0.4 m X 1.3 m

Sowing date : 06th February, 2015

3.1.10 Field operations

The different operations were carried out on the experimental plot included:

1	:	Media preparation
2	:	Mixing of media using rotavator
3	:	Fumigation of media
4	:	Layout marking on the field
5	:	Bed preparation
6	:	Installation of drip irrigation system
7	:	Testing of drip irrigation system
8	:	Laying of silver black plastic mulch
9	:	Sowing of cucumber seeds
10	:	Gap filling

Plate 3.6 Top view of study area

Plate 3.7 Bed preparation

Plate 3.8 Laying of silver black plastic mulch

Plate 3.9 Fertigation with gator pump

Plate 3.10 Internal view of white green shade net

Plate 3.11 Internal view of red shade net

3.1.11 Fertilizer application

The Gator pump was used for injecting the fertilizers into the drip irrigation system. NPK @ 125:62.5:62.50 were given as per the schedule shown in Table 3.4

Table 3.4 Fertilizer application for cucumber

Dose	**No. of Splits**	**Quantity of Fertilizer (kg ha^{-1})**	
		19:19:19	Urea (46:00:00)
125:62.5:62.5 (3 days interval)	26	331.25 kg ha^{-1} (12.88 kg ha^{-1}/split or 98 g/ treatment/split)	135 kg ha^{-1} (5.25 kg ha^{-1}/split or 237 g/ treatment/split)

3.1.12 Plant protection measures

As per recommendation the following chemical were spread on the crop as an effective measure against the occurrence of diseases and pest like Leaf miner, White fly, Thrips, Red mite, Mildew, and other fungal diseases. The plant protection measures under taken the growth period of cucumber crop is shown in Table F1 of appendix F.

3.1.13 Harvesting

The marketable size fruits were harvested in 32 pickings. The details are presented in Table 3.5. First picking of fruits was done after 49 days from sowing and last picking was done on 120 days after sowing.

Table 3.5 Harvesting schedule

Picking No.	Date of Harvesting	DAYS	Picking No.	Date of Harvesting	DAYS
1	26/03/2015	49	17	03/05/2014	85
2	29/03/2015	50	18	05/05/2015	88
3	02/04/2015	51	19	07/05/2015	90
4	05/04/2015	54	20	10/05/2015	92
5	08/04/2015	57	21	13/05/2015	95
6	10/04/2015	60	22	16/05/2015	98
7	12/04/2015	62	23	19/05/2015	101
8	15/04/2015	64	24	21/05/2015	103
9	17/04/2015	66	25	23/05/2015	105
10	19/04/2015	68	26	25/05/2015	107
11	21/04/2015	72	27	28/05/2015	109
12	23/04/2015	74	28	30/05/2015	112
13	26/04/2015	76	29	01/05/2015	114
14	29/04/201	78	30	03/06/2015	117
15	30/04/2015	80	31	05/06/2015	119
16	2/05/2015	83	32	07/06/2015	120

3.2 System Evaluation

The average discharge and emission uniformity of drip irrigation system was determined for the different treatments under study. The average discharge and emission uniformity for each treatment was computed by collecting water from each emitter in the catch can for twenty minutes. The constant operating pressure of 1 kg cm^{-2} was maintained throughout the period of application. The same pressure was maintained during the application of irrigation water also. The field emission uniformity was computed by the formula suggested by Karmelli and Keller (1974) and is given in Eq. 3.1.

$$Eua = \frac{1}{2} \times \left(\frac{qmin}{qavg} + \frac{qavg}{qmax}\right) \times 100 \qquad (3.1)$$

Where,

Eua = Absolute Emission uniformity (%)

$qmin$ = Average discharge of minimum quarter of emitter (lit min^{-1})

$qavg$ = Average discharge of all emitter (lit min^{-1})

$qmax$ = Average discharge of maximum 1/8th of emitter (lit min^{-1})

Further, the computed emission uniformity was used for estimating the time of operation of drip irrigation system.

3.3 Irrigation requirement

Irrigation was scheduled on the basis, of climatological approach with application of water equivalent to 60, 80, 100 and 120 % of ETc for shade net and open field trial. Climatological data *viz.* daily maximum and minimum temperature, daily maximum and minimum relative humidity, wind speed at 2 m height, actual sunshine hour and rainfall etc. were collected from the ET Monitoring Station located at the Instructional Farm of Department of Irrigation and Drainage Engineering.

3.3.1 Reference evapotranspiration

The reference evapotranspiration (ETo) was estimated by using FAO based Penman-Monteith method (Allen *et al.* 1998). The proposed equation for estimating the ETo is given below:

$$ETo = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \tag{3.2}$$

Where,

ET_0 = Reference evapotranspiration (mm day^{-1})

R_n = Net radiation at the crop surface (MJ m^{-2} day^{-1})

G = Soil heat flux density (MJ m^{-2} day^{-1})

T = Mean daily air temperature at 2 m height (^oC)

u_2 = Wind speed at 2 m height (m s^{-1})

e_s = Saturation vapour pressure (kPa)

e_a = Actual vapour pressure (kPa)

$(e_s - e_a)$= Saturation vapour pressure deficit (kPa)

Δ = Slope vapour pressure curve (kPa $^oC^{-1}$)

γ = Psychometric constant (kPa $^oC^{-1}$)

3.3.2 Daily crop coefficient

The daily crop coefficient required for computing the daily crop evapotranspiration was estimated using the third degree polynomial equation (Gadge, 2010) based on Kc values adopted from the FAO bulletin and shown in Eq. 3.3:

$$Kc_t = -3.0594\left\{\frac{t}{T}\right\}^3 + 3.4474\left\{\frac{t}{T}\right\}^2 - 0.1636\left\{\frac{t}{T}\right\}^1 + 0.5257 \qquad (3.3)$$

Where,

Kc_t - Crop coefficient of t^{th} day.

t - Day considered.

T - Total period of crop growth from sowing to harvesting (days).

3.3.3 Crop evapotranspiration

The daily crop evapotranspiration was estimated using Eq. 3.4 as shown below:

$$ETc = ETo \times Kc \qquad 3.4$$

Where,

ETc = Crop evapotranspiration (mm day^{-1})

ETo = Reference evapotranspiration (mm day^{-1})

Kc = Crop coefficient

3.4 Observations to be recorded for experiment

3.4.1 Biometric observations

For recording various biometric observations three sample plants were selected from each treatment and tagged for their identification. The observations such as diameter of fruit, length of fruit, weight of fruit, days to 50 % flowering, length of vine at last harvest, number of fruits per vine, total yield per plot were recorded at regular interval.

3.4.1.1 Days to 50 % flowering

The number of days required for flower initiation was recorded from the sowing to the date at which 50 per cent flowers were visible from each treatment plot.

3.4.1.2 Diameter of fruit

The circumference of fruit at three points was recorded with the help of Vernier caliper and the average diameter was worked out and recorded. Five fruits from the identified sample plants were randomly selected for computing the diameter of fruit.

3.4.1.3 Length of fruit

Length of fruit was recorded from stalk to style end with the help of steel tape and the length of fruit was recorded.

3.4.1.4 Weight of fruit

Immediately after the harvest, the five fruits were randomly selected and weighed on electronic balance and the average weight of fruit was recorded.

3.4.1.5 Length of vine at last harvest

The length of main shoot of vine was measured from collar of stem to growing tip with the help of steel scale for tagged plants at last harvest and average length of vine was worked out for each treatment plot.

3.4.1.6 Number of fruits per vine

The number of fruits harvested from each vine at each harvesting was counted and recorded.

3.4.1.7 Yield of fruit

The weight of fruit harvested per plot at each picking was recorded and the total yield of fruits per plot was obtained.

3.5 Efficiencies

3.5.1 Water use efficiency

The water use efficiency of different treatments was estimated from the cucumber yield data and the water requirement, using Eq. 3.5:

$$\text{Field water use efficiency} = \frac{\text{Y}}{\text{WR}} \qquad \text{.... 3.5}$$

Where,

Y = Crop yield (kg ha^{-1})

WR = Water requirement (mm)

3.5.2 Fertilizer use efficiency

The fertilizer use efficiency was determined by using Eq. 3.6:

$$\text{Fertilizer use efficiency} = \frac{\text{Yield (kg ha}-1)}{\text{Quantity of fertilizer applied(kg ha}-1)} \qquad \text{.... 3.6}$$

3.5.3 Soil temperature

Soil temperature was measured by soil thermometer installed in the soil at 10 cm depth in silver black plastic mulch in every main treatment. The thermometers were installed in a treatment with @ 100% of ETc and the temperatures were recorded daily in the morning 8:30 am and in the afternoon 2:30 pm.

3.6 Statistical analysis

The statistical analysis of data was carried out using statistical method known as analysis of variance (ANOVA), appropriate for the split plot design. The standard error (SE) for each factor and their interaction were worked out. Wherever the results vary significantly, critical difference (CD) at five percent level of significantly was worked out. The data is suitably illustrated with graph and figures at appropriate place**.**

3.7 Cost Economics

3.7.1 Cost of production

The cost of production was worked out for each treatment. The cost includes paid out cost on hired human labor, seeds, fertilizers, water charges, interest on working capital, interest on fixed capital, depreciation, repair and maintenance for drip irrigation system and shed net house.

3.7.2 Gross monetary returns

The gross monetary returns per hectare were worked out by considering the fruit yield from different treatments and the prevailing market price of cucumber.

3.7.3 Net income

The net income was worked out by subtracting the cost of production from the gross momentary returns in each treatment.

3.7.4 Benefit-cost ratio

The benefit-cost ratio was worked out by dividing the cost of production to the gross returns in each treatment under study.

The observations recorded by adopting procedure discussed in this section were analyzed and the results obtained are discussed in the chapter 4.

4. Results and Discussion

The research entitled "Yield Response of Drip irrigated Cucumber to Mulch and Irrigation Regimes under Different Shading Nets" was conducted at the Instructional Farm of Department of Irrigation and Drainage Engineering, Dr. A. S. C. A. E., Mahatma Phule KrishiVidyapeeth, Rahuri. The specific objectives of this study are presented in chapter-1.The methodologies adopted for satisfying the different objectives are presented in this chapter-3. The results of the field experiment are presented and discussed in this chapter.

4.1 Physical and chemical properties of the soil

The soil samples were collected and analyzed by adopting standard procedure as described in Section 3.1.3.2. Physical properties consists of percentage of sand, silt and clay particles in soil, textural class of the soil, field capacity, permanent wilting point, bulk density of soil etc. These properties of the soil of experimental field are presented in the Table 4.1

Table 4.1 Physical properties of soil and media

Physical properties		**Values**
Soil texture and class	i) Sand %	26.0
	ii) Silt %	23.5
	iii) Clay %	58.50
	Clay	
Permanent wilting point (%)	i) Media	16.68
	ii) Soil	18.46
Field capacity (%)	i) Media	22.4
	ii) Soil	28.36
Bulk Density (g cm^{-3})	i) Media	1.44
	ii) Soil	1.32

From Table 4.1, it is revealed that, the textural class of the soil was clay. The bulk density, field capacity, permanent wilting point for soil were observed as 1.32 g cm^{-3}, 28.36 %, 18.46 % and that for media in shade net house were 1.44 g cm^{-3}, 22.4 %,28.36 %, respectively. From above table, it seems that media in shade net was more porous than the open field. Available moisture in media and soil was 7.35 % and 9.67 %, respectively. This indicates the water holding capacity was higher in clay soil as compared to media of the shed net house.

The chemical properties of soil/media are presented in Table 4.2. From Table 4.2, it is observed that, EC and pH of the media in shade net house were 0.78 and 7.4, respectively and that for soil in open field were 0.77 and 6.72, respectively. The available N, P and K for media in shade net house was 190,12, 43.12 and 200.12 kg ha^{-1}, respectively and that of for soil in open field was 150.13, 60.12 and 380 kg/ha^{-1}, respectively. The nutrient rating on basis of available nutrient in soil is shown in Appendix - A.

Table 4.2 Chemical properties of soil/media

Chemical Properties	Shade net with house		Open field	
	Values	**Rating**	**Values**	**Rating**
Soil pH	7.4	Slightly acidic	6.72	Slightly acidic
EC (dSm-1)	0.78	Good soil	0.77	Good soil
Available N (kg/ha)	190.12	Low	150.13	Low
Available P (kg/ha)	43.12	Very high	60.12	Very high
Available K (kg/ha)	200.12	Moderately high	380	Very high
Organic carbon	1.18	Very high	1.23	Very high

4.2 Irrigation water analysis

The open dug well water was analyzed by adopting the standard procedure as described in section 3.1.4 for the properties such as EC and pH. The class of water was observed to be C_2S_1. This indicates that the water is suitable for irrigation. The Table 4.3 shows the chemical properties of the water used for irrigation. The classification of chemical properties of irrigation water on basis of available pH, EC and SAR is shown in Appendix - B.

Table 4.3 Chemical properties of irrigation water

Chemical properties	Results
pH	7.15
EC (dS m^{-1})	0.57
SAR	1.12

4.3 Climatological data from ET monitoring station

The climatic data viz. temperature (maximum and minimum), relative humidity (maximum and minimum), wind speed, solar radiation, actual sunshine hours and pan evaporation that influence estimation of ETo were used. The daily climatological data obtained from the ET monitoring station located at the Instructional farm of Department of Irrigation and Drainage Engineering, Dr. Annasaheb Shinde College of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri throughout the season is presented in Appendix- C, Table C1 and graphically presented as below.

4.3.1 Maximum and minimum temperature

The observation of maximum and minimum temperature data showed that the maximum temperature varies from 41.6 to 25.6^{0}C. Similarly, the minimum temperature varies from 24.6 to 10.4^{0}C throughout the crop growth period. The variation of daily maximum and minimum temperature over the crop growth period is shown in Figure 4.1 and Figure 4.2, respectively. The average maximum and minimum temperature during cucumber growth period was 35.6^{0}C and 10.4^{0}C respectively.

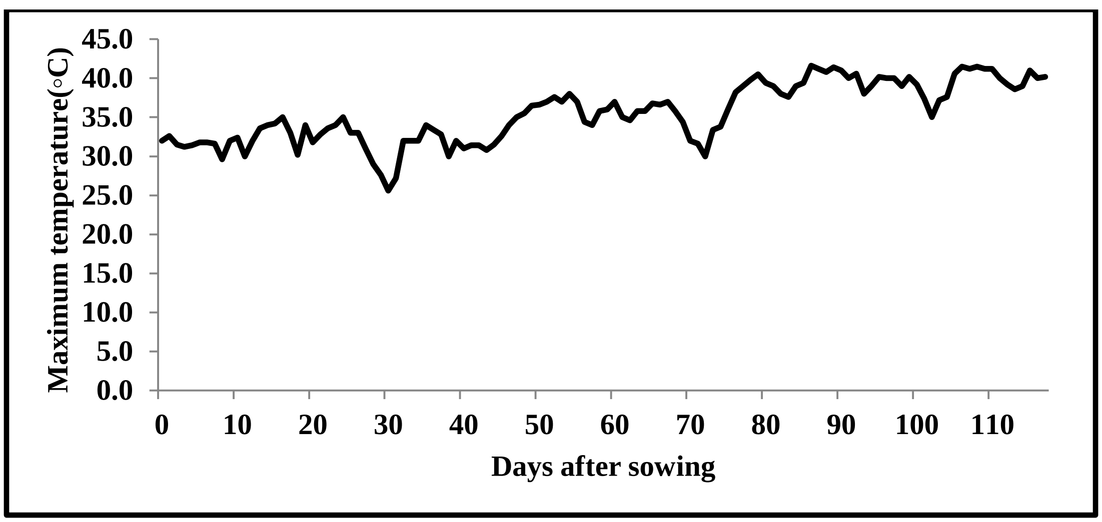

Figure 4.1 Variation in daily values of maximum temperature

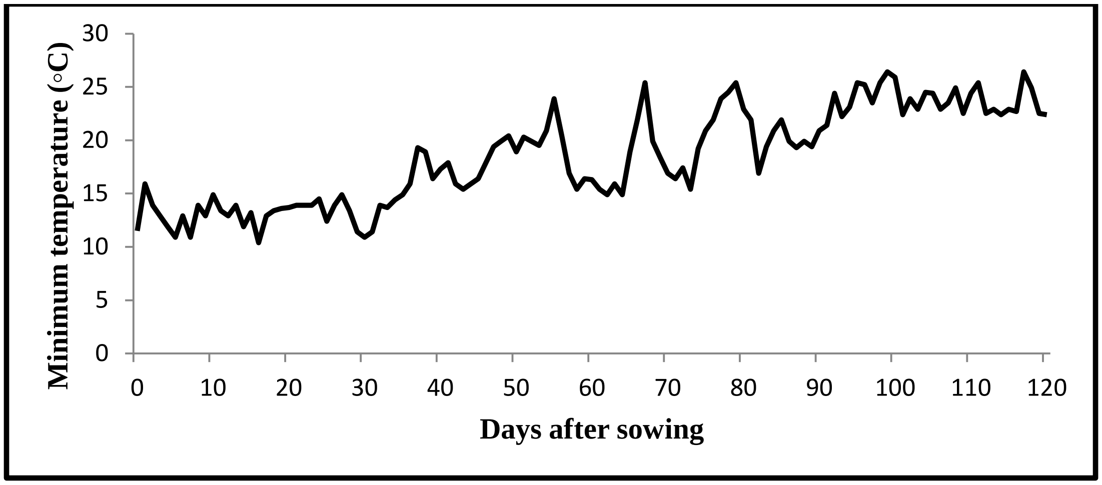

Figure 4.2 Variation in daily values of minimum temperature

4.3.2 Maximum and minimum relative humidity

The observation of maximum and minimum relative humidity data showed that the maximum relative humidity varies from 98.00 to 22.00 %.Similarly, the minimum relative humidity varies from 86.00 to 8.00 % throughout the crop growth period. The variation in daily maximum and minimum relative humidity over the crop growth period is shown in Figure 4.3 and Figure 4.4, respectively. The average maximum and minimum relative humidity during cucumber growth period was 52.0^{0}C and 22.5 ^{0}C respectively.

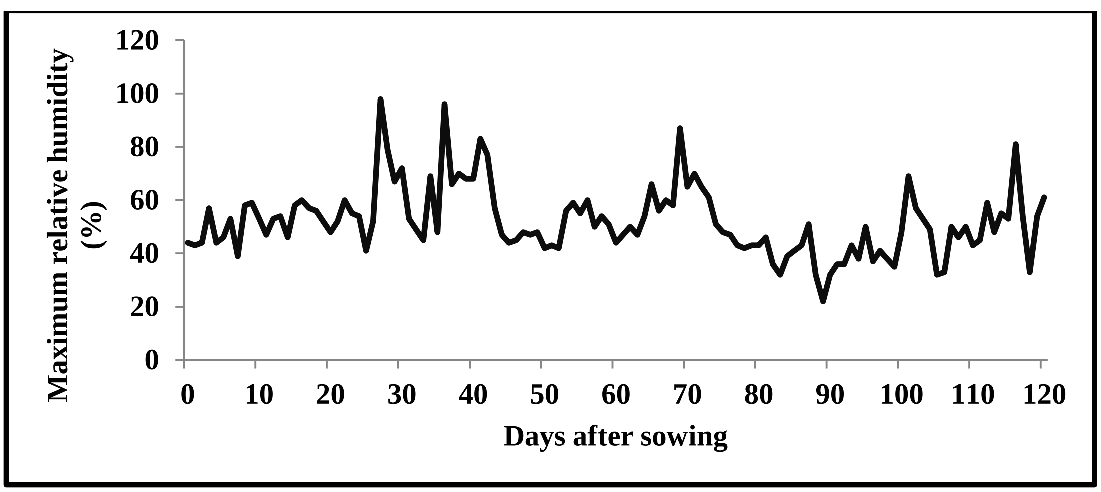

Figure 4.3 Variation in daily values of maximum relative humidity

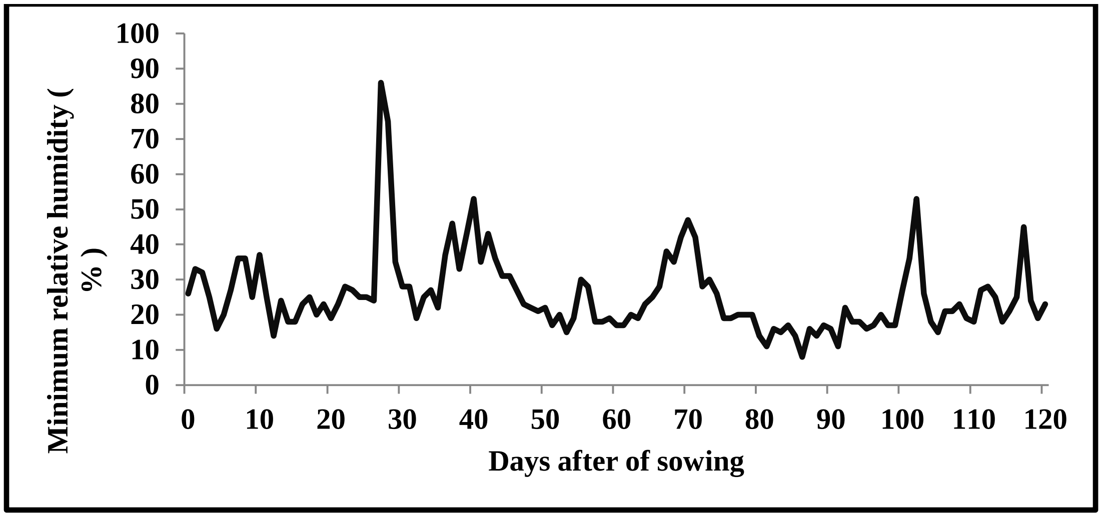

Figure 4.4 Variation in daily values of minimum relative humidity

4.3.3 Actual sunshine hour

The observation of actual sunshine hour data showed that the highest value of actual sunshine hours is 12.00 hrs whereas the lowest value of actual sunshine hours is 1.00hrs during the crop growth period. The variation in daily actual sunshine hours over the crop growth period of cucumber is shown in Figure 4.5.

The average actual sunshine hour during cucumber growth period was 9.16 hrs.

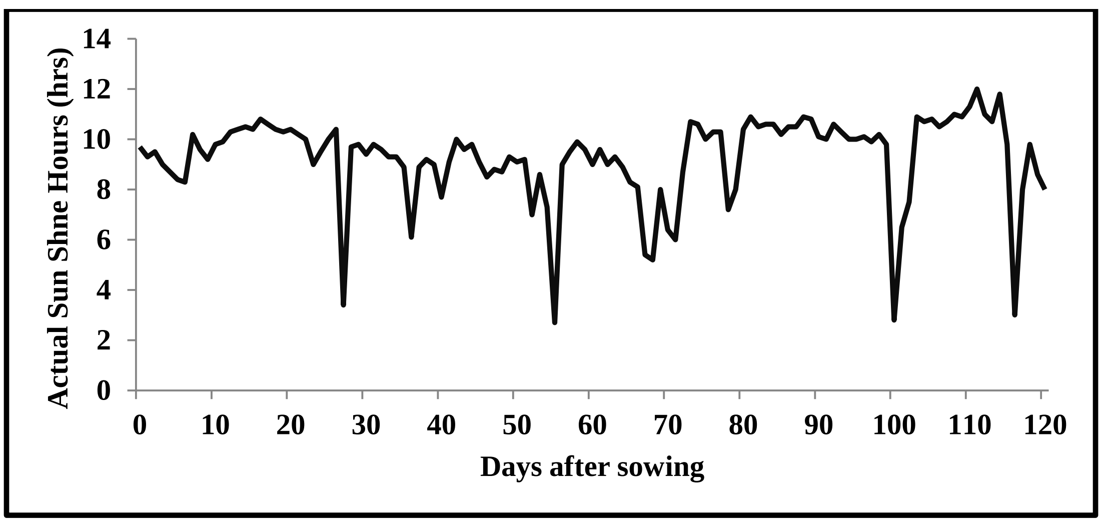

Figure 4.5 Variation in daily values of actual sunshine hours

4.3.4 Wind speed

The observation of wind speed data showed that the highest value of wind speed is 9.5 km hr^{-1} whereas the lowest value of wind speed is 0.20 km hr^{-1} over the crop growth period. The variation in daily wind speed values over the growth period of cucumber is shown in Figure 4.6.

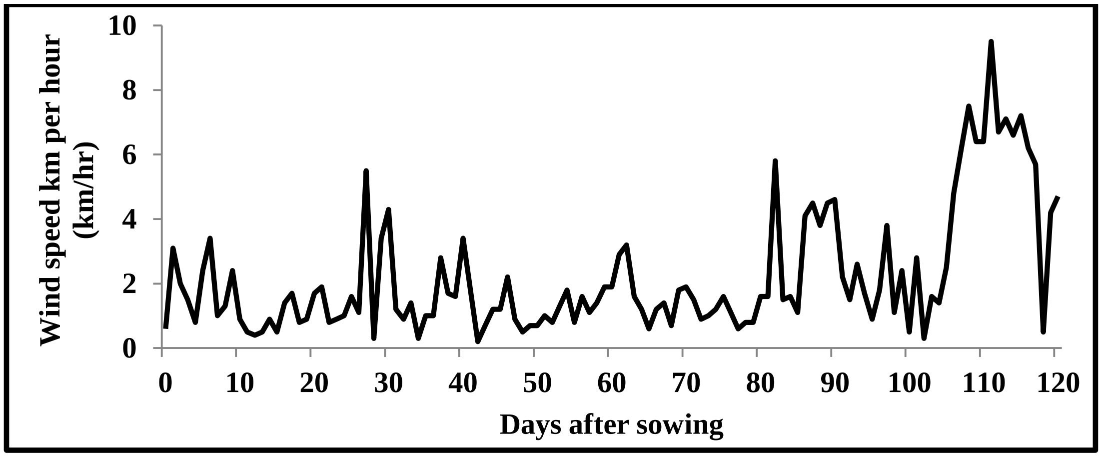

Figure 4.6 Variation in daily values of wind speed

4.3.5 Reference evapotranspiration

The reference evapotranspiration estimated using FAO Penman-Monteith method showed that the maximum reference evapotranspiration over the crop growth period is 8.69 mm day^{-1} while the minimum value is 1.57 $mmday^{-1}$. Higher value of ETo during the latter crop growth period is due to higher temperature, low relative humidity, higher sunshine hours and greater wind speed. The variation in daily reference evapotranspiration values over the growth period of cucumber is shown in Figure 4.7.

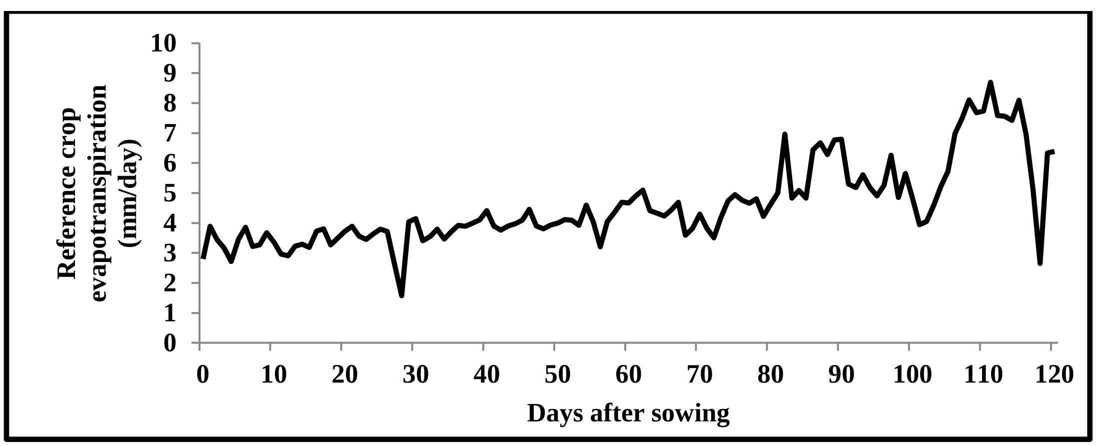

Figure 4.7 Variation in daily values of reference evapotranspiration

4.3.6 Daily crop evapotranspiration

The observation of crop evapotranspiration data shows that the maximum crop evapotranspiration over the crop growth period is 7.73 mm day^{-1} while the minimum value is 1.00 mm day^{-1}. The total crop evapotranspiration was computed by considering daily reference evapotranspiration and it was found 463.26 mm. Higher the value of ETc during the latter crop growth period is due to higher temperature, low relative humidity, higher sunshine hours and greater wind speed. The daily values of crop coefficient, reference evapotranspiration and crop evapotranspiration is shown in Appendix – D. The variation in daily crop evapotranspiration values over the growth period of cucumber is shown in Figure 4.8.

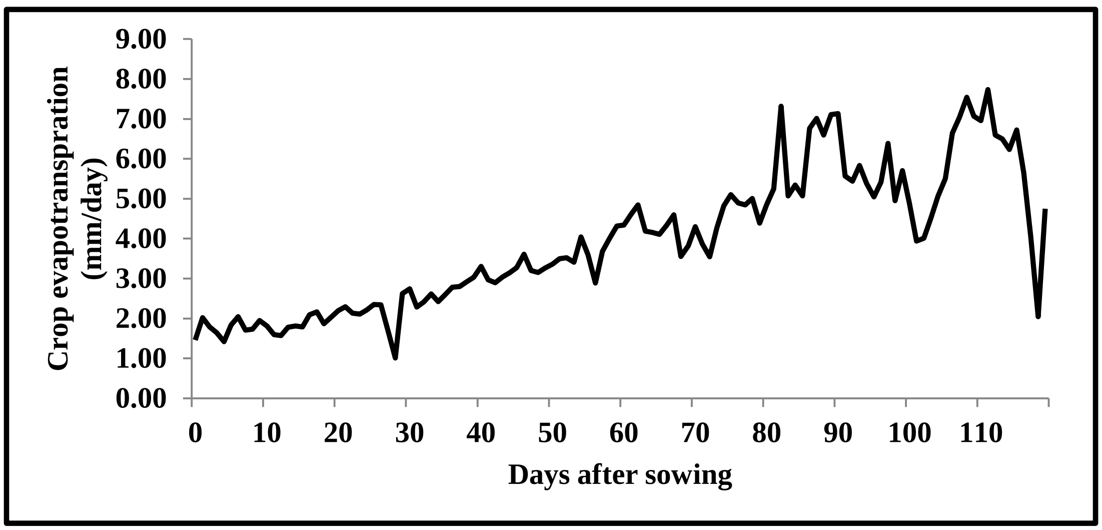

Figure 4.8 Variation in daily values of crop evapotranspiration

4.4 Climatological data from Stevenson's screen

A Stevenson's screen or Instrument shelter is a meteorological screen to shield instruments against precipitation and direct heat radiation from outside sources, while still allowing air to circulate freely around them. It forms part of a standard weather station. The climatic data viz. temperature (maximum and minimum), dry bulb temperature and wet bulb temperature, relative humidity and vapour pressure that influence growth and development of cucumber were obtained in daily basis from the Stevenson's screen installed in shade nets and the open field at the Instructional farm of Department of Irrigation and Drainage Engineering, Dr. AnnasahebShinde College of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri throughout the season and presented in Appendix – E. The climatological data in different shade net is discussed in subsequent section.

4.4.1 Green-white shade net with 35 % shading

4.4.1.1 Maximum and minimum temperature

The observation of maximum and minimum temperature shows that the maximum temperature varies from 46.1 to 37.2 ^{0}C and minimum temperature varies from 39.4 to 31.1 ^{0}C, respectively. The variation of daily maximum and minimum temperature values over the crop growth period is shown in Figure 4.9 and Figure 4.10, respectively.

Maximum temperature 46.1^{o} c was recorded in 21nd metrological week and minimum temperature 12.8^{o} c was recorded in 20th metrological week. The seasonal average temperature in Green-white shade net with 35 % shading was 38.55^{o}c. The weekly maximum, minimum and average temperature values in green-white shade net with 35 % shading are presented in Table E1 of Appendix –E.

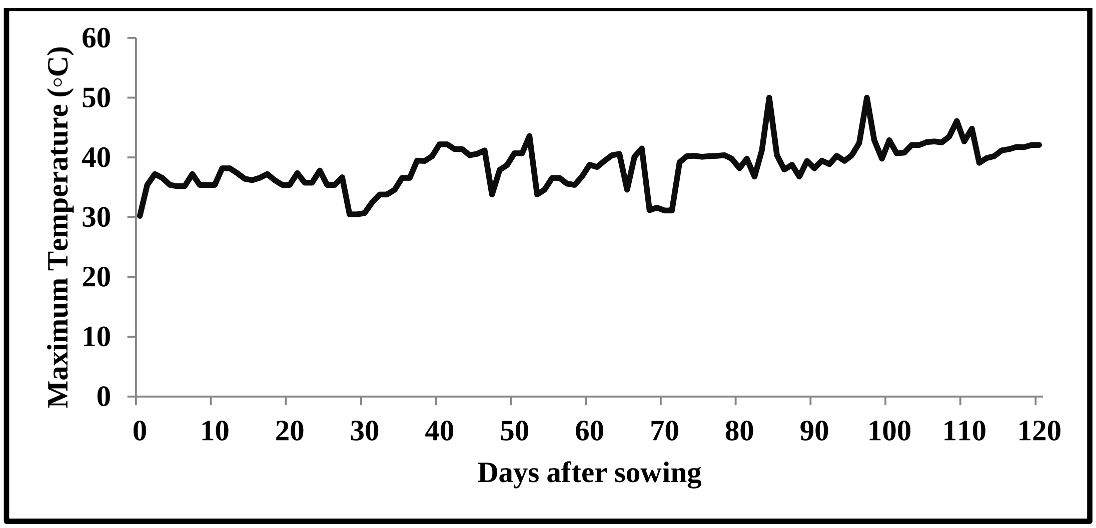

Figure 4.9 Variation in daily values of maximum temperature in green-white shade net with 35% shading

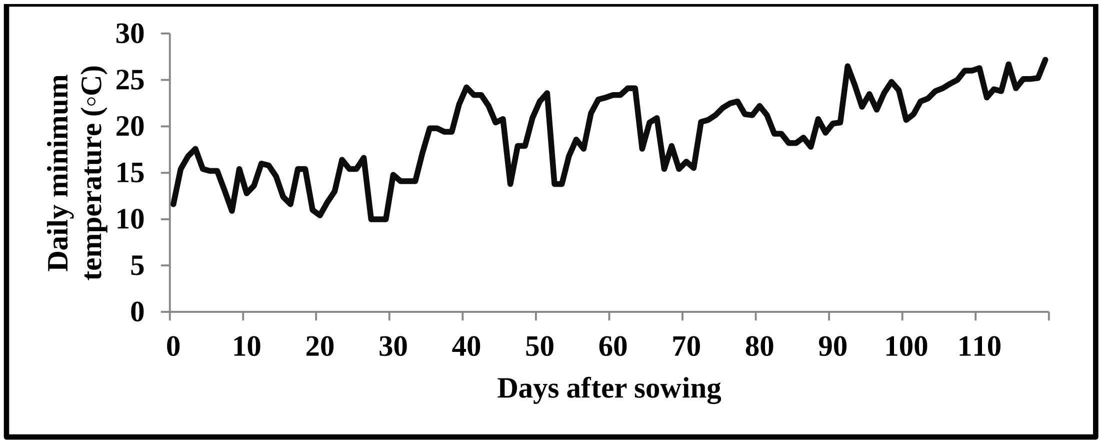

Figure 4.10 Variation in daily values of minimum temperature in green-white shade net with 35% shading

4.4.1.2 Maximum and minimum relative humidity

The observations of relative humidity data showed that the maximum relative humidity varies from 98.50 to 61.86 % Similarly, the minimum relative humidity varies from 59.00 to 24.43 % in the throughout the crop growth period. The variation in daily relative humidity values over the crop growth period is shown in Figure 4.11 and Figure 4.12, respectively. Maximum relative humidity 98.50 % was recorded in 20th metrological week and minimum relative humidity 24.43 % was recorded in 8th metrological week. The seasonal average relative humidity in green-white shade net with 35 % shading was 61.5 %. The weekly maximum, minimum and relative humidity values in green-white shade net with 35 % shading are presented in Table E1 of Appendix –E.

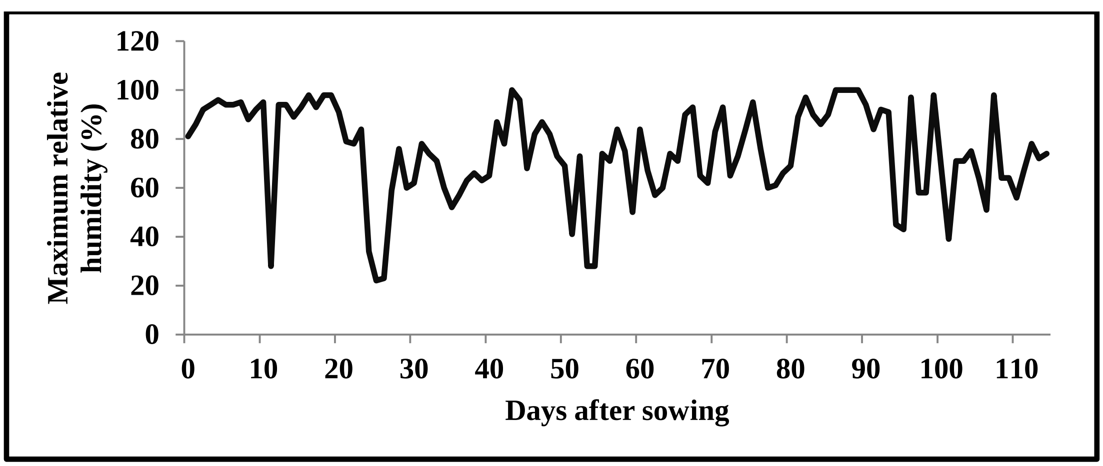

Figure 4.11 Variation in maximum daily values of relative humidity in green-white shade net with 35% shading

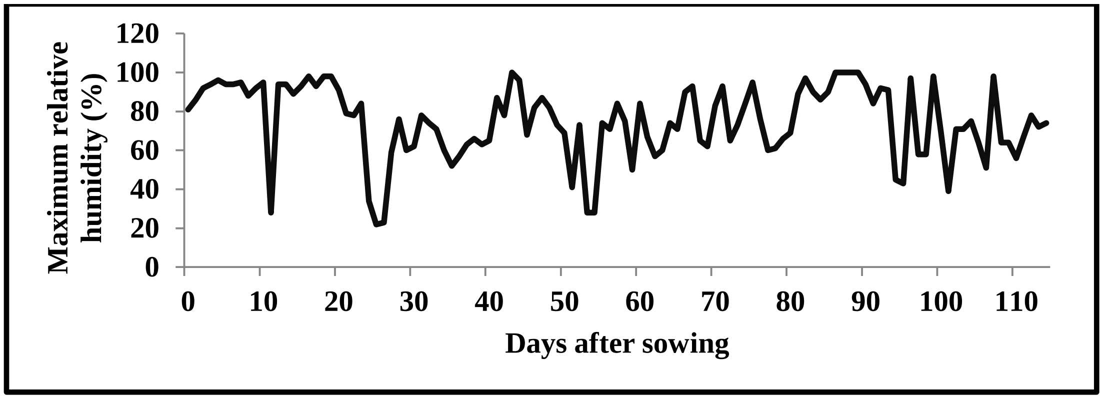

Figure 4.12 Variation in minimum daily values of relative humidity green-white shade net with 35% shading

4.4.2 Green-white shade net with 50 % shading

4.4.2.1 Maximum and minimum temperature

The observation of maximum and minimum temperature shows that the maximum temperature varies from 43.1 to 31.3 ^{0}C and minimum temperature varies from 24.5 to 11.4 ^{0}C, respectively. The variation of daily maximum and minimum temperature values over the crop growth period is shown in Figure 4.13 and Figure 4.14, respectively.

Maximum temperature 43.1^{o} c was recorded in 20th metrological week and minimum temperature 11.4^{o} c was recorded in 9th metrological week. The seasonal average temperature in green-white shade net with 50 % shading was 28.0^{o}c. The weekly maximum, minimum and average temperature values in green-white shade net with 35 % shading are presented in Table E2 of Appendix –E.

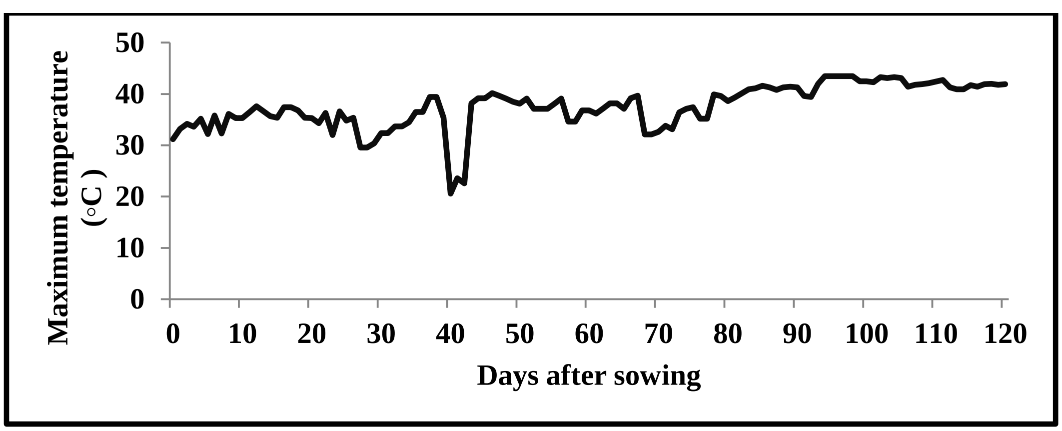

Figure 4.13 Variation in daily values of maximum temperature green-white shade net with 50% shading

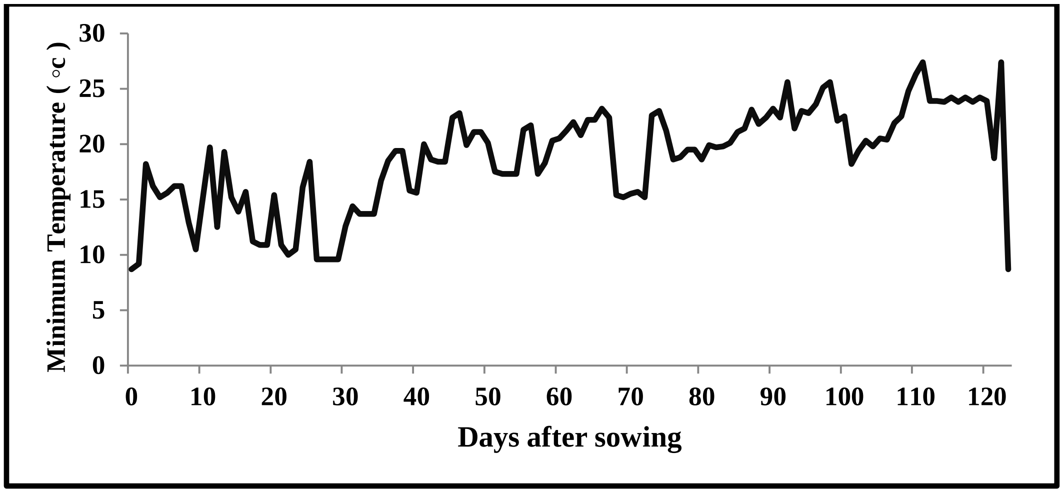

Figure 4.14 Variation in daily values of minimum temperature green-white shade net with 50% shading

4.4.2.2 Maximum and minimum relative humidity

The observations of relative humidity data showed that the maximum relative humidity varies from 95.43 to 34 % Similarly, the minimum relative humidity varies from 69.71 to 27.36 % in the throughout the crop growth period. The variation in daily relative humidity values over the crop growth period is shown in Figure 4.15 and Figure 4.16, respectively. Maximum relative humidity 95.43 % was recorded in 8^{th} metrological week and minimum relative humidity 27.36 % was recorded in 8^{th} metrological week. The seasonal average relative humidity in green-white shade net with 50 % shading was 56.30 %. The weekly maximum, minimum and relative humidity values in green-white shade net with 35 % shading are presented in Table of Appendix –E.

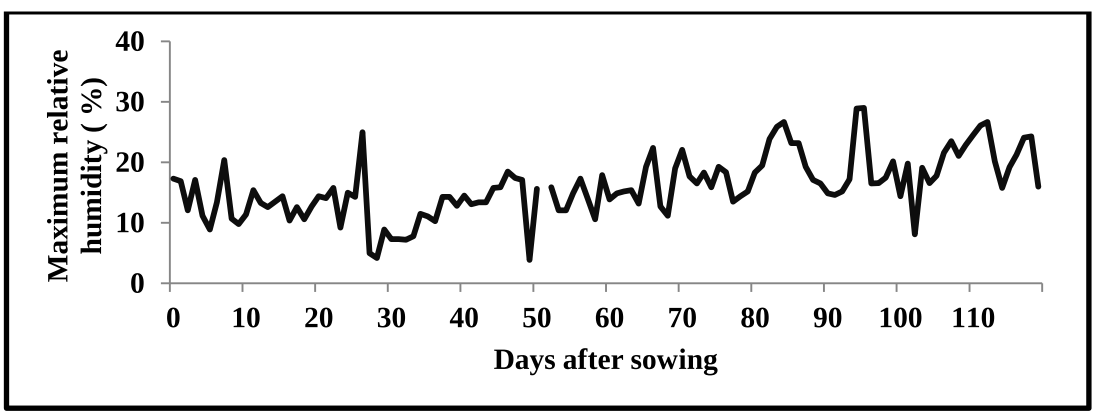

Figure 4.15 Variation in daily values of maximum relative humidity in green-white shade net with 50% shading

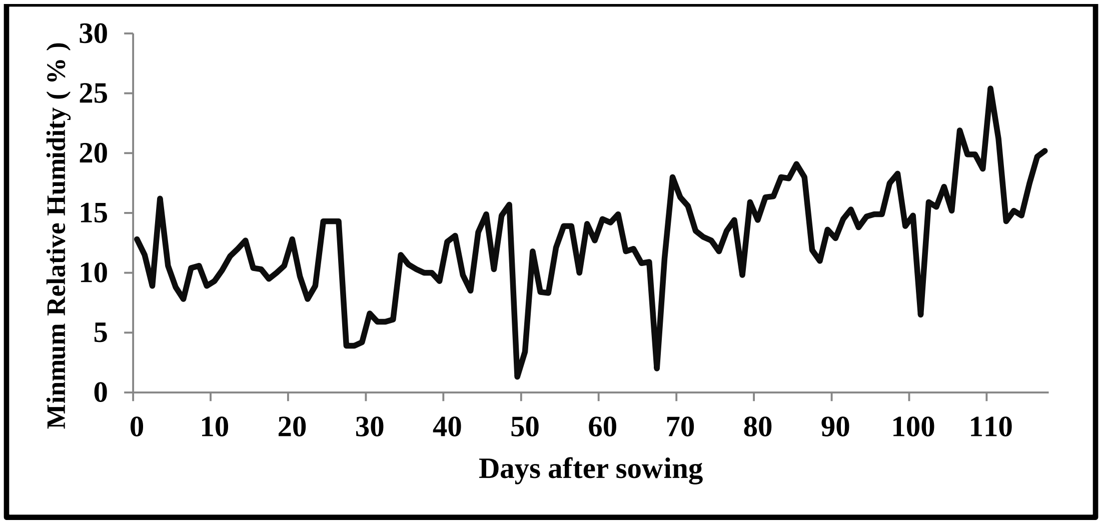

Figure 4.16 Variation in daily values of minimum relative humidity in green-white shade net with 50% shading

4.4.3 Green-white shade net with 75 % shading

4.4.3.1 Maximum and minimum temperature

The observation of maximum and minimum temperature shows that the maximum temperature varies from 9.4 to 31.4 ^{0}C and minimum temperature varies from 7.4 to 19.3^{0}C, respectively. The variation of daily maximum and minimum temperature values over the crop growth period is shown in Figure 4.17 and Figure 4.18, respectively.

Maximum temperature 31.4^{o} c was recorded in 9th metrological week and minimum temperature 7.4^{o} c was recorded in 12th metrological week. The seasonal average temperature in green-white shade net with 50 % shading was 22.4^{o}c. The weekly maximum, minimum and average temperature values in green-white shade net with 35 % shading are presented in in Table of Appendix –E.

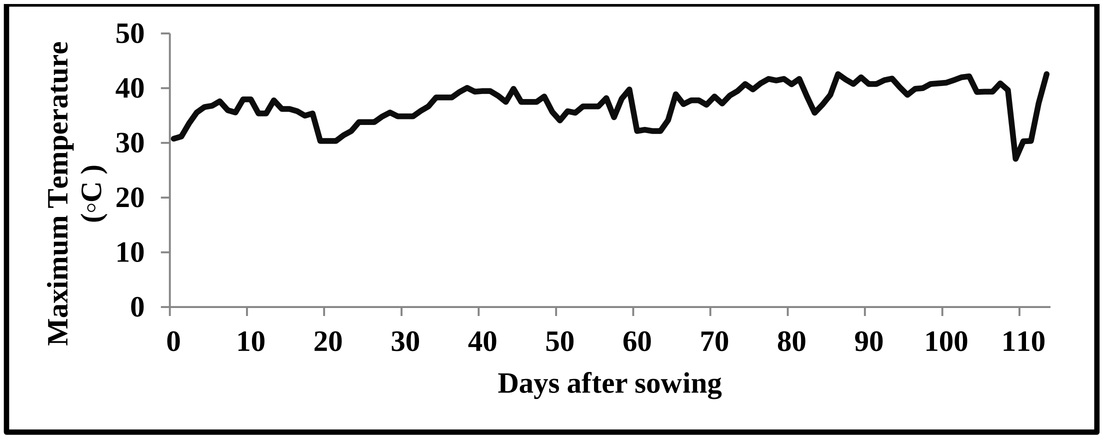

Figure 4.17 Variation in daily values of maximum temperature in green-white shade net with 75% shading

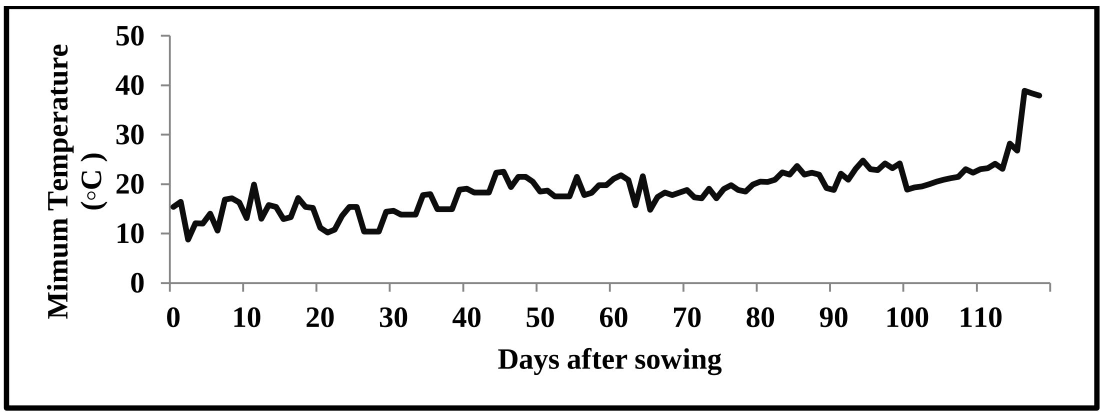

Figure 4.18 Variation in daily values of minimum temperature in green-white shade net with 75% shading

4.4.3.2 Relative humidity

The observations of relative humidity data showed that the maximum relative humidity varies from 90.67 to 63.14 % Similarly, the minimum relative humidity varies from 73.67 to 21.71 % in the throughout the crop growth period. The variation in daily relative humidity values over the crop growth period is shown in Figure 4.19 and Figure 4.20, respectively. Maximum relative humidity 90.67 % was recorded in 7th metrological week and minimum relative humidity 21.71 % was recorded in 10th metrological week. The seasonal average relative humidity in green-white shade net with 75 % shading was 46.43 %. The weekly maximum, minimum and relative humidity values in green-white shade net with 75 % shading are presented in Table E3 of Appendix –E

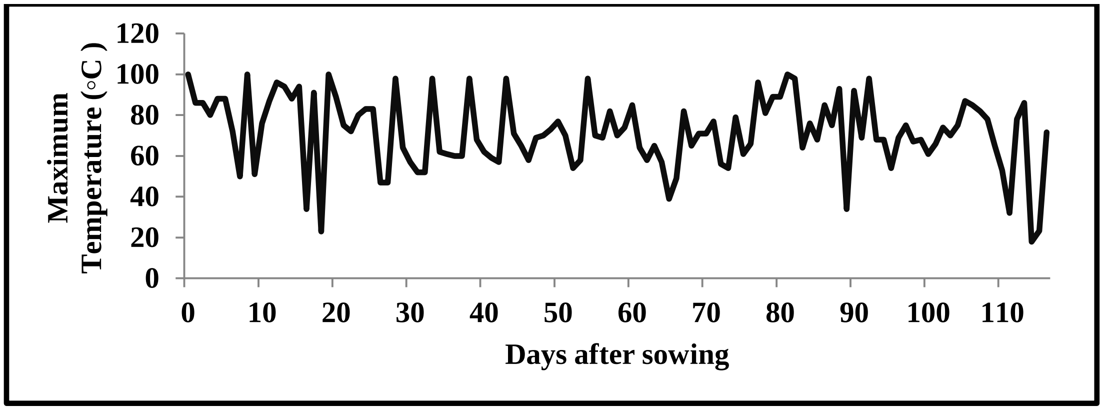

Figure 4.19 Variation in daily values of maximum relative Humidity in green-white shade net with 75 % shading

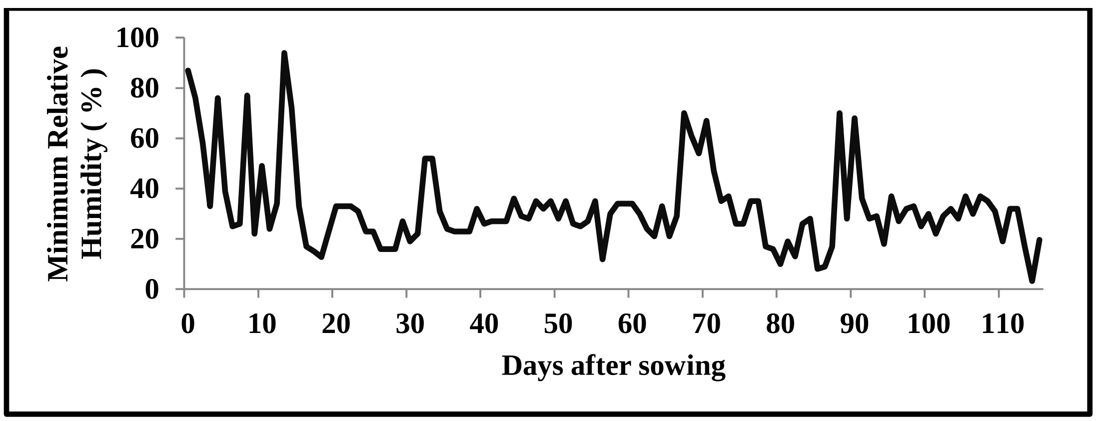

Figure 4.20 Variation in daily values of minimum relative Humidity in green-white shade net with 75 % shading

4.4.4 Red shade net with 50 % shading

4.4.4.1 Maximum and minimum temperature

The observation of maximum and minimum temperature shows that the maximum temperature varies from 32.2 to 42.1 ^{0}C and minimum temperature varies from 11.2 to 28.8^{0}C, respectively. The variation of daily maximum and minimum temperature values over the crop growth period is shown in Figure 4.21 and Figure 4.22, respectively.

Maximum temperature 42.1^{o} c was recorded in 23th metrological week and minimum temperature 11.2^{o} c was recorded in 9th metrological week. The seasonal average temperature in red shade net with 50 % shading was 27.2^{o}c. The weekly maximum, minimum and average temperature values in red shade net with 50 % shading are presented in Table E4 of Appendix –E.

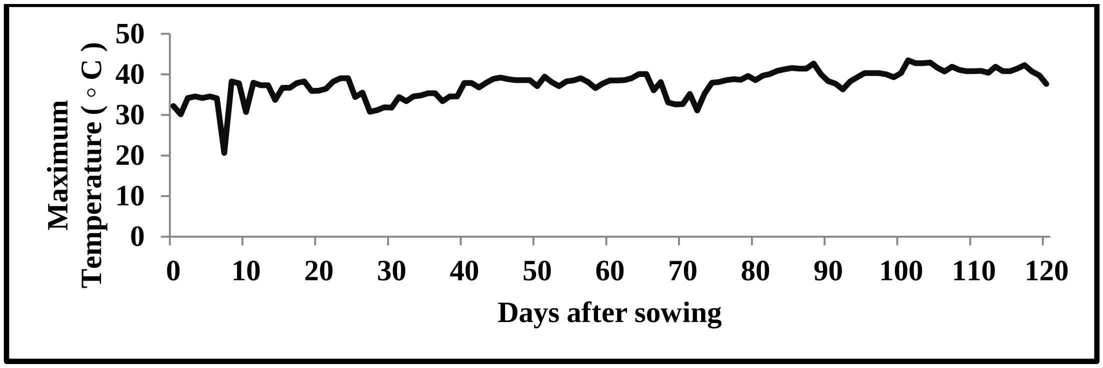

Figure 4.21 Variation in daily values of maximum temperature in red shade net with 50% shading

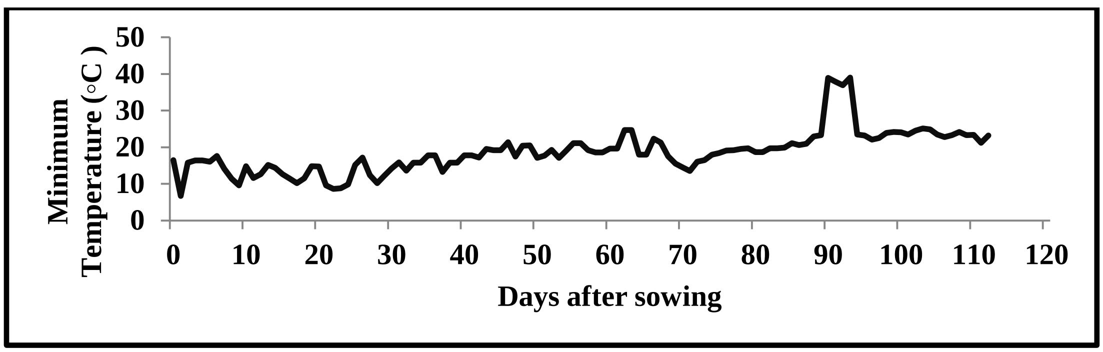

Figure 4.22 Variation in daily values of minimum temperature red shade net with 50% shading

4.4.4.2 Relative humidity

The observations of relative humidity data showed that the maximum relative humidity varies from 92.3 to 59.9 % Similarly, the minimum relative humidity varies from 75.0 to 23.9 % in the throughout the crop growth period. The variation in daily relative humidity values over the crop growth period is shown in Figure 4.23 and Figure 4.24, respectively. Maximum relative humidity 92.3 % was recorded in 18th metrological week and minimum relative humidity 23.9 % was recorded in 10th metrological week. The seasonal average relative humidity red shade net with 50 % shading was 63.0 %. The weekly maximum, minimum and relative humidity values in red shade net with 50 % shading are presented in Table E4 of Appendix –E.

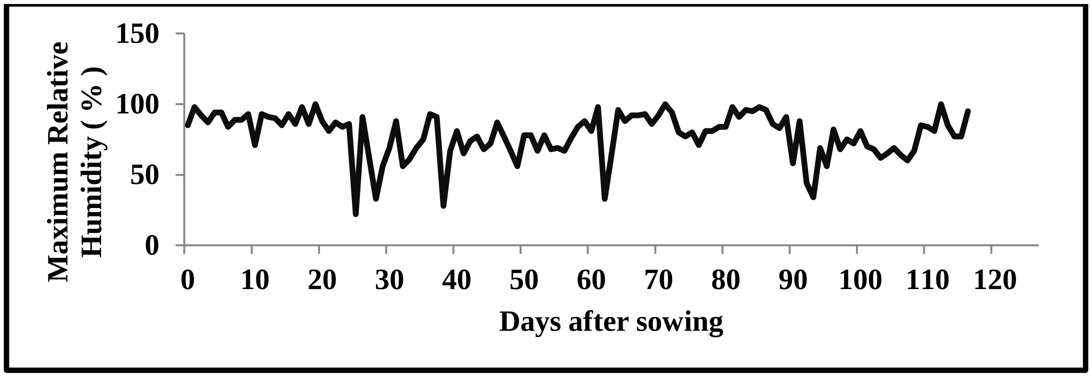

Figure 4.23 Variation in daily maximum relative humidity red shade net with 50% shading

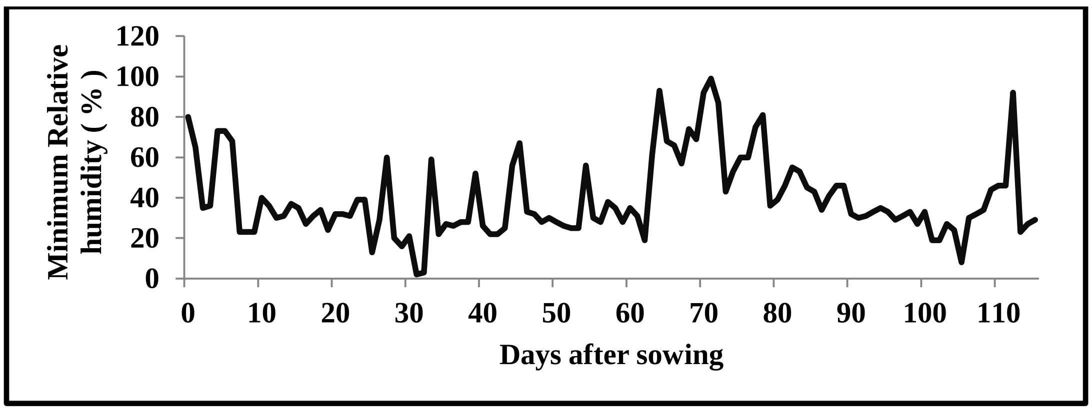

Figure 4.24 Variation in daily minimum relative humidity red shade net with 50% shading

4.4.5 Open field

4.4.5.1 Maximum and minimum temperature

The observation of maximum and minimum temperature shows that the maximum temperature varies from 44.7 to 33.2 ^{0}C and minimum temperature varies from 29.4 to 11.1 ^{0}C, respectively. The variation of daily maximum and minimum temperature values over the crop growth period is shown in Figure 4.25 and Figure 4.26, respectively.

Maximum temperature 44.7^o c was recorded in 13th metrological week and minimum temperature 11.1^o c was recorded in 7th metrological week. The seasonal average temperature in open field was 25.4 ^{o}c. The weekly maximum, minimum and average temperature values in open field (Control) are presented in Table E5 of Appendix –E.

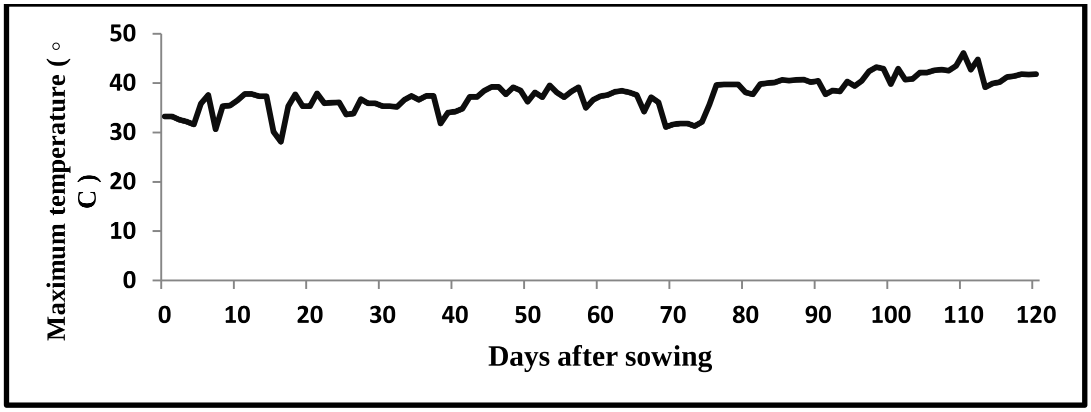

Figure 4.25 Variation in daily maximum temperature in open field (Control treatment)

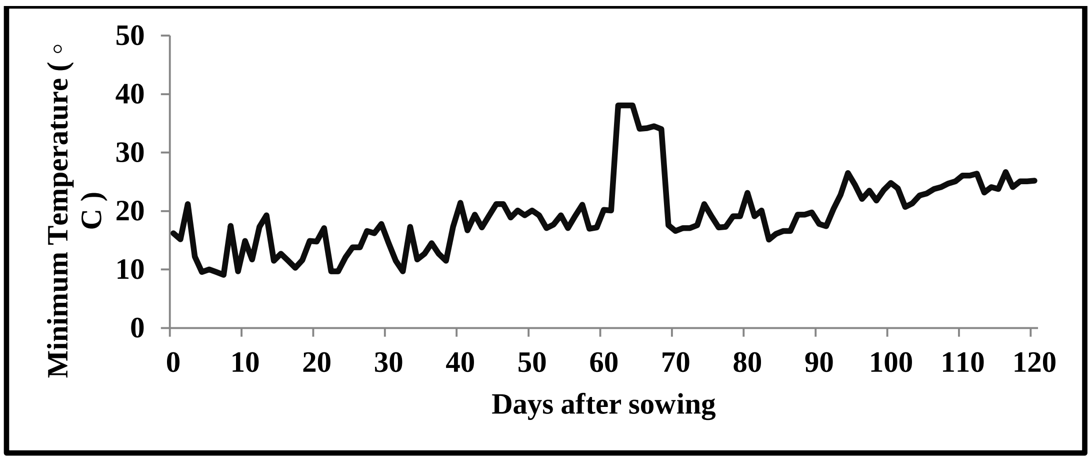

Figure 4.26 Variation in daily maximum temperature in open field (Control treatment)

4.4.5.2 Relative humidity

The observations of relative humidity data showed that the maximum relative humidity varies from 22.56 to 96.71 % Similarly, the minimum relative humidity varies from 84.67 to 13.0 % in the throughout the crop growth period. The variation in daily relative humidity values over the crop growth period is shown in Figure 4.27 and Figure 4.28, respectively. Maximum relative humidity 84.67 % was recorded in 6^{th} metrological week and minimum relative humidity 13.0 % was recorded in 15^{th} metrological week. The seasonal average relative humidity in open field (Control) was 89.33 %. The weekly maximum, minimum and relative humidity values in open field (Control) are presented in Table E5 of Appendix –E.

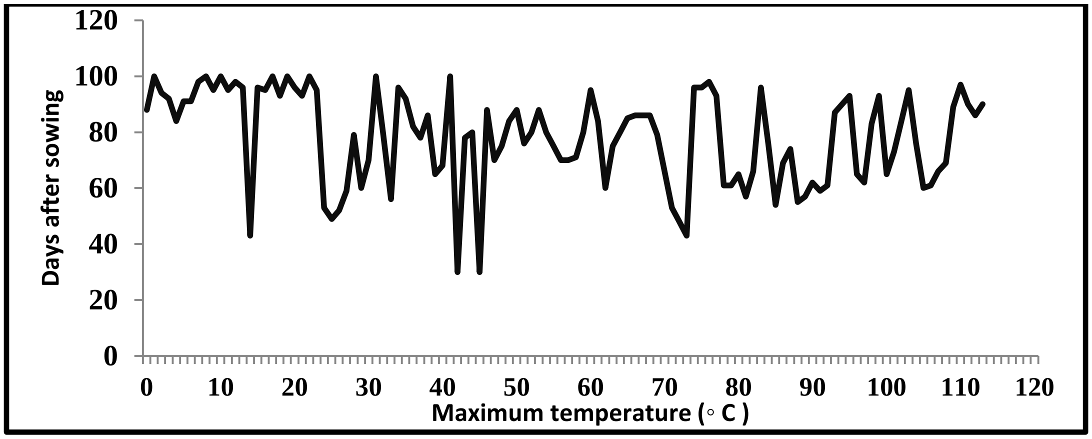

Figure 4.27 Variation in daily maximum relative humidity in open field (Control treatment)

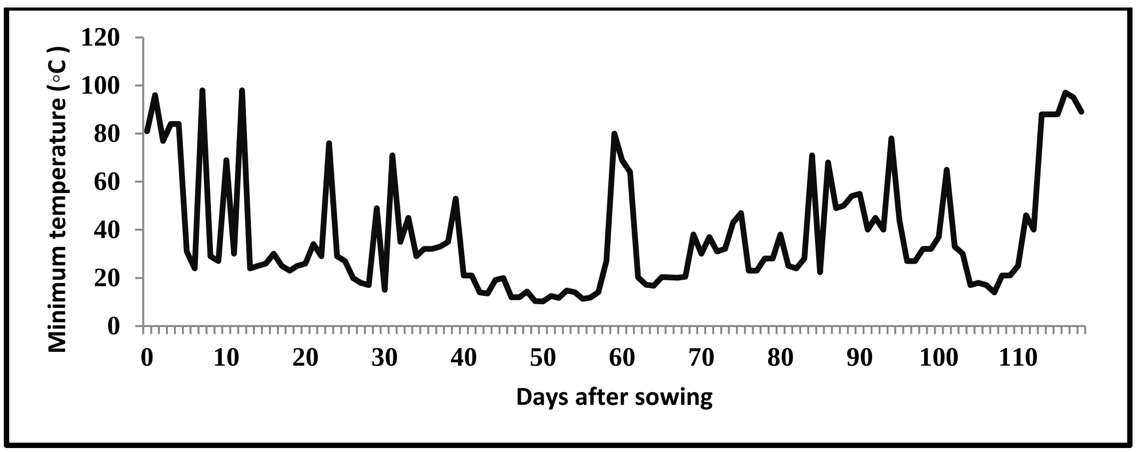

Figure 4.28 Variation in daily maximum relative humidity in open field (Control treatment)

4.6 Water requirement

The net water applied during the growth period of cucumber crop is shown in Appendix – F. Variation in net daily water requirement over the growth period of cucumber is shown in Figure 4.29.

Seasonal water requirement of cucumber crop for treatment T1/T2 was 602.80 mm, for treatment T3/T4 it was 493.89 mm, for treatment T5/T6 it was 400.16 mm and 310.10 mm for treatment T7/T8 during the season .The Figure 4.29 reveals that, the net daily water requirement for cucumber crop for treatment T1/T2 varies from 1.9 mm to 8.0 mm, for treatment T3/T4 it varies from 1.5 mm to 6.7 mm, for treatment T5/T6 varies from 1.2 mm to 5.3 mm and for treatment T7/T8 it varies from 0.9 mm to 4.0 mm during the season. The higher water requirement in later growth period of cucumber may be due to higher temperature, sunshine hours and wind speed.

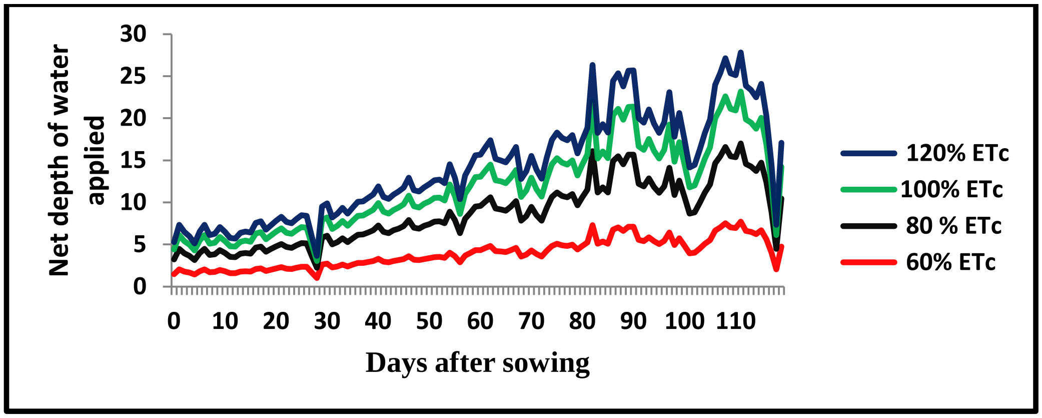

Figure 4.29 Variation in net daily water requirement

4.7 Average discharge and field emission uniformity (EU)

The average emission uniformity and discharge were computed by adopting the procedure as described in section 3.2 for individual plot. The average discharge and emission uniformity is reported in Tables 4.4 and 4.5.

Table 4.4 Average discharge of emitters

Shade net	Average discharge (lit hr^{-1})				Average
S_1	2.14	2.10	2.15	2.15	2.13
S_2	2.10	2.20	2.13	2.14	2.14
S_3	2.11	2.12	2.10	2.09	2.11
S_4	2.13	2.09	2.19	2.14	2.16
S_5	2.30	2.37	2.30	2.25	2.30

Table 4.5 Emission uniformity of irrigation system

Particular Treatment	Emission Uniformity (%)				
	S_1	S_2	S_3	S_4	S_5
T_1/T_2	93.36	94.25	93.12	92.95	92.31
T_3/T_4	95.21	92.16	93.21	94.26	94.15
T_5/T_6	90.4	93.65	93.82	91.32	92.77
T_7/T_8	91	94.57	94.56	91.85	90.81
Average	**92.49**	**93.66**	**93.68**	**92.60**	**92.51**

Table 4.5 reveals that the installed drip system had excellent emission uniformity resulting in uniform distribution of water and injected fertilizer to the cucumber crop.

4.8 Water applied

The emission uniformity of drip system varies for different treatment and hence the gross depth of water applied to cucumber crop in different treatment varies.

4.8.1 Green-white shade net with 35 % shading

The gross depth of water applied throughout growth period of cucumber crop for treatments T1/T2, T3/T4, T5/T6 and T7/T8 were 602.80mm, 493.89 mm, 400.16 mm and 310.01 mm respectively for green-white shade net with 35 % shading. The variation in gross depth of water applied during the growth period of cucumber is graphically depicted in Figure 4.30

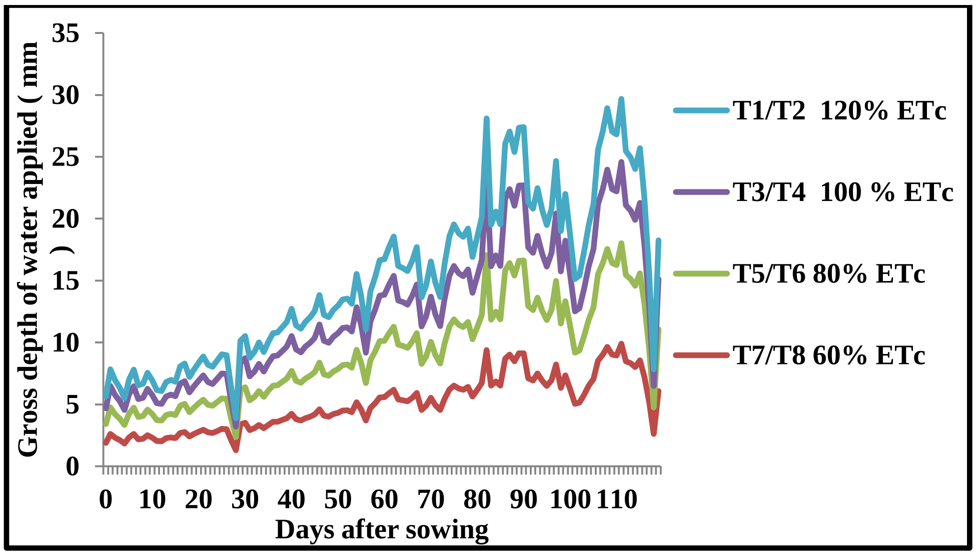

Figure 4.30 Variation in gross daily water requirement 35% green-white shade net

4.8.2 Green-white shade net with 50 % shading

The gross depth of water applied throughout growth period of cucumber crop for treatments T1/T2, T3/T4, T5/T6 and T7/T8 were 600.23 mm, 510.18 mm, 401.65 mm and 300.11 mm respectively for green-white shade net with 50 % shading. Variation in daily values of gross water applied depicted in Figure 4.31.

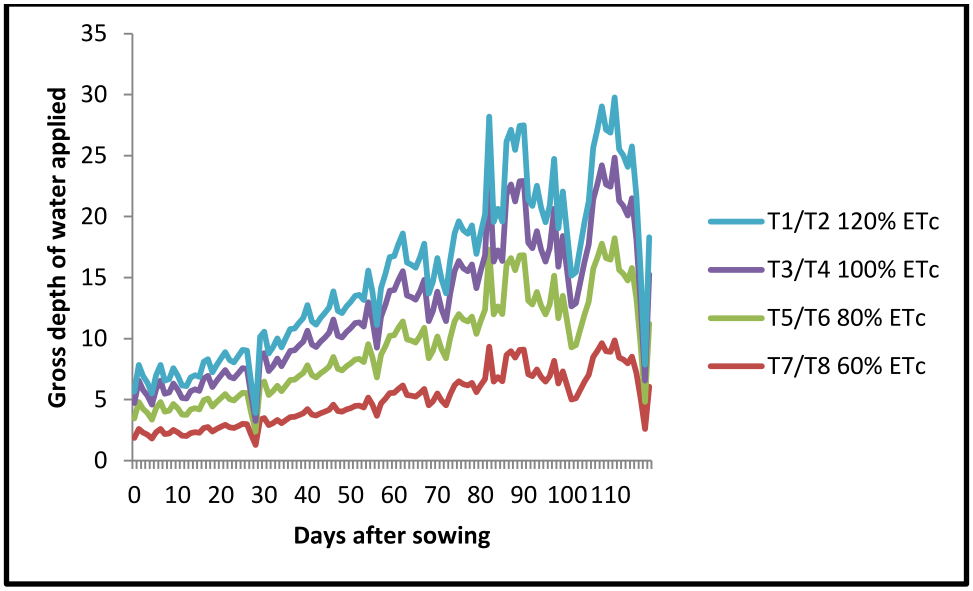

Figure 4.31 Variation in gross daily water requirement 50% green-white shade net

4.8.3 Green-white shade net with 75 % shading

The gross depth of water applied throughout growth period of cucumber crop for treatments T1/T2, T3/T4, T5/T6 and T7/T8 were 605.97 mm, 504.43 mm, 481.10 mm, 358.10 mm respectively for green-white shade net with 75 % shading. Variation in daily values of gross water applied depicted in Figure 4.32.

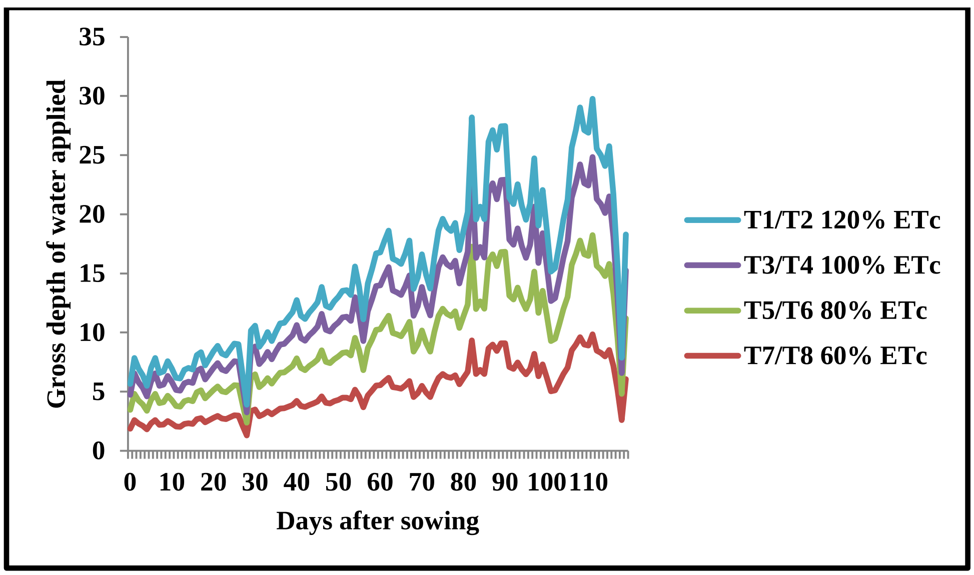

Figure 4.32 Variation in gross daily water requirement 75% green white shade net

4.8.4 Red shade net with 50 % shading

The gross depth of water applied throughout growth period of cucumber crop for treatments T1/T2, T3/T4, T5/T6 and T7/T8 were 611 mm, 493 mm, 413 mm and 307 mm respectively for Red shade net with 50 % shading. Variation in daily values of gross water applied depicted in Figure 4.33.

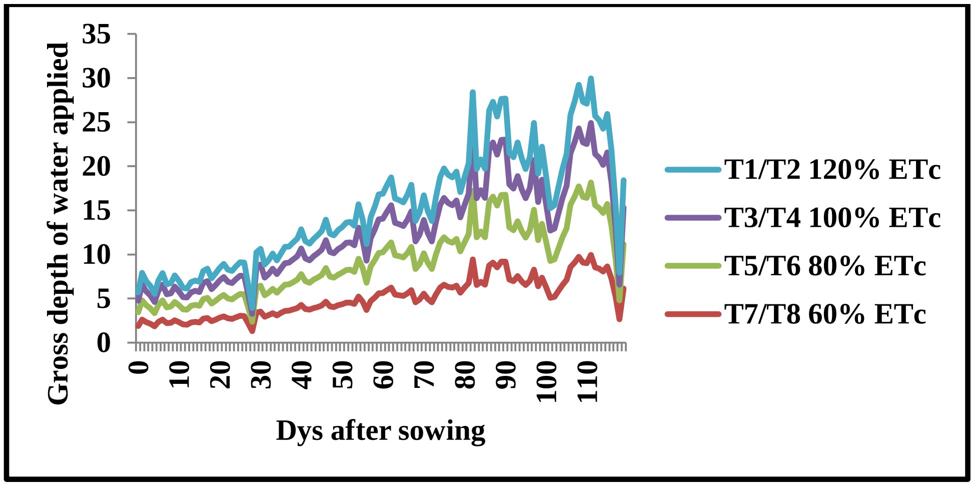

Figure 4.33 Variation in gross daily water requirement 50% red shade net

4.8.5 Open field condition

The gross depth of water applied throughout growth period of cucumber crop for treatments T1/T2, T3/T4, T5/T6 and T7/T8 were 611.22 mm, 499.39 mm, 405.46 mm and 313.45 mm respectively for open field condition. Variation in daily values of gross water applied depicted in Figure 4.34.

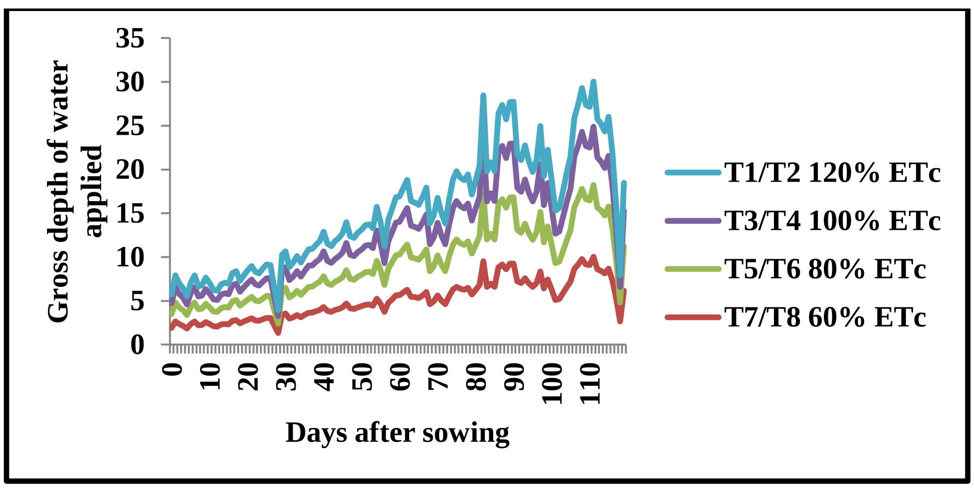

Figure 4.34 Variation in gross daily water requirement open field

4.9 Biometric observations

The biometric observations recorded for cucumber crop grown under different growing environment and agro technique treatments were statistically analyzed and the results are presented in this section.

4.8.1 Days to 50 % flowering

The number of days taken for 50 percent flowering was influenced by shade net color, shading percentage and irrigation levels as shown in Table 4.6 to 4.7 and depicted in Figure 4.35 and 4.3.6. Plate 4.1 and 4.2 shows the flowering and fruit setting stage of cucumber, respectively.

Plate 4.1 Flowering stage of Cucumber crop

Plate 4.2 Fruit setting of Cucumber crop

Effect of growing environment

The number of days required for 50 percent flowering was significantly influenced by growing environment as shown in Table 4.6 and depicted by Figure 4.33.

Table 4.6, reveals that, days required for 50% flowering in treatment S_1 was 34.17, 39.00 in treatment S_2, 43.67 in treatment S_3 and 33.42 in treatment S_4. The growing environment had influence on days to 50% flowering of cucumber crop both in open field and shade net house condition. The cucumber crop grown under shade house condition took less number of days (33.42) for 50% flowering as compared to open field (47.17). This might be due to improper growth in open field due to adverse climatic condition.

Table 4.6 Effect of growing environment on days to 50 % flowering

Treatment	Days to 50 % flowering
S1 (Green-white net 35% shading)	34.17^{d}
S2(Green-white net 50% shading)	39.00^{c}
S3(Green-white net 75% shading)	43.67^{b}
S4(Red net 50 % shading)	33.42^{d}
S5(open/ control treatment)	47.17^{a}
S. E. ±	0.17
C.D. at 5%	0.55

Note: Higher superscript denotes best treatment

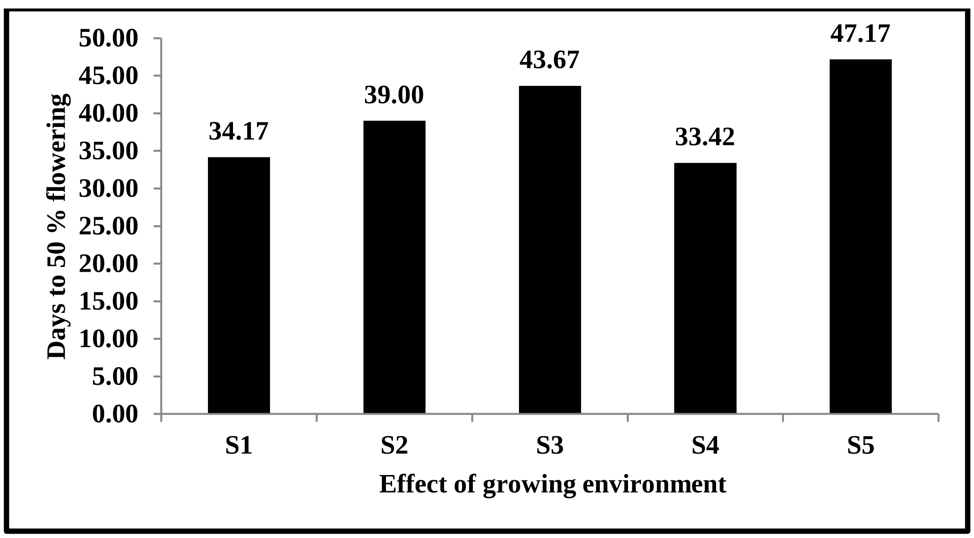

Figure 4.35 Effect of growing environment on days to 50 % flowering

Among the different shade nets, the Red shade net exhibited significantly early flowering which was at par with green-white shade net with 35 % shading and followed by green-white shade net with 50 % shading. The period for 50 % flowering for green-white shade net with 75 % shading was highest among the green-white shade nets but lesser than open field condition.

4.8.1.2 Effect of agro technique

The number of days required for 50 % flowering was significantly influenced by different agro technique treatments as shown in Table 4.7 and depicted in Figure 4.36.

The minimum days required for 50 % flowering were observed in treatment T_1 (37.73) which was followed with treatment T_3 (37.73), T_7 (38.60) and T_5 (38.80). The maximum days required for 50% flowering in treatment T_6 (41.747). Early flowering in mulched treatment (T1, T3, T5 and T7) as compared to the corresponding non-mulched treatments may be due to higher soil temperature and better environmental conditions for accelerated growth and development of the crop.

Table 4.7 Effect of agrotechnique on days to 50 % flowering

Treatment	Days to 50 % flowering
T1(120% with plastic mulch)	37.73[a]
T2(120% ETc without plastic mulch)	40.20[b]
T3(100% ETc with plastic mulch)	37.73[a]
T4(100% ETc without plastic mulch)	40.93[b]
T5(80% ETc with plastic mulch)	38.80[a]
T6(80% ETc without plastic mulch)	41.47[b]
T7(60% ETc with plastic mulch)	38.60[a]
T8(60% ETc without plastic mulch)	40.40[b]
S. E. ±	0.31
C.D. at 5%	0.86

Note: Higher superscript denotes best treatment.

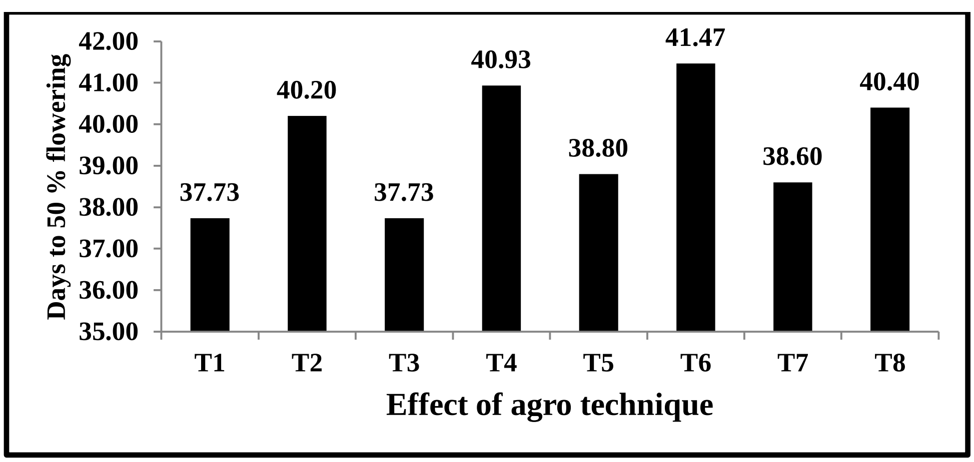

Figure 4.36 Effect of agrotechnique on days to 50 % flowering

4.8.1.3 Effect of interaction

The number of days required for 50 % flowering was significantly influenced by effect of growing environment and agro technique as shown in Table 4.8. The minimum days required for 50 % flowering was reported in treatment S_4T_1 (31.67) which were followed by treatment S_4T_3 (31.33), S_2T_3 (33.67), S_4T_8 (32.33) and S_1T_7 (34.67) and superior to all other treatments. Maximum days required for 50 % flowering was reported in control treatment S_5T_5 (48.33).Maximum days required for 50 % flowering was observed in control treatment.

Table 4.8 Two way table of days to 50 % flowering

Treatment	S1	S2	S3	S4	S5	Mean
T1(120% with plastic mulch)	32.67	37.67	41.00	31.67	45.67	**37.73**
T2(120% ETc without plastic mulch)	35.00	42.00	45.67	33.67	44.67	**40.20**
T3(100% ETc with plastic mulch)	34.00	36.00	39.33	32.00	47.33	**37.73**
T4(100% ETc without plastic mulch)	35.00	41.67	46.00	34.67	47.33	**40.93**
T5(80% ETc with plastic mulch)	33.33	37.33	42.33	32.67	48.33	**38.80**
T6(80% ETc without plastic mulch)	34.67	41.33	48.67	34.33	48.33	**41.47**
T7(60% ETc with plastic mulch)	32.67	36.67	40.67	34.67	48.33	**38.60**
T8(60% ETc without plastic mulch)	36.00	39.33	45.67	33.67	47.33	**40.40**
Mean	**34.17**	**39.00**	**43.67**	**33.42**	**47.17**	**39.48**
Interaction	S. E. ±		C. D. (5%)			
Level A		12.58		NS		
Level B		13.32		NS		

Note: 1. Level A- Between two subplots means at same level of main plot mean

2. Level B - Between two main plots means at same level of sub plot mean.

4.8.2 Diameter of the fruit

The effects of growing environment and agro technique on diameter of fruit at the time of harvest are presented in Table 4.9 to 4.11 and are depicted graphically in Figure 4.37 and 4.38.

4.8.2.1 Effect of growing environment

The diameter of the fruit was significantly influenced by the growing environment as shown in Table 4.9 and depicted in Figure 4.37.

The growing environment has influence on diameter of cucumber fruit both in open field and shade net house condition. The highest diameter of fruit was recorded in treatment S_4

(3.61 cm) which were at par with treatment S_2 (3.56 cm), followed by S_3 (3.34 cm) and S_1 (3.15 cm). The lowest diameter of the fruit (3.15 cm) was recorded from treatment S_5 i. e. control. The diameter of the fruit from shade net was superior to that of open field which might be due to favorable crop growth environment in the shade net.

Table 4.9 Effect of growing environment on diameter of fruit

Treatment	Diameter of the fruit (cm)
S1 (Green-white net 35% shading)	3.23^{a}
S2(Green-white net 50% shading)	3.56^{c}
S3(Green-white net 75% shading)	3.34^{b}
S4(Red net 50 % shading)	3.61^{c}
S5(open/ control treatment)	3.15^{a}
S. E. ±	**0.06**
C. D. (5%)	**0.20**

Note: Higher superscript denotes best treatment.

The red shade net exhibited significantly higher fruit diameter as compared to other shade net and open field condition. Among the different shading percentage of green-white shade net, the fruit diameter were at par and it was highest in green-white shade net with 50 % shading but lowest in open field condition.

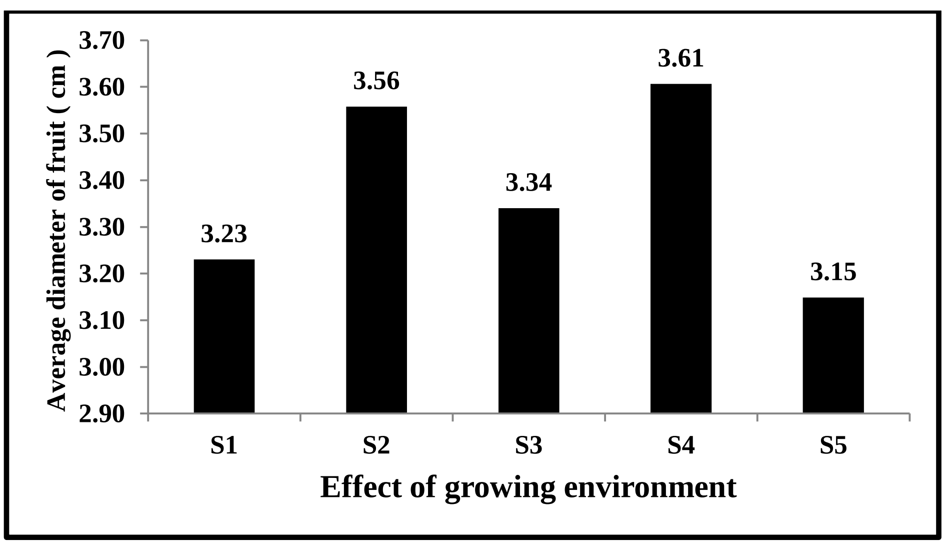

Figure 4.37 Effect of growing environment on diameter of fruit

4.8.2.2 Effect of agrotechnique treatments

It was observed that the diameter of the fruit was non-significantly influenced by different irrigation treatments as shown in Table 4.10 and depicted in Figure 4.38.

Table 4.10 Effect of agro technique treatments on diameter of fruit

Treatment	Diameter of the fruit (cm)
T1(120% with plastic mulch)	3.39[a]
T2(120% ETc without plastic mulch)	3.29[a]
T3(100% ETc with plastic mulch)	3.41[c]
T4(100% ETc without plastic mulch)	3.37[b]
T5(80% ETc with plastic mulch)	3.52[d]
T6(80% ETc without plastic mulch)	3.45[c]
T7(60% ETc with plastic mulch)	3.36[b]
T8(60% ETc without plastic mulch)	3.23[a]
S. E. ±	0.07
C. D. (5%)	NS

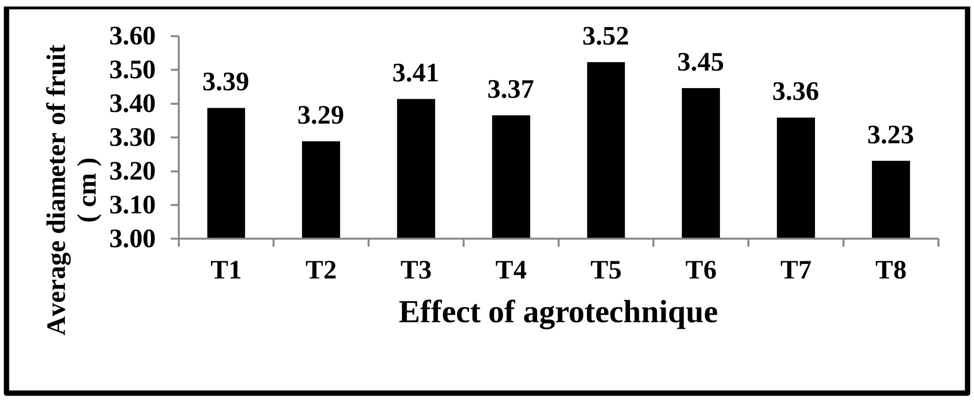

Figure 4.38 Effect of agrotechnique treatments on diameter of the fruit

4.8.2.3 Effect of interaction

The interaction effect shows in Table 4.11 reveals that the diameter of the fruit was non significantly influenced by interaction of shading percentage of shade net and irrigation treatments.

Table 4.11 Two way table of diameter of the fruit

Treatment	S1	S2	S3	S4	S5	Mean
T1(120% with plastic mulch)	3.08	3.54	3.35	3.43	3.53	**3.39**
T2(120% ETc without plastic mulch)	2.88	3.78	3.31	3.44	3.04	**3.29**
T3(100% ETc with plastic mulch)	3.27	3.46	3.43	3.70	3.20	**3.41**
T4(100% ETc without plastic mulch)	3.19	3.46	3.28	3.56	3.34	**3.37**
T5(80% ETc with plastic mulch)	3.45	3.60	3.41	3.80	3.35	**3.52**
T6(80% ETc without plastic mulch)	3.34	3.71	3.33	3.54	3.31	**3.45**
T7(60% ETc with plastic mulch)	3.00	3.67	3.27	3.82	3.03	**3.36**
T8(60% ETc without plastic mulch)	2.98	3.24	3.33	3.55	3.05	**3.23**
Mean	**3.15**	**3.56**	**3.34**	**3.61**	**3.23**	**3.38**

Interaction	S. E. ±	C. D. (5%)	
Level A	0.16	NS	
Level B	0.16	NS	

Note : 1. Level A - Between two subplots means at same level of main plot mean
2. Level B - Between two main plots means at same level of sub plot mean

4.8.3 Length of fruit

The length of fruit at the time of harvest was non-significantly influenced by different growing environment and agrotechnique treatments are shown in Table 4.12 to 4.14 and are graphically depicted in Figure 4.39 and 4.40.

4.8.3.1 Effect of growing environment of shade net

The fruit length differed non significantly under open field and shade house shown in Table 4.12 and depicted in Figure 4.39.

Table 4.12 Effect of growing environment on length of fruit

Treatment	Length of fruit(cm)
S1 (Green-white net 35% shading)	14.96
S2(Green-white net 50% shading)	15.06
S3(Green-white net 75% shading)	14.73
S4(Red net 50 % shading)	15.18
S5(open/ control treatment)	14.43
S. E. ±	0.18
C.D. at 5%	NS

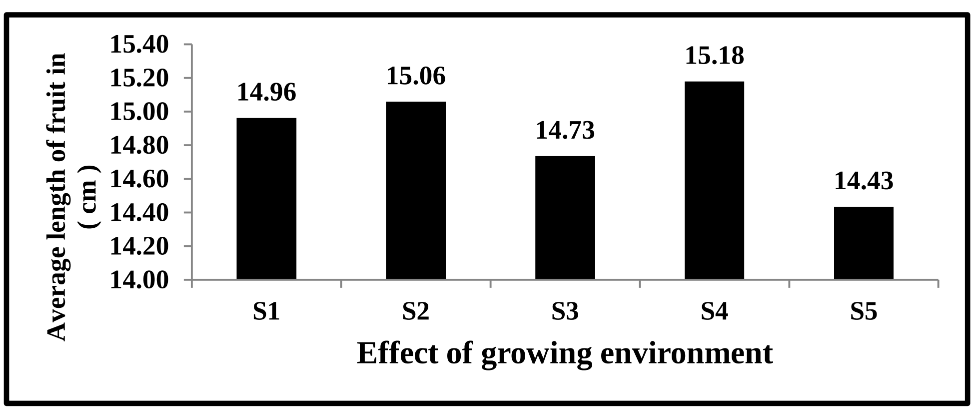

Figure 4.39 Effect of growing environment on length of fruit

4.8.3.2 Effect of agrotechnique treatments

Table 4.13 and Figure 4.40 reveal that the longest length of fruit (15.31 cm) was observed in treatment $T_{5.}$ Further, the treatment T_1 (15.04 cm) and T_3 (14.96) were at par and followed by treatment T_7 (14.86), T_6 (14.81 cm), and T_2 (14.70 cm), T_6 (14.74 cm). The shorter length of fruit was observed in treatment T_8 (14.61 cm) and T_4 (14.69 cm). This might be due to improper growth of cucumber crop, due to unfavorable environmental conditions during the growth period in the open field.

Longer the length of fruit in mulched treatments ($T_{5,}$ $T_{7,}$ T_3 and T_1) compared to non-mulched treatments ($T_{6,}$ $T_{4,}$ T_8 and T_2) reveals that the mulching results in longer of length of fruit. This may be either due to better utilization of available water in the mulched treatments.

Table 4.13 Effect of agrotechnique treatments on length of fruit

Treatment	Length of fruit(cm)
T1(120% with plastic mulch)	15.04[b]
T2(120% ETc without plastic mulch)	14.70[a]
T3(100% ETc with plastic mulch)	14.96[a]
T4(100% ETc without plastic mulch)	14.69[a]
T5(80% ETc with plastic mulch)	15.31[b]
T6(80% ETc without plastic mulch)	14.81[a]
T7(60% ETc with plastic mulch)	14.86[a]
T8(60% ETc without plastic mulch)	14.61[a]
S. E. ±	0.13
C. D. (5%)	0.37

Note: Higher superscript denotes best treatment.

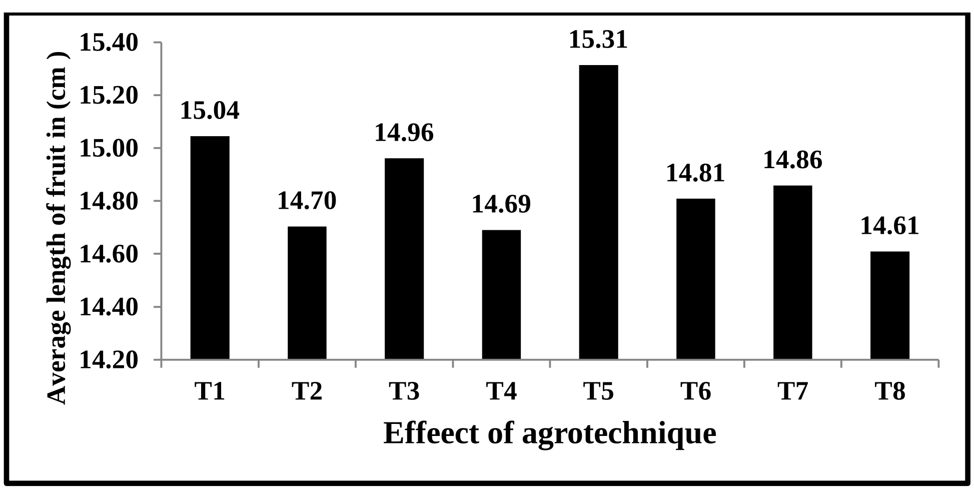

Figure 4.40 Effect of agrotechnique on length of fruit

4.8.3.3 Effect of interaction

The interaction effect of the length of the fruit was non-significantly influenced by growing environment and agrotechnique treatments as shown in Table 4.14.The highest length of the fruit (15.47 cm) was observed from treatment S_4T_3. The lowest fruit length (14.46 cm) was observed in control treatment.

Table 4.14 Two way table of length of fruit

Treatment	S1	S2	S3	S4	S5	Mean
T1(120% with plastic mulch)	14.79	15.27	15.23	15.44	14.49	**15.04**
T2(120% ETc without plastic mulch)	14.64	15.19	14.11	15.00	14.58	**14.70**
T3(100% ETc with plastic mulch)	15.59	15.08	14.34	15.47	14.33	**14.96**
T4(100% ETc without plastic mulch)	14.89	14.76	14.59	15.31	13.90	**14.69**
T5(80% ETc with plastic mulch)	15.59	15.36	15.25	15.32	15.06	**15.31**
T6(80% ETc without plastic mulch)	15.10	15.07	15.11	15.00	13.75	**14.81**
T7(60% ETc with plastic mulch)	14.60	14.96	14.26	15.44	15.04	**14.86**
T8(60% ETc without plastic mulch)	14.50	14.77	14.99	14.46	14.31	**14.61**
Mean	**14.96**	**15.06**	**14.73**	**15.18**	**14.43**	**14.87**
Interaction	S. E. ±		C. D. (5%)			
Level A	0.29		NS			
Level B	0.33		NS			

Note :1 Level A- Between two subplots means at same level of main plot mean

2. Level B - Between two main plots means at same level of sub plot mean

4.8.4 Fruit weight

The statistical data in respect of the fruit weight at harvest was influenced by different growing environment and agrotechnique treatments are presented in Table 4.15 to 4.17 and graphically depicted in Figure 4.41 and 4.42.

4.7.4.1 Effect of growing environment of shade net

The growing environment has influence on the fruit weight of cucumber crop. The weight of the fruit was significantly influenced by the different growing environment as shown in Table 4.15 and depicted in Figure 4.41.

The maximum weight of fruit (207.14 g) was recorded in treatment S_4 which was followed by S_1 (176.55g) and from treatment S_3 (160.98 g) recorded. Further, treatment S_2 (159.70 g) was at par to treatment S_1 (155.88 g).The minimum weight of fruit (159.70

g) was recorded from treatment S_5 i.e. control treatment. The weight of the fruit recorded from the red shade net (with 50 % shading) was significantly superior to rest of the treatments. This might be due to the effect of shade net which modified the micro climatic situation making it more favorable to crop growth and hence resulted in higher weight of the fruits.

Table 4.15 Effect of growing environment on weight of fruit

Treatment	Weight of fruit (g)
S1 (Green-white net 35% shading)	176.55^{c}
S2(Green-white net 50% shading)	159.70^{b}
S3(Green-white net 75% shading)	160.98^{c}
S4(Red net 50 % shading)	207.14^{d}
S5(open/ control treatment)	143.63^{a}
S. E. ±	**6.24**
C. D. (5%)	**20.35**

Note: Higher superscript denotes best treatment

Among the different shading percentage of green-white shade net, the maximum fruit weight was recorded from green-white shade net with 35 % shading followed by green-white shade net with 75 % and 50% shading.

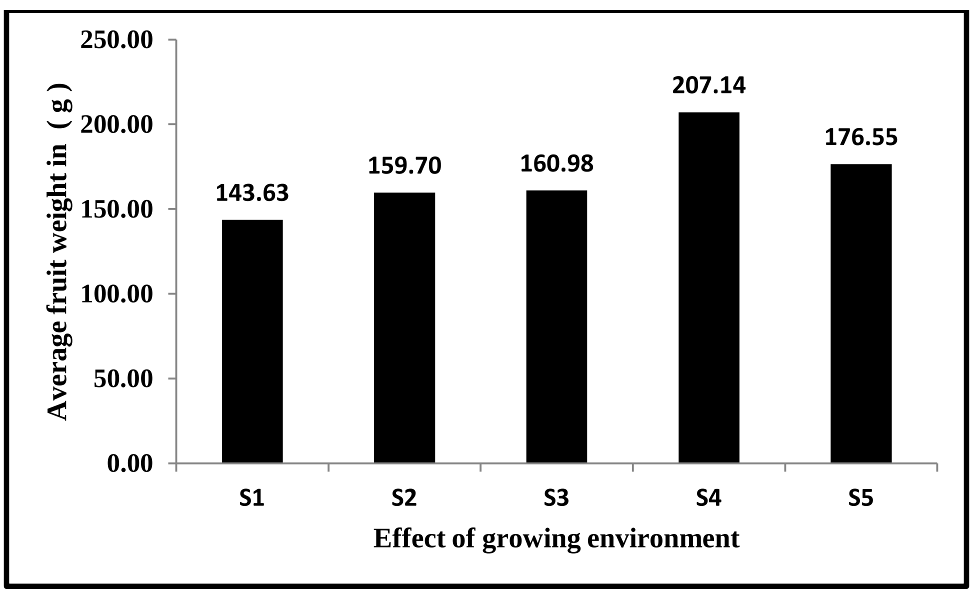

Figure 4.41 Effect of growing environment on weight of the fruit

4.8.4.2 Effect of agrotechniques treatments

The weight of the fruit was significantly influenced by the different agrotechnique treatments as shown in Table 4.16 and depicted in Figure 4.42.

Table 4.16 Effect of agrotechnique treatments on weight of fruit

Treatment	Weight of fruit (g)
T1(120% with plastic mulch)	174.51
T2(120% ETc without plastic mulch)	171.07
T3(100% ETc with plastic mulch)	169.64
T4(100% ETc without plastic mulch)	166.27
T5(80% ETc with plastic mulch)	176.29
T6(80% ETc without plastic mulch)	169.46
T7(60% ETc with plastic mulch)	168.56
T8(60% ETc without plastic mulch)	161.02
S. E. ±	5.63
C. D. (5%)	NS

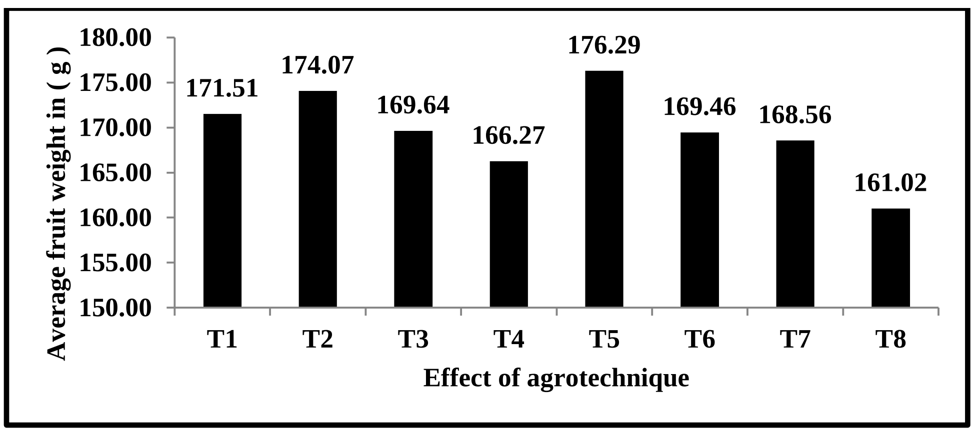

Figure 4.42 Effect of agrotechnique on weight of the fruit

4.8.4.3 Effect of interaction

The interaction effect on the fruit weight was significantly influenced by interaction of shading percentage of shade net and irrigation treatments as given in Table 4.17.

Table 4.17 Two way table of weight of fruit

Treatment	S1	S2	S3	S4	S5	Mean
T1(120% with plastic mulch)	165.9	167.6	189.68	209.39	157.28	177.78
T2(120% ETc without plastic mulch)	159.2	159.4	188.82	210.09	147.19	173.17
T3(100% ETc with plastic mulch)	155.8	170.5	182.07	212.89	155.79	173.63
T4(100% ETc without plastic mulch)	148.1	164.4	173.72	202.11	142.37	167.97

T5(80% ETc with plastic mulch)	177.9	158.3	194.28	225.26	155.35	182.23
T6(80% ETc without plastic mulch)	145.6	165.9	169.47	198.33	152.46	166.38
T7(60% ETc with plastic mulch)	155.2	170.1	178.89	200.18	159.04	171.51
T8(60% ETc without plastic mulch)	138.8	147.7	172.86	184.12	134.30	156.78
Mean	155.8	163.0	181.23	205.30	150.47	171.18
Interaction	S. E. ±		C. D. (5%)			
Level A	3.12		8.82			
Level B	4.76		14.75			

Note: 1. Level A - Between two subplots means at same level of main plot mean
2. Level B - Between two main plots means at same level of sub plot mean

The maximum weight of fruit (225.26 g) was reported in treatment S_4T_5 i.e. Red shade net with 50 % shading and drip irrigation @ 80 % ETc with silver black plastic mulch which was at par to treatment S_4T_3 (212.89 g) followed by a treatment S_4T_2 (210.09 g), S_4T_1 (209.39 g), S_4T_4 (202.11g), S_4T_7 (200.18g), S_4T_6 (198.33g) and S_3T_5 (194.28g) and S_4T_5 significantly superior over others. Minimum weight of fruit was reported in treatment S_5T_7 (159.04 g) i.e. from control treatment and drip irrigation @ 60 % ETc without silver black plastic mulch.

Plate 3.15 Growth of Cucumber at last harvesting in green-white shade net with 35 % shading

Plate 3.16 Growth of Cucumber at last harvesting in green-white shade net with 50 % shading

Plate 3.17 Growth of Cucumber at last harvesting in green-white shade net with 75 % shading

Plate 3.18 Growth of Cucumber at last harvesting in red shade net with 50% shading

Plate 3.19 Growth of Cucumber at last harvesting in open field condition

4.8.5 Length of vine at last harvest

The cucumber crop was highly influenced by the environment with respect to length of vine at last harvest. The observed data for length of vine at last harvest as influenced by different treatments are shown in Table 4.18 to 4.43 and depicted in Figure 4.43 and 4.44.

4.7.5.1 Effect of growing environment

During the last harvest, the length of vine was significantly influenced by different growing environment as shown in Table 4.18 and depicted in Figure 4.43.

The maximum length of vine (4.74 m) was observed in treatment S_4, which was followed by treatment S_3 (3.82 m), S_2 (3.46 m), S_1 (2.99 m). The minimum length of vine (2.31 m) was observed in treatment S_5 i.e. control treatment. This might be due to unfavorable environment in open field (control) on account of higher temperature that has adverse effect on growth and development of the crop. The environment was comparatively more favorable in shade net house resulted in longer vine length of the crop.

Table 4.18 Effect of growing environment on length of vine at last harvest

Treatment	Length of vine at last harvest (m)
S1 (Green-white net 35% shading)	2.99^{a}
S2(Green-white net 50% shading)	3.46^{b}
S3(Green-white net 75% shading)	3.82^{c}
S4(Red net 50 % shading)	4.74^{d}
S5(open/ control treatment)	2.31^{a}
S. E. ±	**0.10**
C. D. (5%)	**0.32**

Note: Higher superscript denotes best treatment

The red shade net exhibited significantly higher length of vine as compared to other shade net and open field condition. Among the different growing environment of green-white shade net the length of vine followed by in green-white shade net with 50 % shading but lowest in open field condition.

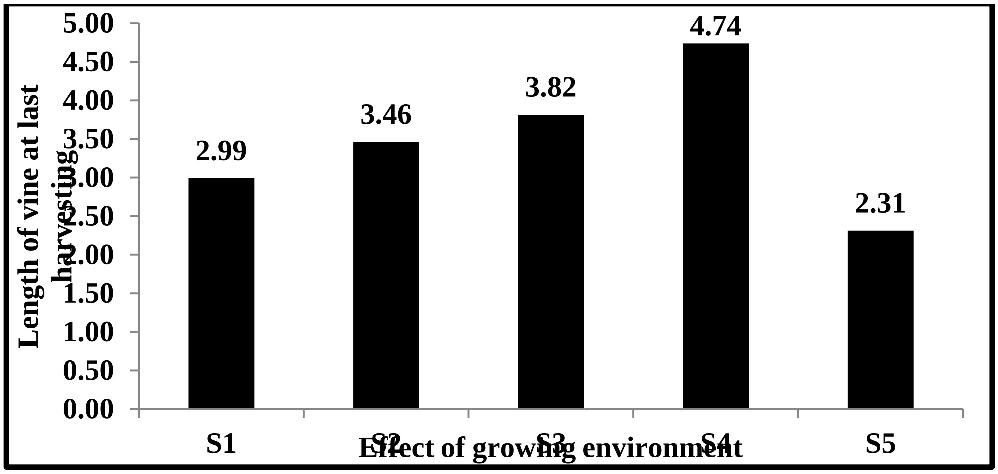

Figure 4.43 Effect of growing environment on weight of the fruit

4.7.5.2 Effect of agrotechnique treatments

It is revealed from the Table 4.19 and Figure 4.44 that the length of vine at last harvest was significantly influenced by agrotechniques treatments. However, the maximum length of vine (5.21 m) was observed in treatment $T_{5.}$ Further, treatment T_3 (4.97 m) was observed to be at par with T_1 (4.80 m) and followed by treatments $T_{6,}$ T_7, T_2 and T_4. Minimum length of vine (3.75 m) recorded in treatment T_8 (3.75 m). The maximum length of vine at last harvest in silver black mulched treatments was probably associated with the conservation of moisture, improved microclimate both beneath and above the soil surface, light reflection and great weed control compared to bare soil.

Table 4.19 Effect of agrotechnique treatments on length of vine at last harvest

Treatment	**Length of vine at last harvest (m)**
T1(120% with plastic mulch)	4.80^{c}
T2(120% ETc without plastic mulch)	4.02^{a}
T3(100% ETc with plastic mulch)	4.97^{c}
T4(100% ETc without plastic mulch)	3.98^{a}
T5(80% ETc with plastic mulch)	5.21^{d}
T6(80% ETc without plastic mulch)	4.31^{b}
T7(60% ETc with plastic mulch)	4.26^{b}
T8(60% ETc without plastic mulch)	3.75^{a}
S. E. ±	0.11
C. D. (5%)	0.31

Note: Higher superscript denotes best treatment.

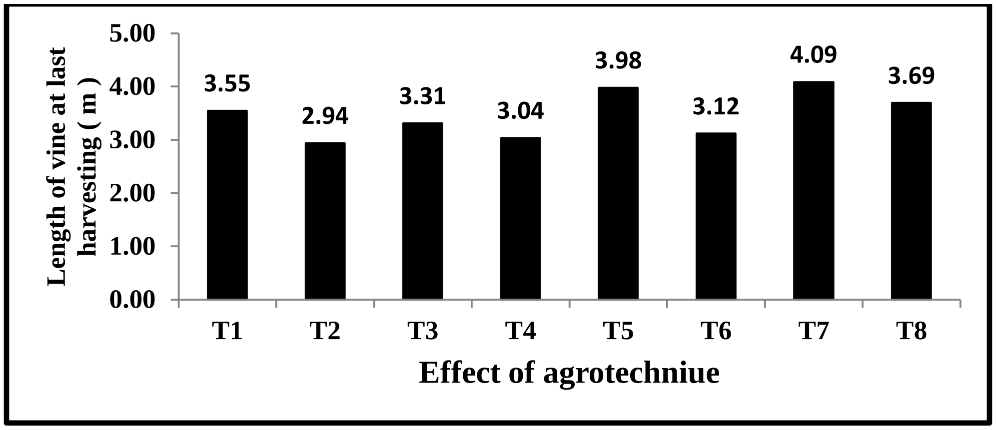

Figure 4.44 Effect of agrotechnique treatments on length of vine at last harvesting

4.7.5.3 Effect of interaction

The interaction effect of the length of vine at last harvesting influenced by growing environment and agrotechnique treatments as shown in Table 4.20.The highest length of vine at last harvesting S_4T_5 (5.83 cm) . The lowest length of vine at last harvesting was observed in S_5T_4 (2.70 cm) in control treatment.

Table 4.20 Two way table of length of vine at last harvesting

Treatment	**S1**	**S2**	**S3**	**S4**	**S5**	**Mean**
T1(120% with plastic mulch)	2.97	3.67	3.80	5.04	3.37	**3.77**
T2(120% ETc without plastic mulch)	2.15	4.17	3.47	3.07	2.57	**3.08**
T3(100% ETc with plastic mulch)	3.08	4.87	3.90	5.17	2.71	**3.94**
T4(100% ETc without plastic mulch)	2.65	3.87	4.73	3.20	2.70	**3.43**
T5(80% ETc with plastic mulch)	2.97	4.7	5.41	5.83	3.47	**4.48**
T6(80% ETc without plastic mulch)	3.07	4.6	5.23	4.90	2.33	**4.04**
T7(60% ETc with plastic mulch)	3.33	4.4	4.70	5.92	3.67	**4.40**
T8(60% ETc without plastic mulch)	2.57	3.6	4.83	4.77	3.13	**3.79**
Mean	**2.85**	**4.25**	**4.51**	**4.74**	**2.99**	**3.87**
Interaction	S. E. ±		C. D. (5%)			
Level A	0.097		0.315			
Level B	0.130		0.365			

Note: 1. Level A - Between two subplots means at same level of main plot mean
2. Level B - Between two main plots means at same level of sub plot mean

4.8.6 Number of fruits per vine

The data in respect of the number of fruits per vine at the time of harvest was influenced by different shading percentage and irrigation treatments shown in Table 4.21 to 4.22 and depicted in Figure 4.45 to 4.46.

4.8.6.1 Effect of growing environment of shade net

The growing environment has influence on number of fruits per vine both in open and shade house condition. The number of fruits per vine was significantly influenced by different growing environment and agrotechnique as shown in Table 4.21 and depicted in Figure 4.45.

The cucumber grown under shade house condition, on an average produced higher number of fruits per vine. The treatment S_4 (12.68) was significantly superior to S_3 (11.73) and all other treatment. The minimum number of fruits per vine was recorded in open field condition (7.54) i.e. treatment S_5. This might be due to effect of shading of shade net in creating an environment more favorable for growth and development of the crop as compared to open field condition.

Table 4.21 Effect of growing environment on number of fruits

Treatment	No of fruits per vine
S1 (Green-white net 35% shading)	8.63[b]
S2(Green-white net 50% shading)	9.50[c]
S3(Green-white net 75% shading)	11.73[d]
S4(Red net 50 % shading)	12.68[d]
S5(open/ control treatment)	7.54[a]
S. E. ±	0.39
C. D. (5%)	1.28

Note: Higher superscript denotes best treatment.

The red shade net exhibited highest number of fruits per vine as compared to other shade net and open field condition. Among the different shading percentage of green-white shade net the number of fruits per vine was highest in green-white shade net with 75 % shading which was followed by green-white shade net with 50 % and 35 % shading. Lowest number of fruits per vine was in open field due to adverse climatic conditions.

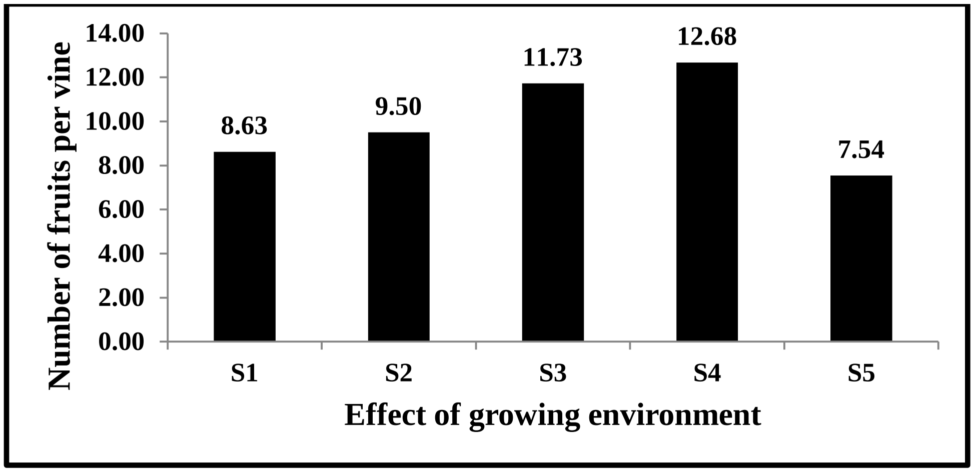

Figure 4.45 Effect of growing environment on number of fruits

4.8.6.2 Effect of agrotechnique treatments

The number of fruits per vine was significantly influenced by agrotechnique treatments as shown in Table 4.22 and depicted in Figure 4.46. The maximum number of fruits per vine was reported in treatment T_5 (12.67), T_1 (11.25) and followed by treatments T_3 (11.0) T_7 (10.93). Minimum number of fruits recorded in no mulch treatmentsT_8 (9.20),T_6 (8.67), T_4 (8.40), T_2(8.00).This might be due to improper growth of cucumber crop, due to unfavorable soil conditions during the growth period on bare soil compared to soil covered with silver black mulch.

Maximum number of fruits per vine's recorded in mulched treatments ($T_{5,}$ $T_{7,}$ T_3 and T_1) compared to non-mulched treatments ($T_{6,}$ $T_{4,}$ T_8 and T_2) reveals that the mulching results in increasing the number of fruits per vine.

Table 4.22 Effect of agrotechnique treatments on number of fruits

Treatment	No of fruits per vine
T1(120% with plastic mulch)	11.25^{c}
T2(120% ETc without plastic mulch)	8.00^{a}
T3(100% ETc with plastic mulch)	11.00^{c}
T4(100% ETc without plastic mulch)	8.40^{a}
T5(80% ETc with plastic mulch)	12.67^{d}
T6(80% ETc without plastic mulch)	8.67^{a}
T7(60% ETc with plastic mulch)	10.93^{b}
T8(60% ETc without plastic mulch)	9.20^{a}
S. E. ±	0.39
C. D. (5%)	0.11

Note: Higher superscript denotes best treatment.

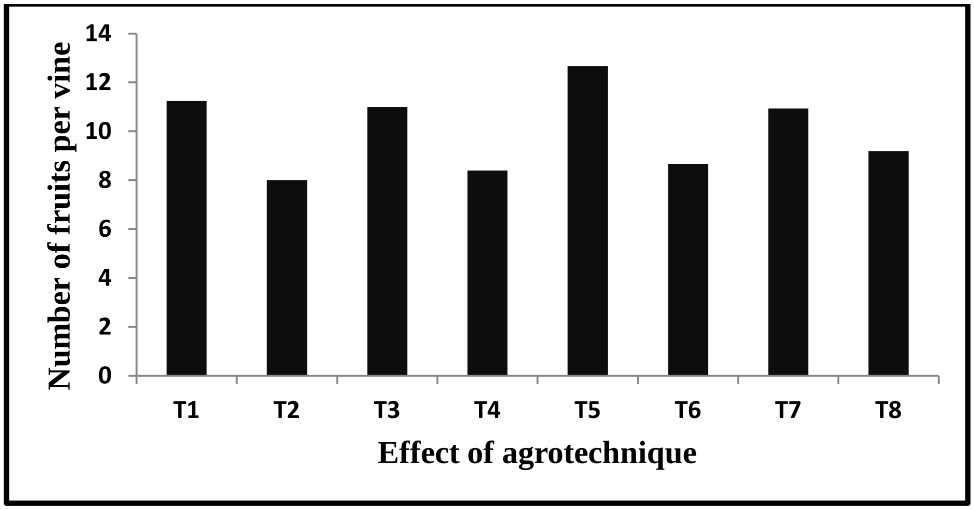

Figure 4.46 Effect of agrotechnique on number of fruits

Table 4.23 Two way table of number of fruits per vine

Treatment	S1	S2	S3	S4	S5	Mean
T1(120% with plastic mulch)	10.00	11.67	13.17	14.73	6.67	**11.25**
T2(120% ETc without plastic mulch)	6.00	6.67	10.67	12.00	4.67	**8.00**
T3(100% ETc with plastic mulch)	9.33	12.00	11.00	13.67	9.00	**11.00**
T4(100% ETc without plastic mulch)	5.67	8.67	10.00	11.67	6.00	**8.40**
T5(80% ETc with plastic mulch)	12.00	12.33	14.33	13.33	11.33	**12.67**
T6(80% ETc without plastic mulch)	8.00	5.67	11.33	12.00	6.33	**8.67**
T7(60% ETc with plastic mulch)	10.67	10.33	11.33	12.33	10.00	**10.93**
T8(60% ETc without plastic mulch)	7.33	8.67	12.00	11.67	6.33	**9.20**
Mean	**8.63**	**9.50**	**11.73**	**12.68**	**7.54**	**10.01**

Note: 1. Level A - Between two subplots means at same level of main plot mean
2. Level B - Between two main plots means at same level of sub plot mean

4.8.6.3 Effect of interaction

The interaction effect of number of fruits per vine influenced by growing environment and agrotechnique treatments as shown in Table 4.23.The highest number of fruits per vine was observed in S_4T_1 (14.73) . The lowest number of fruits per vine was observed in S_5T_2 (4.67) was observed in control treatment

4.8.7 Yield of fruits per vine

It is observed in statistical analysis that the data in respect of the yield of fruits per vine was influenced by growing environment and agrotechnique treatments as shown in Table 4.24 to 4.26 and depicted in Figure 4.46 and 4.47.

4.7.7.1 Effect of growing environment of shade net

The growing environment had influence on yield of fruits per vine of cucumber crop both in open field and shade house condition. The yield of fruits per vine was non-significantly influenced by growing environment of shade net as shown in Table 4.24 and graphically depicted in Figure 4.46.

Table 4.24 Effect of growing environment on yield of fruits per vine

Treatment	Yield per vine
S1 (Green-white net 35% shading)	1.49
S2(Green-white net 50% shading)	1.47
S3(Green-white net 75% shading)	1.51
S4(Red net 50 % shading)	1.52
S5(open/ control treatment)	1.40
S. E. ±	0.04
CD at 5%	NS

The effect of shading percentage was non-significantly observed on yield of fruits per vine.

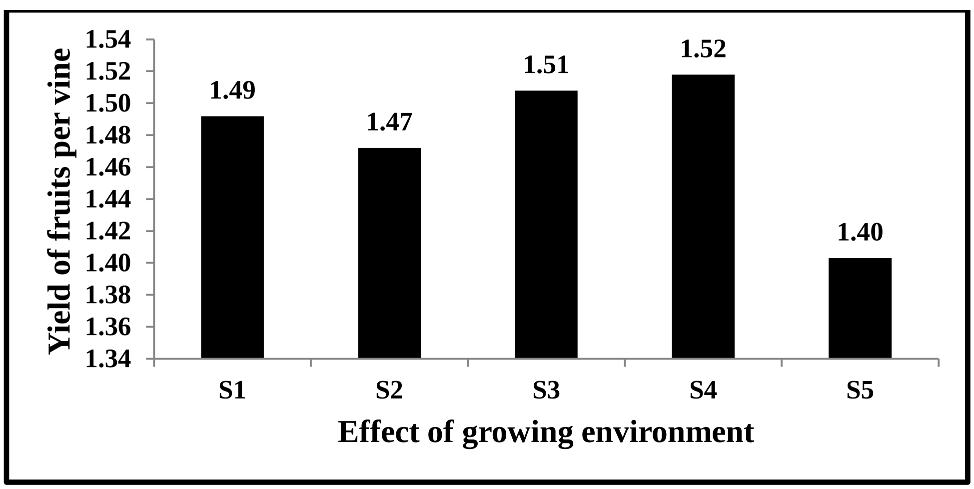

Figure 4.47 Effect of growing environment on number of fruits

4.8.7.2 Effect of agrotechnique treatments

The yield of fruits per vine was significantly influenced by different agrotechnique treatments as shown in Table 4.25 and graphically depicted in Figure 4.47.

The maximum yield of fruit per vine was observed in treatment T_5 (1.68 kg) which followed by treatments T_1 (1.53 kg), T_6 (1.50 kg), T_7 (1.49 kg), and T_3 (1.47 kg).

Minimum yield of fruit per vine was observed in non-mulched treatments T_4 (1.45 kg), T_8 (1.35 kg) and T_2 (1.35 kg). This might be due to better environmental conditions for accelerated crop growth and development of the crop. Higher the yield of fruit per vine in T_5, T_7, T_3 and T_1 compared to T_6, T_4, T_8 and T_2 reveals that the mulching results in higher yield of fruit per vine. This may be either due to better utilization of available water in the mulched treatments.

Table 4.25 Effect of agrotechnique treatments on yield of fruits per vine

Treatment	Yield of fruits per vine(kg)
T1(120% with plastic mulch)	1.53^{c}
T2(120% ETc without plastic mulch)	1.35^{a}
T3(100% ETc with plastic mulch)	1.47^{b}
T4(100% ETc without plastic mulch)	1.45^{b}
T5(80% ETc with plastic mulch)	1.68^{d}
T6(80% ETc without plastic mulch)	1.50^{c}
T7(60% ETc with plastic mulch)	1.49^{b}
T8(60% ETc without plastic mulch)	1.35^{a}
S. E. ±	0.04
C. D. (5%)	0.11

Note: Highest superscript denotes best treatment

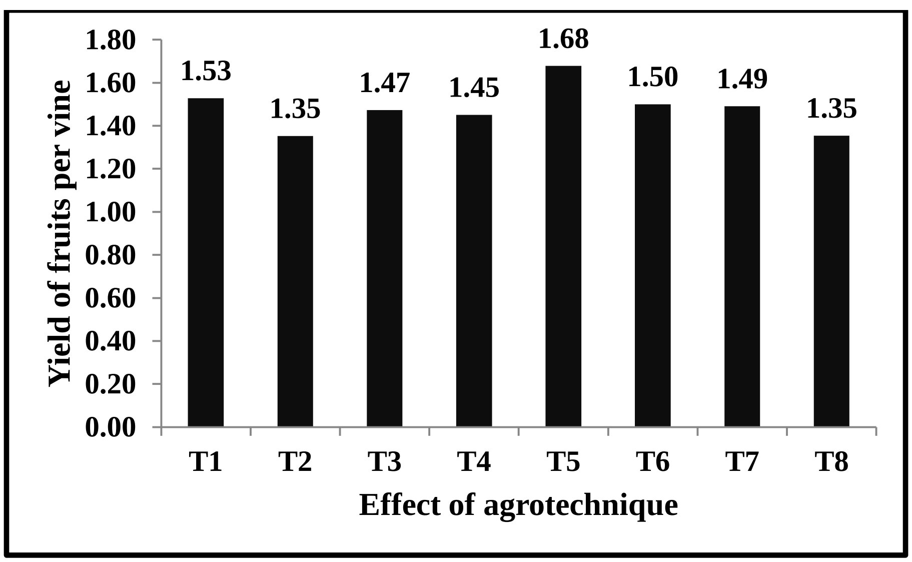

Figure 4.48 Effect of agrotechnique on number of fruits

4.8.7.3 Effect of interaction

The yield of fruits per vine was significantly influenced by interaction of growing environment and agrotechnique treatments as shown in Table 4.26.

The highest yield was obtained in the treatment S_4T_5 (2.11 kg). The lowest yield of fruit per vine was registered in control treatment (1.31 kg). This decrease in yield in case of control treatment might be due to absence of shading and conveyance losses of fertilizers during application.

Table 4.26 Two way table of yield of fruits per vine

Treatment	S1	S2	S3	S4	S5	Mean
T1(120% with plastic mulch)	1.65	1.59	1.58	1.40	1.43	**1.53**
T2(120% ETc without plastic mulch)	1.38	1.42	1.39	1.26	1.31	**1.35**
T3(100% ETc with plastic mulch)	1.51	1.47	1.50	1.49	1.38	**1.47**
T4(100% ETc without plastic mulch)	1.77	1.28	1.53	1.35	1.33	**1.45**
T5(80% ETc with plastic mulch)	1.47	1.69	1.56	2.11	1.56	**1.68**
T6(80% ETc without plastic mulch)	1.35	1.42	1.62	1.71	1.40	**1.50**
T7(60% ETc with plastic mulch)	1.48	1.56	1.50	1.49	1.42	**1.49**
T8(60% ETc without plastic mulch)	1.33	1.35	1.37	1.33	1.40	**1.35**
Mean	**1.49**	**1.47**	**1.51**	**1.52**	**1.40**	**1.48**
Interaction	S. E. ±		C. D. (5%)			
Level A	0.086		0.244			
Level B	0.092		0.270			

Note: 1. Level A- Between two subplots means at same level of main plot mean

2. Level B - Between two main plots means at same level of sub plot mean

4.8.8 Yield per plot

The growing environment has significant effect on the yield per plot both under open field and shade house condition as shown in Table 4.27 to 4.29 and graphically depicted in Figure 4.48 and 4.49.

4.7.8.1 Effect of growing environment percentage of shade net

The yield per plot was significantly influenced by shading percentage of shade net shown in Table 4.27 and graphically depicted in Figure 4.48. The maximum yield of fruit per

plot was observed in treatment S_4 (32.14 kg) which was significantly superior to all other treatments. Treatment S_3 (29.83 kg) followed by treatment S_2 (20.50 kg) and S_1 (19.77 kg). Minimum yield was observed in treatment S_5 (14.87 kg) i. e. in open field condition.
The red shade net exhibited significantly highest yield as compared to other shade net and open field condition. Among the different shading percentage of green-white shade nets the highest yield was observed in green-white shade net with 75 % shading and lowest yield was observed in green-white shade net with 35 % shading.

Table 4.27 Effect of growing environment on yield of fruit per plot

Treatment	Yield per plot (kg)
S1 (Green-white net 35% shading)	19.77^{b}
S2(Green-white net 50% shading)	20.50^{b}
S3(Green-white net 75% shading)	29.83^{c}
S4(Red net 50 % shading)	32.14^{d}
S5(open/ control treatment)	14.87^{a}
S. E. ±	**2.01**
C. D. (5%)	**6.55**

Note: Higher superscript denotes best treatment

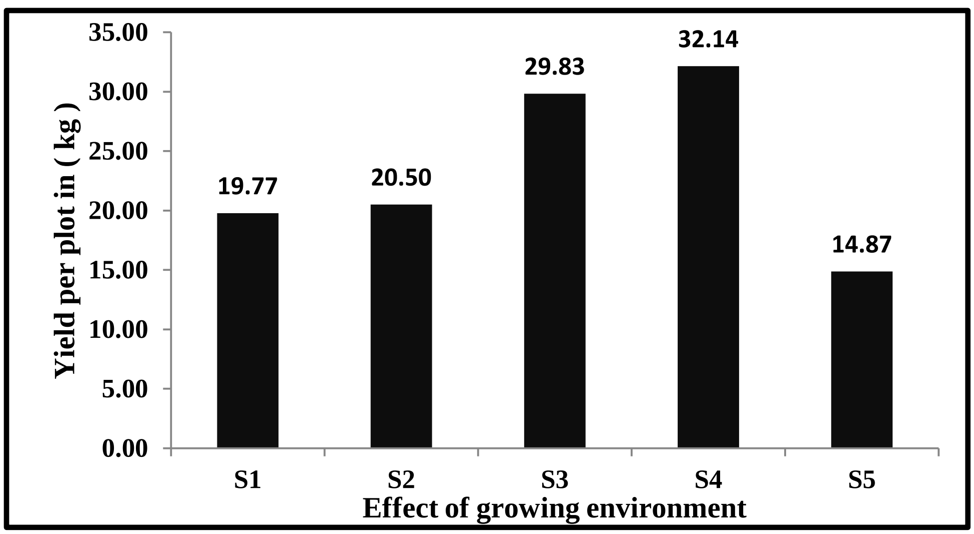

Figure 4.49 Effect of growing environment on yield of fruit per plot

4.8.8.2 Effect of agrotechnique treatments

The yield per plot was significantly influenced by different agrotechnique treatments as shown in Table 4.28 and depicted in Figure 4.4.9.

The yield of fruits per vine was significantly influenced by different agrotechnique treatments as shown in Table 4.25 and graphically depicted in Figure 4.47.

The maximum yield of fruit per plot was observed in treatment T_5 (29.65 kg) which followed by treatments T_3 (26.20 kg), T_7 (24.57 kg), T_1 (23.32 kg). Minimum yield of fruit per vine was observed in non-mulched treatments T_6 (23.97 kg), T_8 (21.70 kg) and (19.02 kg), T_2 (18.93 kg). This might be due to better environmental conditions for accelerated crop growth and development of the crop. Higher the yield of fruit per vine in T_5, T_7, T_3 and T_1 compared to T_6, T_4, T_8 and T_2 reveals that the mulching results in higher yield of fruit per vine. This may be either due to better utilization of available water in the mulched treatments.

Table 4.28 Effect of agrotechnique treatments on yield of fruit per plot

Treatment	**Yield per plot(kg)**
T1(120% with plastic mulch)	23.32^{b}
T2(120% ETc without plastic mulch)	18.93^{a}
T3(100% ETc with plastic mulch)	26.20^{c}
T4(100% ETc without plastic mulch)	19.02^{a}
T5(80% ETc with plastic mulch)	29.65^{d}
T6(80% ETc without plastic mulch)	23.97^{b}
T7(60% ETc with plastic mulch)	24.57^{c}
T8(60% ETc without plastic mulch)	21.70^{b}
S. E. ±	0.67
C. D. (5%)	1.90

Note: Higher superscript denotes best treatment

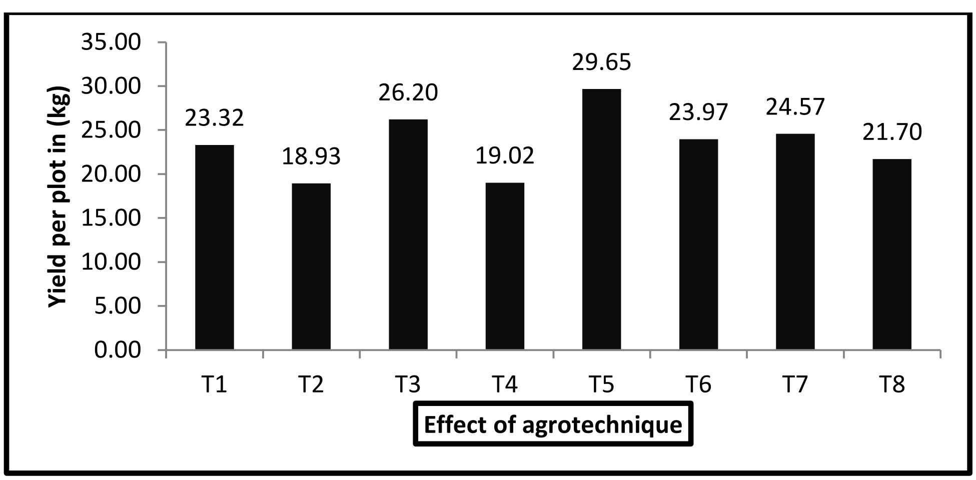

Figure 4.50 Effect of agrotechnique treatments on yield of fruit per plot

4.8.8.3 Effect of interaction

The yield per plot was non-significantly influenced by interaction of growing environment and agrotechnique treatments as shown in Table 4.28

The highest yield of fruit per plot was obtained in the treatment S_4T_5 (40.76 kg) which was followed by treatment S_3T_7 (36.09 kg), S_4T_3 (35.62 kg), S_4T_1 (35.55 kg). The lowest yield of fruit per plot was observed in control treatment (11.53 kg), this decrease in yield in case of control treatment might be due adverse climatic condition in open field.

The yield obtained per plot has been worked out on per hectare basis and presented in Table 4.30.

Table 4.29 Two way table of yield of fruit per plot

Treatment	S1	S2	S3	S4	S5	Mean
T1(120% with plastic mulch)	19.31	20.14	30.10	31.77	15.28	**23.32**
T2(120% ETc without plastic mulch)	13.68	17.65	24.65	27.15	11.53	**18.93**
T3(100% ETc with plastic mulch)	20.35	24.51	32.92	35.62	17.60	**26.20**
T4(100% ETc without plastic mulch)	14.78	16.97	23.04	27.78	12.53	**19.02**
T5(80% ETc with plastic mulch)	28.58	24.48	37.19	40.76	17.26	**29.65**
T6(80% ETc without plastic mulch)	20.76	20.11	31.96	31.51	15.49	**23.97**
T7(60% ETc with plastic mulch)	22.81	19.82	32.81	32.53	14.89	**24.57**
T8(60% ETc without plastic mulch)	17.88	20.33	25.95	29.98	14.39	**21.70**
Mean	**19.77**	**20.50**	**29.83**	**32.14**	**14.87**	**23.42**
Interaction	S. E. ±		C. D. (5%)			
Level A	1.505		NS			
Level B	2.452		NS			

Note: 1. Level A - Between two subplots means at same level of main plot mean

2. Level B - Between two main plots means at same level of sub plot mean

The yield of fruit per plot was significantly influenced by interaction of growing environment and agrotechnique treatments. The highest yield was obtained in the treatment S_4T_5 (52.25 t ha^{-1}). The lowest yield of fruit per plot was registered in control treatment (14.78 t ha^{-1}). This decrease in yield in case of control treatment might be due to adverse climatic condition in open field.

Table 4.30 Total yield of cucumber obtained under different treatments (t ha^{-1})

Treatment	S1	S2	S3	S4	S5	Mean
T1(120% with plastic mulch)	24.76	25.83	38.59	42.07	29.19	**32.09**
T2(120% ETc without plastic mulch)	17.54	22.63	31.60	33.26	33.27	**27.66**
T3(100% ETc with plastic mulch)	26.09	31.42	42.21	40.73	19.59	**32.01**
T4(100% ETc without plastic mulch)	18.94	21.76	29.54	34.81	14.78	**23.97**
T5(80% ETc with plastic mulch)	36.64	31.39	47.68	52.25	22.56	**38.10**
T6(80% ETc without plastic mulch)	26.62	25.78	40.98	35.62	16.07	**29.01**
T7(60% ETc with plastic mulch)	29.24	25.40	42.07	45.66	22.13	**32.90**
T8(60% ETc without plastic mulch)	22.92	26.07	33.26	40.40	19.86	**28.50**
Mean	**25.34**	**26.29**	**38.24**	**40.60**	**22.18**	**30.53**
Interaction	S. E. ±		C. D. (5%)			
Level A	2.524		7.120			
Level B	3.174		9.578			

4.9 Efficiencies

4.9.1 Water use efficiency

The water use efficiency and total water requirement for all the treatments were calculated according to procedure adopted in section 3.5.1. The field water use efficiency for different treatments are presented in Table 4.31. The data presented in the Table 4.31 revealed that the WUE in green-white shade net with 35% shading percentage ranged from 43.87 to 129.55 kg/ha-mm and maximum WUE observed in treatment T_7. WUE in green-white shade net with 50 % shading ranges from 60.16 to 128.27 kg/ha-mm and maximum WUE observed in treatment T_7. WUE in green-white shade net with 75 % shading ranges from 84.01 to 192.09 kg/ha-mm and maximum WUE observed from treatment T_7. Further, WUE in red shade net with 50 % shading ranges from 92.53 to 204.78 kg/ha-mm and maximum WUE observed from treatment T_7. Lowest WUE was observed in the control treatments.

Comparison of the average values of WUE among the green-white and red shade net, reveals that the highest average WUE was observed in red shade net with 50 % shading (204.78 kg/ha-mm) followed by green-white shade net with 75 % (192.090 kg/ha-mm), green-white shade net with 35 % (129.5 kg/ha-mm) and green-white shade net with 50 % (128.27 kg/ha-mm) The lowest average WUE was observed in open field i.e. in control treatment (105.12 kg/ha-mm).

4.9.2 Fertilizer use efficiency

The fertilizer use efficiency for all the treatments were calculated according to procedure described in section 3.5.2. The fertilizer use efficiency for different treatments is presented in Table 4.32. In green-white shade net with 35 % shading, FUE ranges from 53.10 to 106.95 and maximum FUE recorded in treatment T_5. In green-white shade net with 50 % shading, FUE ranges from 70.01 to 101.10 and maximum FUE recorded from treatment T_3. In green-white shade net with 75 % shading, FUE ranges from 95.03 to 149.42 and maximum FUE recorded from treatment T_5. Further, FUE in red shade net with 50 % shading ranges from 111.98 to 168.10 and maximum FUE observed from treatment T_5. Lowest FUE was observed in the control treatments.

Comparison of the average values of FUE among the green-white and red shade net, reveals that the highest average FUE was observed in Red shade net with 50 % shading (168.10) followed by green-white shade net with 75 % (149.42), Green-white shade net with 35 % (106.95) and green-white shade net with 50 % (101.10). The lowest average FUE was observed in open field i.e. in control treatment (76.33). This reveals that shading net conserve fertilizer and hence enhances the FUE.

Table 4.31 Water use efficiency

Treatments	Average yield in ($kgha^{-1}$)	Net depth of water applied (mm)	Water use efficiency (kg/ha-mm)
S1 : GreenWhite shade net with 35 % shading			
T1(120% with plastic mulch)	24756.41	564.2	43.9
T2(120% ETc without plastic mulch)	26310.9	564.2	46.6
T3(100% ETc with plastic mulch)	39127.56	470.2	83.2

T4(100% ETc without plastic mulch)	28414.1	470.2	60.4
T5(80% ETc with plastic mulch)	49863.46	451.4	110.5
T6(80% ETc without plastic mulch)	39926.28	451.4	88.5
T7(60% ETc with plastic mulch)	43858.97	338.5	129.6
T8(60% ETc without plastic mulch)	34381.41	338.5	101.6
S2: 50% greenshade net			
T1(120% with plastic mulch)	38738.46	564.2	68.7
T2(120% ETc without plastic mulch)	33947.44	564.2	60.2
T3(100% ETc with plastic mulch)	47136.54	470.2	100.3
T4(100% ETc without plastic mulch)	32642.31	470.2	69.4
T5(80% ETc with plastic mulch)	44710.26	451.4	99.1
T6(80% ETc without plastic mulch)	38671.79	451.4	85.7
T7(60% ETc with plastic mulch)	43424.36	338.5	128.3
T8(60% ETc without plastic mulch)	39102.56	338.5	115.5
S3: 75 % shade net			
T1(120% with plastic mulch)	57887.18	564.2	102.6
T2(120% ETc without plastic mulch)	47403.85	564.2	84.0
T3(100% ETc with plastic mulch)	63307.69	470.2	134.6
T4(100% ETc without plastic mulch)	44309.62	470.2	94.2
T5(80% ETc with plastic mulch)	69665.38	451.4	154.3
T6(80% ETc without plastic mulch)	61464.1	451.4	136.2
T7(60% ETc with plastic mulch)	65028.85	338.5	192.1
T8(60% ETc without plastic mulch)	49896.79	338.5	147.4
S4 : Red shade net			
T1(120% with plastic mulch)	61089.74	564.2	108.3
T2(120% ETc without plastic mulch)	52210.26	564.2	92.5
T3(100% ETc with plastic mulch)	68493.59	470.2	145.7

T4(100% ETc without plastic mulch)	53427.56	470.2	113.6
T5(80% ETc with plastic mulch)	78376.03	451.4	173.6
T6(80% ETc without plastic mulch)	60601.28	451.4	134.3
T7(60% ETc with plastic mulch)	69325	338.5	204.8
T8(60% ETc without plastic mulch)	57651.92	338.5	170.3
S5 : Open field			
T1(120% with plastic mulch)	29387.18	564.2	52.1
T2(120% ETc without plastic mulch)	22166.67	564.2	39.3
T3(100% ETc with plastic mulch)	33847.44	470.2	72.0
T4(100% ETc without plastic mulch)	24102.56	470.2	51.3
T5(80% ETc with plastic mulch)	33192.31	451.4	73.5
T6(80% ETc without plastic mulch)	29783.97	451.4	66.0
T7(60% ETc with plastic mulch)	35586.54	338.5	105.1
T8(60% ETc without plastic mulch)	27666.67	338.5	81.7

Table 4.32 Fertilizer use efficiency

Treatments	Average yield in ($kgha^{-1}$)	Quantity of fertilizer applied ($kgha^{-1}$)	Fertilizer use efficiency
S1 : GreenWhite shade net with 35 % shading			
T1(120% with plastic mulch)	24756.41	466.25	53.1
T2(120% ETc without plastic mulch)	26310.9	466.25	56.4
T3(100% ETc with plastic mulch)	39127.56	466.25	83.9
T4(100% ETc without plastic mulch)	28414.1	466.25	60.9
T5(80% ETc with plastic mulch)	49863.46	466.25	106.9
T6(80% ETc without plastic mulch)	39926.28	466.25	85.6
T7(60% ETc with plastic mulch)	43858.97	466.25	94.1
T8(60% ETc without plastic mulch)	34381.41	466.25	73.7

S2 : GreenWhite shade net with 50 % shading			
T1(120% with plastic mulch)	38738.46	466.25	83.1
T2(120% ETc without plastic mulch)	33947.44	466.25	72.8
T3(100% ETc with plastic mulch)	47136.54	466.25	101.1
T4(100% ETc without plastic mulch)	32642.31	466.25	70.0
T5(80% ETc with plastic mulch)	44710.26	466.25	95.9
T6(80% ETc without plastic mulch)	38671.79	466.25	82.9
T7(60% ETc with plastic mulch)	43424.36	466.25	93.1
T8(60% ETc without plastic mulch)	39102.56	466.25	83.9
S3 : GreenWhite shade net with 75 % shading			
T1(120% with plastic mulch)	57887.18	466.25	124.2
T2(120% ETc without plastic mulch)	47403.85	466.25	101.7
T3(100% ETc with plastic mulch)	63307.69	466.25	135.8
T4(100% ETc without plastic mulch)	44309.62	466.25	95.0
T5(80% ETc with plastic mulch)	69665.38	466.25	149.4
T6(80% ETc without plastic mulch)	61464.1	466.25	131.8
T7(60% ETc with plastic mulch)	65028.85	466.25	139.5
T8(60% ETc without plastic mulch)	49896.79	466.25	107.0
S4 : Red shade net with 50% shading			
T1(120% with plastic mulch)	61089.74	466.25	131.0
T2(120% ETc without plastic mulch)	52210.26	466.25	112.0
T3(100% ETc with plastic mulch)	68493.59	466.25	146.9
T4(100% ETc without plastic mulch)	53427.56	466.25	114.6
T5(80% ETc with plastic mulch)	78376.03	466.25	168.1
T6(80% ETc without plastic mulch)	60601.28	466.25	130.0

T7(60% ETc with plastic mulch)	69325	466.25	148.7
T8(60% ETc without plastic mulch)	57651.92	466.25	123.7
S5 : Open field			
T1(120% with plastic mulch)	29387.18	466.25	63.0
T2(120% ETc without plastic mulch)	22166.67	466.25	47.5
T3(100% ETc with plastic mulch)	33847.44	466.25	72.6
T4(100% ETc without plastic mulch)	24102.56	466.25	51.7
T5(80% ETc with plastic mulch)	33192.31	466.25	71.2
T6(80% ETc without plastic mulch)	29783.97	466.25	63.9
T7(60% ETc with plastic mulch)	35586.54	466.25	76.3
T8(60% ETc without plastic mulch)	27666.67	466.25	59.3

4.10 Soil temperature

Soil temperature under different shade nets was measured at 10 cm depth throughout cucumber crop period. The variation of daily maximum and minimum soil temperature values over the crop growth period are shown from Figure 4.50 to Figure 4.54. The weekly maximum, minimum, average soil temperature values over the crop growth period are presented in Table 4.33. The soil temperature values throughout the season are presented in Table G1 of Appendix –G.

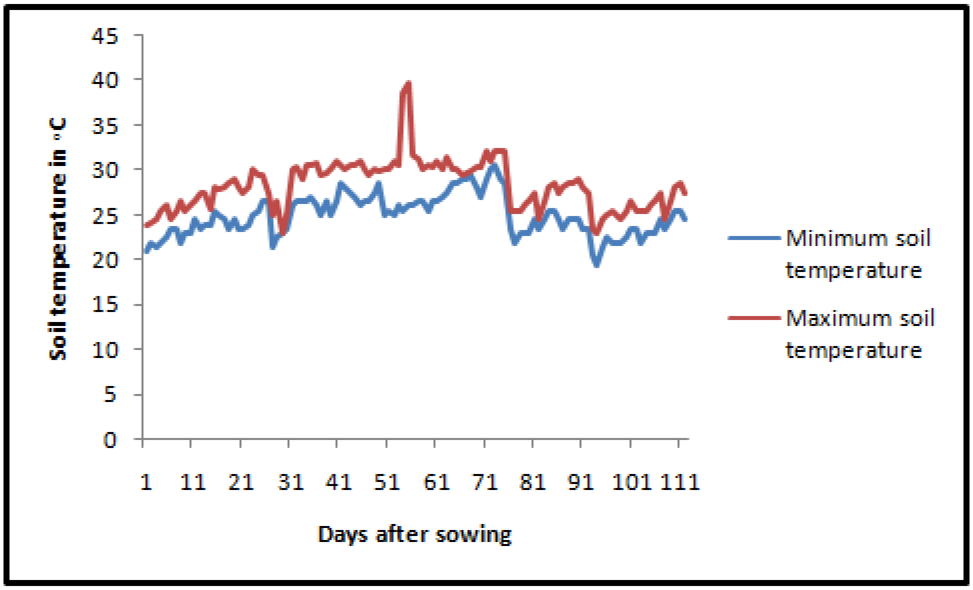

Figure 4.51 Daily variations in soil temperature under green-white shade net with 35 % shading

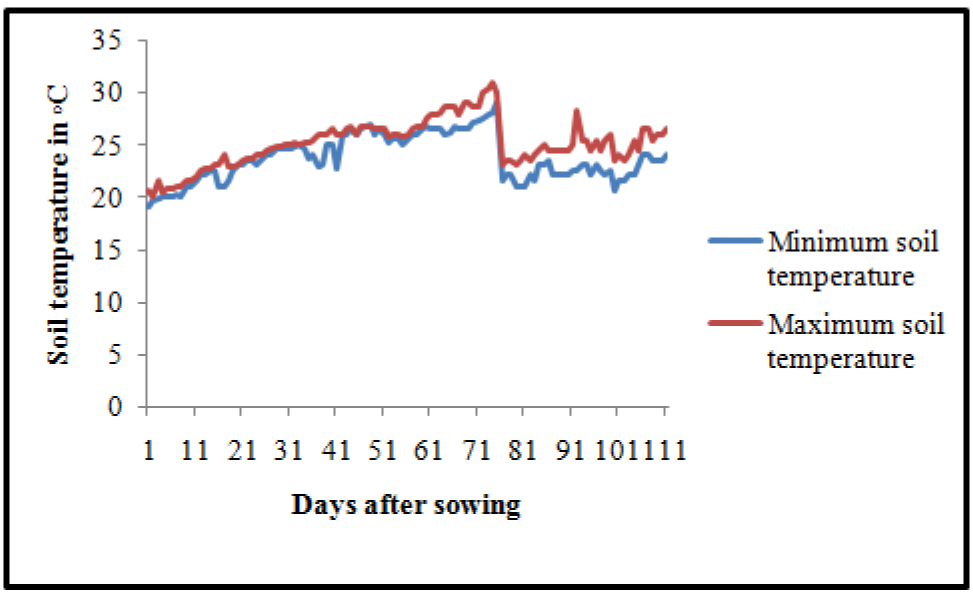

Figure 4.52 Daily variations in soil temperature under green-white shade net with 50 % shading

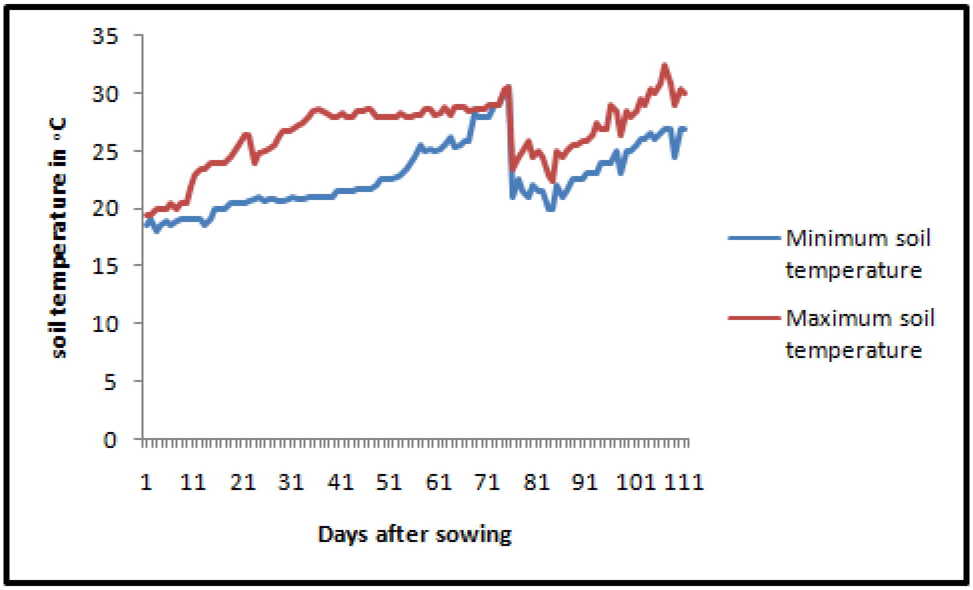

Figure 4.53 Daily variations in soil temperature under green-white shade net with 75 % shading

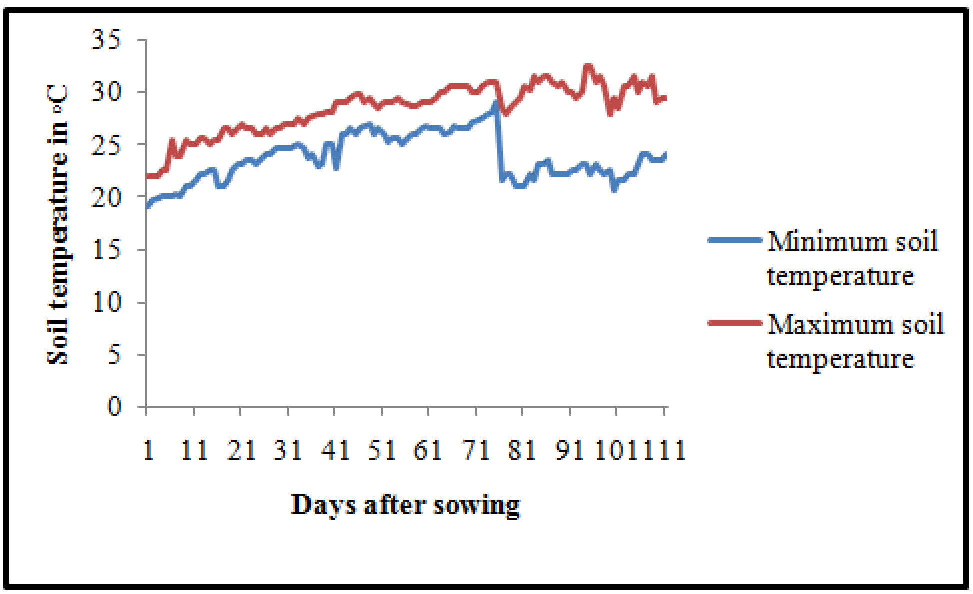

Figure 4.54 Daily variations in soil temperature under Red shade net with 50 % shading

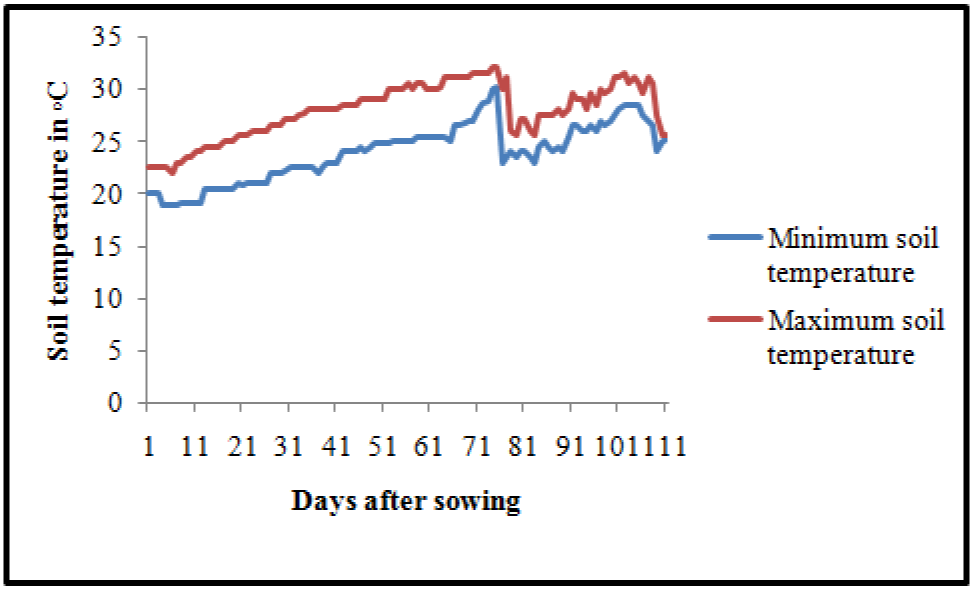

Figure 4.55 Daily variations in soil temperature under open filed

From Table 4.33, comparison among shade nets and open field reveals that the higher soil temperature values were recorded under shade net house as compared to the open field. This might be due to trapping of energy inside the shade net on account of negligible wind flow. The higher soil temperatures in the root zone of cucumber crop accelerated the microbial activities in the mulch treatment and hence the resulted in higher yield.

Average maximum soil temperature 33.5 ^{o}C was recorded in 24th metrological week in green-white shade net with 35 % shading and average minimum soil temperature 20. ^{o}C was recorded in 11th metrological week in open field. The rise in soil temperatures values in green-white shade nets due to its ability to pass the radiation through the net and trap the heat energy on account of negligible wind movement. Average maximum soil temperature of 30.2 ^{o}C was recorded in red shade net with 50 % shading this might be due to the better plant growth in this shade net which modifies the micro climate in the vicinity of the crop canopy.

Table 4.33 Weekly maximum, minimum, average soil temperature values for different treatment

Metrological week	Soil temperature (^{o}c)														
	S1			S2			S3			S4			S5		
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
9	26.5	21.5	23.8	22.5	18.5	20.6	24.5	20.0	22.4	25.5	20.5	22.5	25.5	18.0	21.2
10	27.5	22.0	24.5	23.5	20.0	22.1	26.0	20.0	22.5	25.5	22.0	23.7	25.0	21.0	23.1
11	28.5	23.5	26.3	25.0	21.0	23.1	25.0	20.0	22.6	27.0	22.5	25.0	27.0	20.0	23.3
12	30.5	23.5	26.7	28.3	22.0	23.8	27.5	21.5	24.3	27.5	23.0	25.2	27.0	21.0	24.3
13	30.5	23.0	27.6	26.0	20.5	23.6	29.0	23.0	26.0	29.0	25.0	26.8	25.0	21.0	22.8
14	31.5	23.5	27.7	26.5	21.5	23.8	32.5	25.5	28.2	31.5	26.5	28.9	27.0	22.5	24.5
15	31.5	25.0	28.0	27.5	23.5	25.3	31.5	24.5	28.8	31.0	26.5	28.7	26.0	22.0	24.0
16	31.5	25.0	28.0	27.5	23.5	25.3	31.5	24.5	28.8	31.0	26.5	28.7	26.0	22.0	24.0
17	31.5	25.0	28.5	28.5	25.0	26.4	32.5	26.0	29.8	32.5	27.0	29.3	27.0	23.0	24.9
18	32.5	26.0	28.5	28.5	24.0	26.4	29.0	23.0	26.0	31.5	26.5	28.7	28.0	23.0	25.8
19	31.5	25.0	27.6	30.5	24.0	27.3	31.0	23.5	27.0	31.5	25.5	27.9	29.5	25.5	27.5
20	30.5	25.5	28.0	32.5	26.0	29.1	34.5	28.5	31.4	31.5	26.0	28.7	31.5	26.5	29.0
21	32.5	26.5	29.6	32.0	26.5	28.8	34.5	26.5	30.8	32.0	26.5	29.6	31.0	24.0	28.0
22	32.5	26.5	29.9	33.0	28.0	30.4	32.0	25.0	28.5	31.0	26.5	28.7	31.5	26.5	29.0
23	32.5	27.0	29.9	33.0	25.5	29.9	37.5	28.5	32.3	33.5	26.0	30.4	32.0	26.5	29.5
24	33.5	30.0	31.8	33.0	27.5	30.3	34.0	29.0	31.6	32.5	29.0	31.0	32.5	27.5	30.0
Seasonal Average	30.9	24.9	27.8	28.6	23.5	26.0	30.7	24.3	27.5	30.2	25.3	27.7	28.2	23.1	25.6

4.10.1 Cost economics

The cost economics of cucumber production under different shading percentage of shade net house and different irrigation levels was worked out by considering the present price of inputs and produce and adopting the procedure as presented in section 3.7. The details are presented in table I1 of Appendix–I. While working out the cost economics, cost of cultivation, gross monetary returns, benefit cost ratio are presented in Table 4.3.4.

4.10.2 Cost of cultivation

The cost of cucumber cultivation was worked out for all treatments and data regarding cost of production is presented in Appendix –I. Comparison of cost of cultivation among the green-white and red shade net as shown in Table 4.34.It reveals that the maximum cost of production in treatment combinations S_4T_1 (In red shade net with 50 % shading and application of drip irrigation @ 120 % ETc with plastic mulch) (Rs. 28384.14 /1008 m^2). The minimum is observed in treatment S_1T_1(green-white shade net with 35 % shading and application of drip irrigation @ 120% ETc without plastic mulch) (Rs.26039.18/1008 m^2). Open field, the maximum cost of production was observed in treatment combination S_5T_1 (Rs. 363088.9/ha) and minimum in treatment combination S_5T_8 (Rs. 362778.3 /ha) i.e. control treatment.

4.10.3 Gross monetary returns

Data regarding gross monetary returns is presented in Appendix –H. The values of gross monetary returns observed in different treatment combinations were worked out and is presented in the Table 4.34. It reveals, maximum gross monetary returns of Rs. 138845 in treatment combination S_4T_5 (In red shade net with 50 % shading and application of drip irrigation @ 80 % ETc with plastic mulch) and minimum gross monetary returns Rs. 49105 in treatment S_1T_2 (green-white shade net with 35 % shading and application of drip irrigation @ 120 % ETc without plastic mulch) for shade net house of 1008 m^2 area. In open field, maximum gross monetary returns of Rs. 1021349/ha was reported in treatment combination S_5T_5 and the minimum gross monetary returns were obtained from control treatment (Rs. 511912.4/ha).

4.10.4 Net income

The values of net income observed in different treatments were worked out and presented in Appendix –H. Comparison of the values of net income among the green-white and red shade net with in Table 4.41, reveals that the maximum net income was gained from treatment combination S_4T_5 (In red shade net with 50 % shading and application of drip irrigation @ 80 % ETc with plastic mulch) (Rs. 110481.00/1008m^2) whereas minimum net income was reported in treatment combination S_1T_2 (green-white shade net with 35 % shading and application of drip irrigation @ 120 % ETc without plastic mulch) (Rs 26185.77/1008m^2). Open field, maximum gross monetary returns of Rs. 1021349/ha was reported in treatment combination S_5T_2 and the minimum gross monetary returns were obtained from control treatment (Rs. 511912.4/ha).

4.10.5 Benefit cost ratio

From Table 4.34, comparison among green-white shade net and red shade net reveals that, the benefit cost ratio was maximum in S_4T_5 (In red shade net with 50 % shading and application of drip irrigation @ 80 % ETc with plastic mulch) i. e. 2.85 and minimum benefit cost ratio was observed in treatment combination S_1T_2 (Green-white net with 35 % shading and application of drip irrigation @ 120 % ETc without plastic mulch) i.e 1.06. The economic analysis of cucumber production under open field was varied from 0.66 to 1.00.

Table 4.34 Cost economics of cucumber under different treatments

Items	Cost of cultivation (Rs./1008 m^2)	Gross monetary returns (Rs./1008 m^2)	Net income (Rs./1008 m^2)	B:C Ratio
S1: White – GreenShade net with 35 % shading				
T1(120% with plastic mulch)	26039.18	67200	41160.82	1.37
T2(120% ETc without plastic mulch)	22919.23	49105	26185.77	1.06
T3(100% ETc with plastic mulch)	26027.79	70035	44007.21	1.45
T4(100% ETc without plastic mulch)	22909.44	50365	27455.56	1.15

T5(80% ETc with plastic mulch)	26018.96	92540	66521.04	2.03
T6(80% ETc without plastic mulch)	22899.57	69755	46855.43	1.61
T7(60% ETc with plastic mulch)	26008.35	78015	52006.65	1.62
T8(60% ETc without plastic mulch)	22889.29	59885	36995.71	1.39
S2: White – GreenShade net with 50 % shading				
T1(120% with plastic mulch)	26226.12	71750	45523.9	1.36
T2(120% ETc without plastic mulch)	23109.54	59150	36040.5	1.73
T3(100% ETc with plastic mulch)	26217.59	77490	51272.4	1.31
T4(100% ETc without plastic mulch)	23098.01	59500	36402.0	1.73
T5(80% ETc with plastic mulch)	26205.99	87850	61644.0	1.55
T6(80% ETc without plastic mulch)	23086.88	70315	47228.1	1.40
T7(60% ETc with plastic mulch)	26195.67	81830	55634.3	1.57
T8(60% ETc without plastic mulch)	23077.66	70350	47272.3	1.36
S3: White – GreenShade net with 75% shading				
T1(120% with plastic mulch)	26226.9	103740.0	77513.1	2.13
T2(120% ETc without plastic mulch)	23107.1	85645.0	62537.9	2.14
T3(100% ETc with plastic mulch)	26216.7	115850.0	89633.3	2.33
T4(100% ETc without plastic mulch)	23097.4	79730.0	56632.6	1.78
T5(80% ETc with plastic mulch)	26206.2	115500.0	89293.8	2.63
T6(80% ETc without plastic mulch)	23088.4	80430.0	57341.6	2.47
T7(60% ETc with plastic mulch)	26195.8	112455.0	86259.2	2.32
T8(60% ETc without plastic mulch)	23077.1	88655.0	65577.9	2.01
S4: Red Shade net with 50 % shading				
T1(120% with plastic mulch)	28384.14	110250.00	81865.86	2.22
T2(120% ETc without plastic mulch)	25264.33	92400.00	67135.67	2.08
T3(100% ETc with plastic mulch)	28373.97	124425.00	96051.03	2.49
T4(100% ETc without plastic mulch)	25254.61	95095.00	69840.39	2.12
T5(80% ETc with plastic mulch)	28363.44	138845.00	110481.56	2.85

T6(80% ETc without plastic mulch)	25245.68	107520.00	82274.32	2.41
T7(60% ETc with plastic mulch)	28353.09	128310.00	99956.91	2.28
T8(60% ETc without plastic mulch)	25234.32	101605.00	76370.68	2.29
S5: Open field				
T1(120% with plastic mulch)	105929.6	738126.07	-236653.14	0.64
T2(120% ETc without plastic mulch)	32698.8	511912.39	-243176.50	0.66
T3(100% ETc with plastic mulch)	105929.6	844644.23	-130019.51	0.73
T4(100% ETc without plastic mulch)	32698.8	589966.88	-165022.95	0.76
T5(80% ETc with plastic mulch)	105929.6	1021349.36	46776.39	0.79
T6(80% ETc without plastic mulch)	32698.8	769132.48	14258.25	1.00
T7(60% ETc with plastic mulch)	105929.6	865913.46	-108564.22	0.75
T8(60% ETc without plastic mulch)	32698.8	697083.33	-57695.01	0.90

Figure 4.56 shows the variation in benefit cost ratio over different treatments of shading percentage of shade net with and irrigation levels.

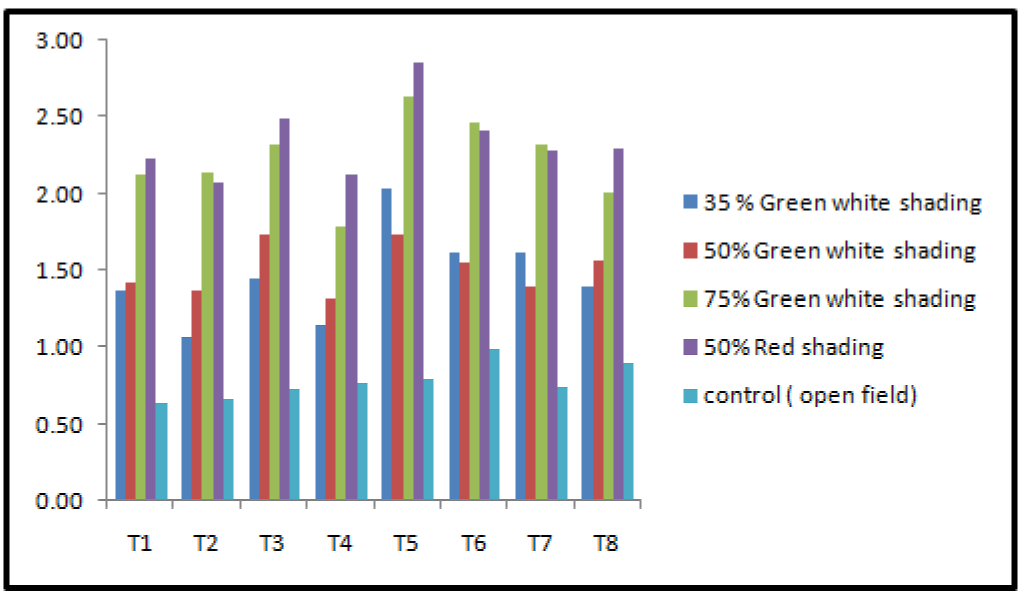

Figure 4.56 Benefit cost ratio observed in different treatments

4.11Crop water production function

4.11.1 Crop water production function mulch treatment

A curvilinear second order polynomial relationship is observed for CWPF for treatments with mulch. Evapotranspiration (mm) and crop yield for various treatments (t/ha) with mulch is shown in Table 4.35. The developed relationship is shown in Figure 4.57 to 4.61 and the equations are shown in Table 4.35.

Table 4.35 Evapotranspiration (mm) and crop yield for various treatments (t/ha) with mulch

Main Treatments	Sub Treatments	Crop evapotranspiration (mm)	Total Yield (t/ha)
S1	T1	564.2	24.76
	T3	470.2	26.09
	T5	451.4	36.64
	T7	338.5	29.24
S2	T1	564.2	23.00
	T3	470.2	31.20
	T5	451.4	30.54
	T7	338.5	24.32
S3	T1	564.2	38.59
	T3	470.2	42.24
	T5	451.4	47.68
	T7	338.5	42.07
S4	T1	564.2	42.07
	T3	470.2	40.73
	T5	451.4	52.25
	T7	338.5	45.66

S5	T1	564.2	41.70
	T3	470.2	19.59
	T5	451.4	22.56
	T7	338.5	22.13

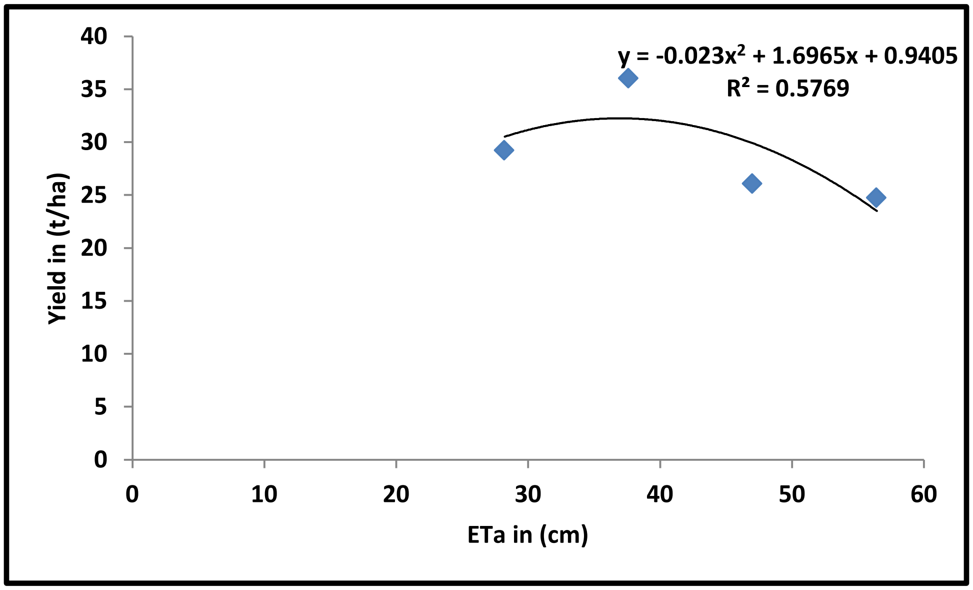

Figure 4.57 Crop water production function for 35% shading of green-white shade net with plastic mulch

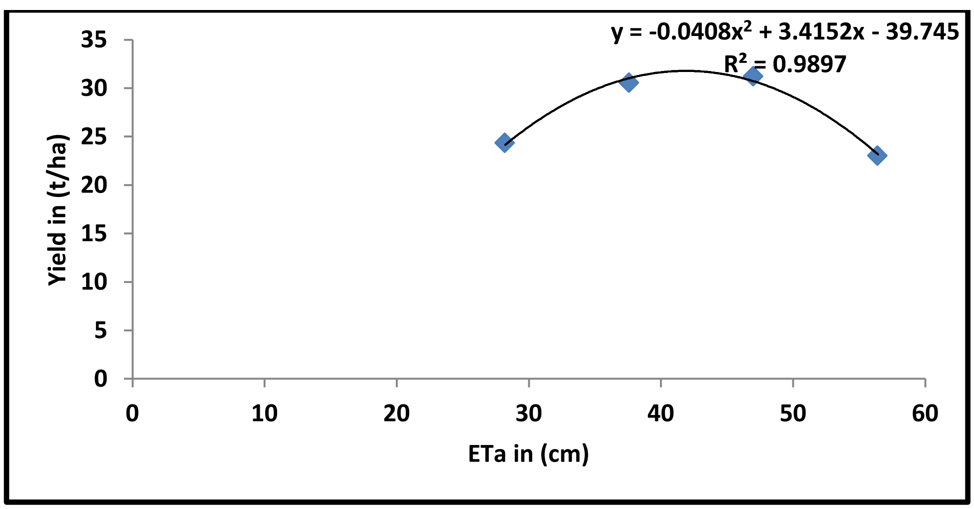

Figure 4.58 Crop water production function for 50% green-white shade nets with mulch

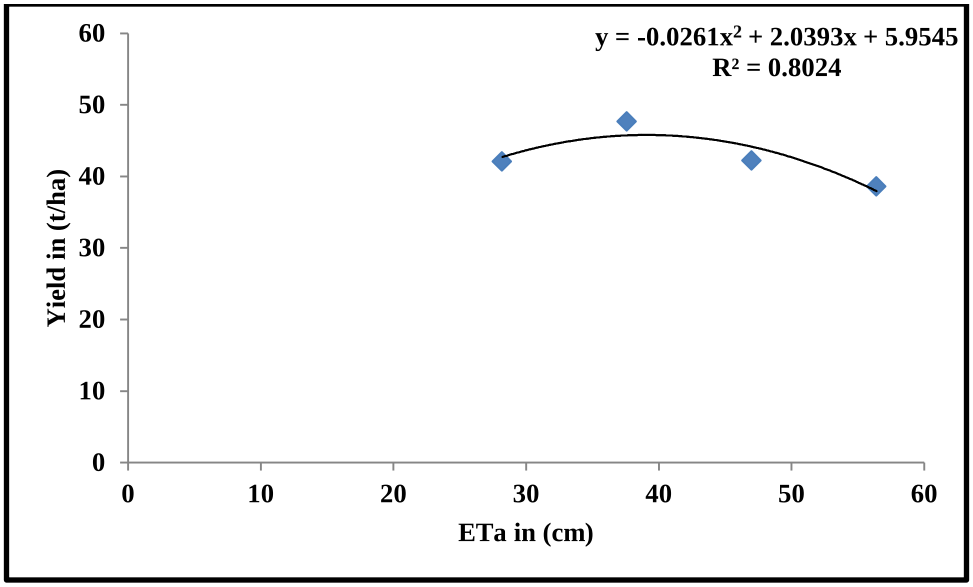

Figure 4.59 Crop water production function for 75% green-white shade nets with mulch

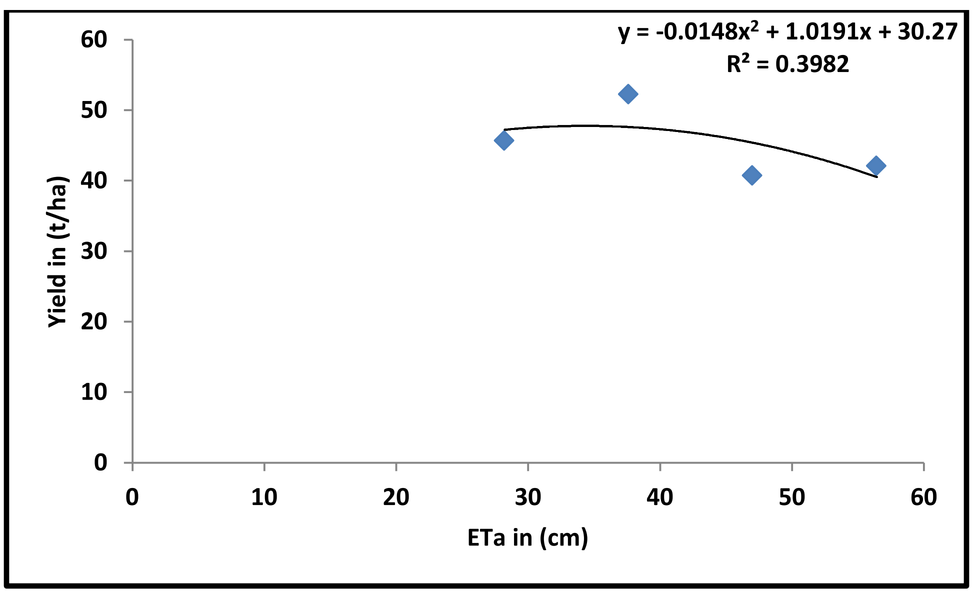

Figure 4.60 Crop water production function for 50% red shade nets with mulch

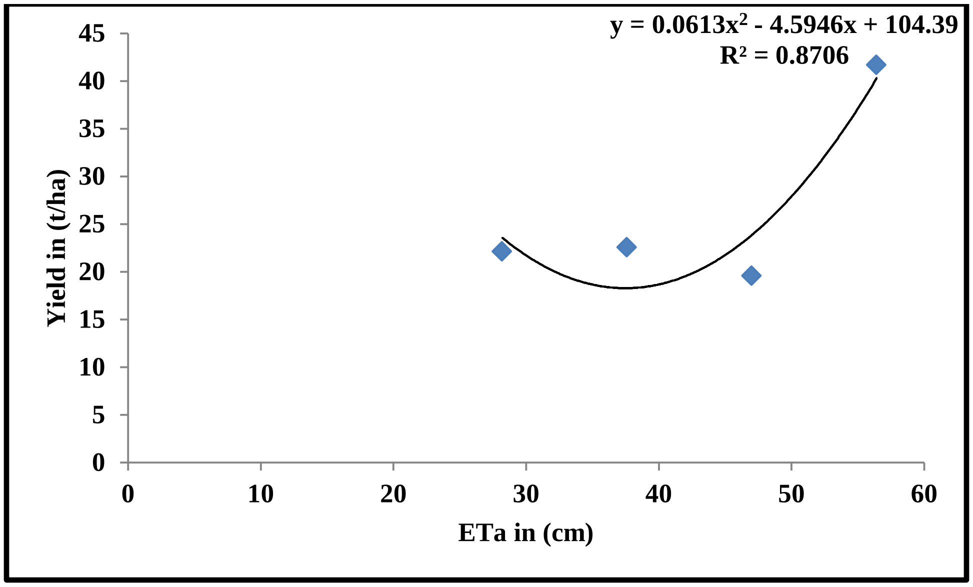

Figure 4.61 Crop water production function for open filed with mulch

Table 4.36 Crop water production functionfor different treatments with mulch

Treatment	**Crop water production function equations**	R^2
S1 (Green-white net 35% shading)	$y = -0.023x^2 + 1.696x + 0.940$	$R^2 = 0.576$
S2(Green-white net 50% shading)	$y = -0.040x^2 + 3.415x - 39.74$	$R^2 = 0.989$
S3(Green-white net 75% shading)	$y = -0.014x^2 + 1.019x + 30.27$	$R^2 = 0.398$
S4(Red net 50 % shading)	$y = -0.014x^2 + 1.019x + 30.27$	$R^2 = 0.398$
S5(open/ control treatment)	$y = 0.061x^2 - 4.594x + 104.3$	$R^2 = 0.870$

Where,

Y= Cucumber crop yield (t/ha) obtained from mulched treatments

X= Seasonal evapotranspiration (mm) from mulched treatments

4.11.2 Crop water production functions without mulch

A curvilinear second order polynomial relationship is observed for CWPF for treatment without mulch. Evapotranspiration (mm) and crop yield for various treatments (t/ha) without mulch is shown in Table 4.37. The developed relationship is shown in Figure 4.61to 4.65 and the equations are shown in Table 4.38.

Table 4.37 Evapotranspiration (mm) and crop yield for various treatments (t/ha) with mulch

Main Treatments	Sub Treatments	Evapotranspiration (mm)	Total Yield (t/ha)
S1	T2	564.2	17.54
	T4	470.2	18.94
	T6	451.4	26.62
	T8	338.5	22.92
S2	T2	564.2	20.95
	T4	470.2	20.94
	T6	451.4	23.15
	T8	338.5	22.96
S3	T2	564.2	31.60
	T4	470.2	29.54
	T6	451.4	40.98
	T8	338.5	33.26
S4	T2	564.2	33.26
	T4	470.2	34.81
	T6	451.4	35.62
	T8	338.5	40.40
S5	T2	564.2	38.43
	T4	470.2	14.78
	T6	451.4	16.07
	T8	338.5	19.86

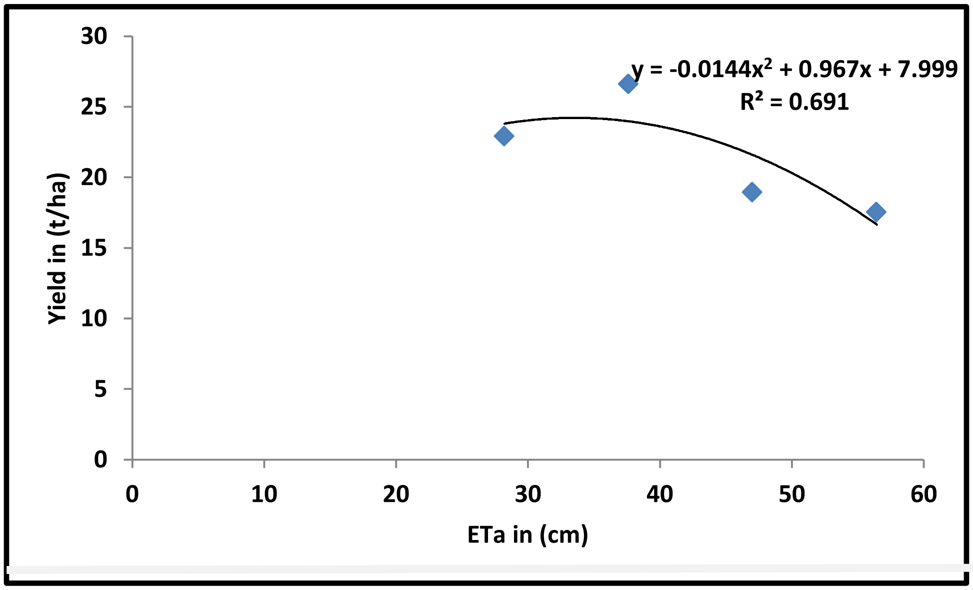

Figure 4.62 Crop water production function for 35% green-white shade nets without mulch

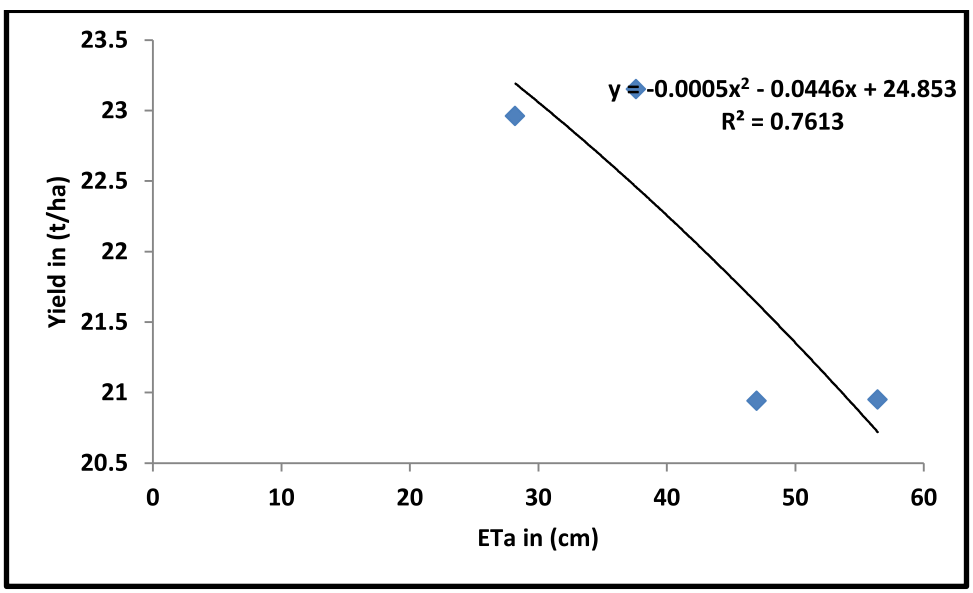

Figure 4.63 Crop water production function for 50% green-white shade nets without mulch

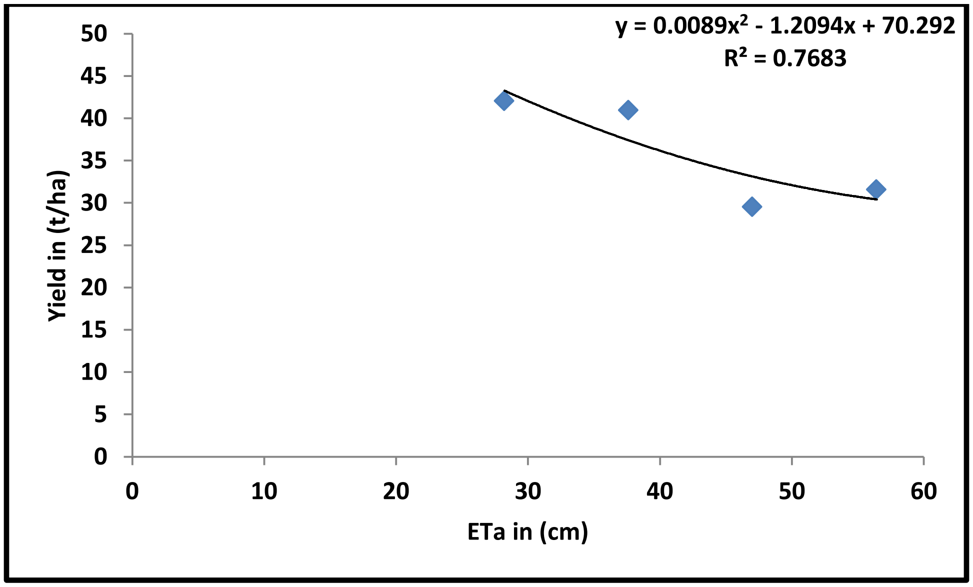

Figure 4.64 Crop water production function for 75% green-white shade nets without mulch

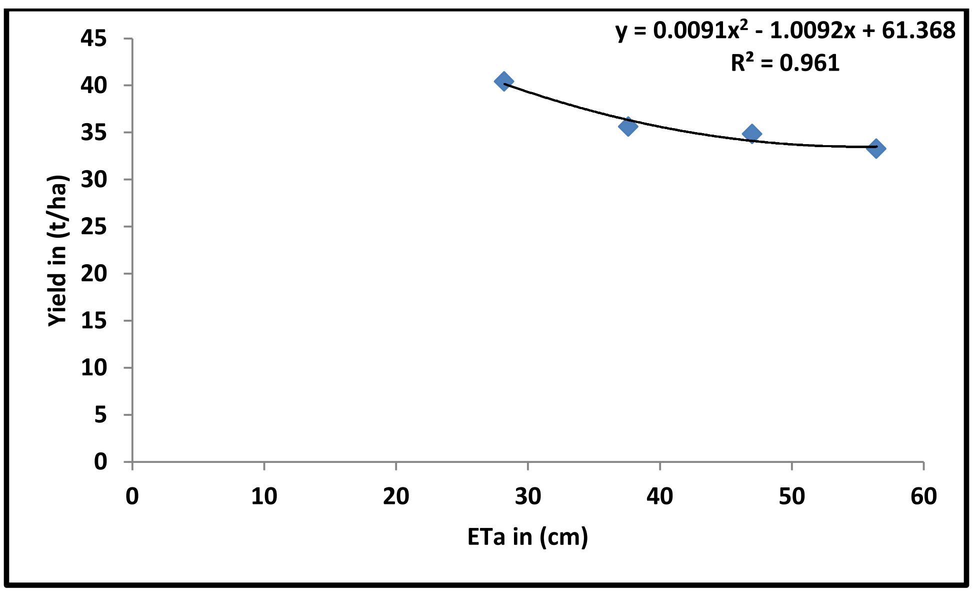

Figure 4.65 Crop water production function for Red 50% shade nets without Mulch

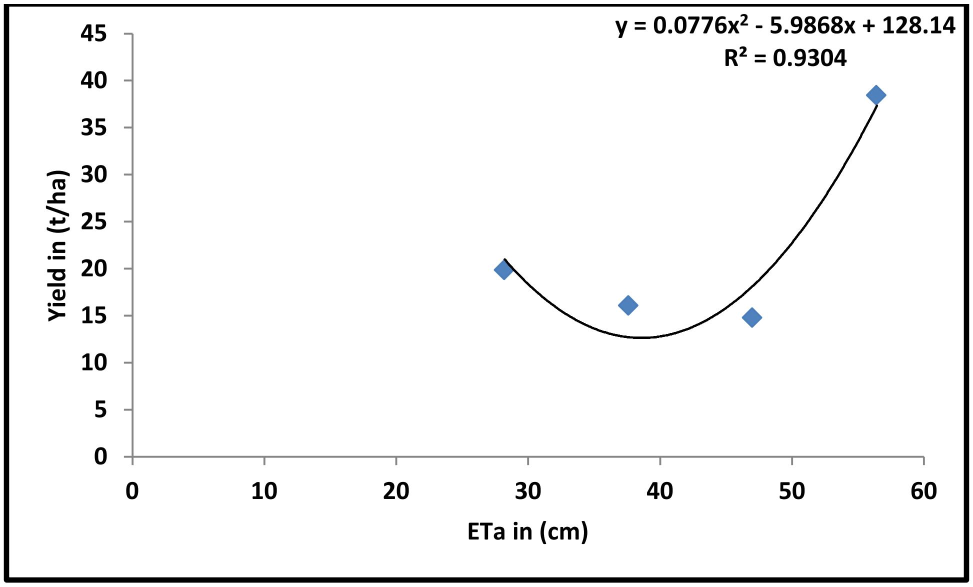

Figure 4.66 Crop water production function for open field (control) shade nets without mulch

Table 4.38 Crop water production function for different treatments without mulch

Treatment	Crop water production function equations	R^2
S1 (Green-white net 35% shading)	$y = -0.014x^2 + 0.967x + 7.999$	$R^2 = 0.691$
S2(Green-white net 50% shading)	$y = -0.000x^2 - 0.044x + 24.85$	$R^2 = 0.761$
S3(Green-white net 75% shading)	$y = 0.008x^2 - 1.209x + 70.29$	$R^2 = 0.768$
S4(Red net 50 % shading)	$y = 0.009x^2 - 1.009x + 61.36$	$R^2 = 0.961$
S5(open/ control treatment)	$y = 0.077x^2 - 5.986x + 128.1$	$R^2 = 0.930$

Where,

Y= Cucumber crop yield (t/ha) obtained from non-mulched treatments

X= Seasonal evapotranspiration (mm) from non-mulched treatments

5. Summary and Conclusions

The field experiment entitled "Yield Response of Drip Irrigated Cucumber to Mulch and Irrigation Regimes under Different Shading Nets" was carried out at Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist– Ahmednagar (M.S.) during the summer season, Feb, 2015 – June, 2015.The experiment was conducted by adopting split plot design with five main treatments (0, 35, 50, 75 % shading Green-white shade net and Red shade net with 50 % shading), eight irrigation sub-treatments with three replications. The sowing was done on the date 06^{th} February, 2015 and harvested up to 05^{th} June, 2015.

5.1 Summary

5.1.1 Physical and chemical properties of the soil/media

The soil media in shade net house consist of red soil, farm yard manure (FYM) and sand mixed with wheat husk in the proportion of 1:1:1:1. .The available N, P and K for media in shade net house was 190.12, 43.12 and 200.12 kg ha^{-1}, respectively and that of for soil in open field was 150.13, 60.12 and 380 kg/ha^{-1}, respectively . The open field soil had textural class clay (sand, silt and clay 26%, 23 and 58.50 %, respectively) .The field capacity and permanent wilting point in media was 22.4 % and 16.68 %, respectively. Available moisture in media and soil was 7.35 % and 9.67 %, respectively. The bulk density of media and soil was 1.44 g cm^{-3} and 1.32 g cm^{-3}, respectively. The media was weakly alkaline to reaction (pH 7.51) and EC was 0.57 dSm^{-1}. Thus, indicating media and soil both, fit for seed germination.

5.1.2 Chemical properties of water

The water source was open dug well. The water used for irrigation had EC, pH and SAR value 0.57 dSm^{-1}, 7.51 and 1.12 respectively. water quality was C_2S_1.

5.1.3 Fertilizer application

Fertilizers were applied through drip irrigation system to meet the nutritional requirement of the crop as per the laid treatments. The water soluble fertilizers *viz.* 19:19:19, urea, 13:00:45 were used for fertigation through drip irrigation system NPK @ 125:62.5:62.50.

5.1.4 Emission uniformity

The field emission uniformity was calculated by randomly collecting discharges from drippers from different treatments and replications. The field emission uniformity was observed to vary from 90.44 to 95.46 %for the drip irrigation system. The installed drip system had excellent emission uniformity resulting in uniform distribution of water and injected fertilizer to the cucumber crop.

5.1.5 Water requirement

The actual climatological data was recorded during the crop growth period (Feb, 2015 to June, 2015) on daily basis at meteorological observatory situated at the Instructional Farm of Department of Irrigation and Drainage Engineering, Dr. ASCAE, Mahatma Phule Krishi Vidyapeeth, Rahuri. By using these climatological data, irrigation @ 60, 80, 100 and 120 % of ETc were applied on daily basis throughout the season. The daily reference evapotranspiration was estimated using Penman –Monteith equation. The crop water requirement was estimated from the daily reference evapotranspiration and the daily Kc values.

The total net water requirement of cucumber was found to be for 120 % ETc 602.80 mm, for 100% ETc 493.89 mm, for 80% ETc 400.16 mm and 60 % ETc 310.10 mm respectively.

5.1.6 Biometric observations

After analyzing the statistical data, it was observed that the red shade net with 50 % shading had maximum fruit diameter (3.61 cm), fruit length (15.18 cm), fruit weight (207.14 g), number of fruits per vine (12.67), length of vine at last harvest (4.74 m), yield per vine (2.21 kg), total yield (52.25 t ha^{-1}). The days to 50 % flowering were recorded early in red shade net with 50 % shading. Among the different agrotechique treatments, treatments T_5 i.e. drip irrigation @ 80% of ETc with plastic mulch recorded maximum fruit diameter (3.52 cm) and fruit length (15.31 cm). The maximum fruit weight (176.29 g), yield per vine (1.69 kg), length of vine at last harvest (4.74 m) and early flowering was observed in treatment T_5 i.e. drip irrigation @ 80% of ETc with plastic mulch. The maximum number of fruits (12.67) and yield (52.25 t ha^{-1}) was observed in treatment T_5 (Drip irrigation @ 80% of ETc with plastic mulch). This may be either due to better utilization of available water in the mulched treatments. The modified spectral environment might also have resulted in better assimilation of the nutrients and minerals.

5.1.7 Water use efficiency

Among the green-white shade net with 35% shading percentage ranged from 129.55 to 43.87 kg/ha-mm and maximum WUE observed in treatment T_7. WUE in green-white shade net with 50 % shading ranges from 128.27 to 60.16 kg/ha-mm and maximum WUE observed in treatment T_7. WUE in green-white shade net with 75 % shading ranges from 192.09 to 84.01 kg/ha-mm and maximum WUE observed from treatment T_7. Further, WUE in red shade net with 50 % shading ranges from 204.78 to 92.53 kg/ha-mm and maximum WUE observed from treatment T_7. Lowest WUE was observed in the control treatments.

5.1.8 Fertilizer use efficiency

Among the green-white shade net, the FUE was observed to vary in 35 % shading, FUE ranges from 53.10 to 106.95 and maximum FUE recorded in treatment T_5. In green-white shade net with 50 % shading, FUE ranges from 70.01 to 101.10 and maximum FUE recorded from treatment T_3. In green-white shade net with 75 % shading, FUE ranges from 95.03 to 149.42 and maximum FUE recorded from treatment T_5. Further, FUE in red shade net with 50 % shading ranges from 111.98 to 168.10 and maximum FUE observed from treatment T_5. Lowest FUE was observed in the control treatments.

5.1.9 Cost economics

The benefit cost ratio was maximum in S_4T_5 (red shade net with 50 % shading and application of drip irrigation @ 80% of ETc with plastic mulch) i. e. (2.85). This was followed by treatment S_3T_5 (2.63), S_1T_5 (2.03), and S_2T_3 (1.73). Minimum benefit cost ratio was observed in treatment combination S_1T_2 (green-white shade net with 35% shading and application of drip irrigation @ 120% of ETc without plastic mulch) i.e.1.06. The maximum cost of production was observed in treatment combinations S_4T_1 (Rs. 28363.14 /1008 m^2) and minimum in treatment S_1T_8 i.e. green-white shade net with 35 % shading and application of drip irrigation @ 60 % ETc without plastic mulch (Rs.2639.18/1008 m^2). The maximum gross monetary returns of Rs. 138845.00/1008 m^2 was reported in treatment combination S_4T_5 (red shade net with 50 % shading and application of drip irrigation @ 80 % ETc with plastic mulch and minimum gross monetary returns (Rs. 49105/1008 m^2) was obtained from S_1T_2 (green-white shade net with 35% shading and application of drip irrigation @ 120 % ETc without plastic mulch. The maximum net income was obtained from treatment combination S_4T_5 (Rs. 11048.56/1008 m^2) whereas minimum net income was reported in treatment combination S_1T_2 (green-white shade net with 35 % shading and application of drip irrigation @ 120 % ETc without plastic mulch i.e. Rs. 26185.77/1008 m^2.

5.2 Conclusions

From the results of the present investigation, the following conclusions are drawn:

1. The total net water requirement of cucumber crop based on irrigation @ 60 % ETc, 80 % ETc, 100 % ETc and 120 % ETc were found to be 310.10 mm, 400.16 mm, 493.89 mm and 602.80 mm respectively.
2. The mean air temperature variations from 41.6 to 25.6 ^{0}C, mean relative humidity variation from 98 to 22.00 %, mean sunshine hour's variation from0.70 to 9.10 hrs, wind speed variation from0.20to 9.50 km hr^{-1} under open field condition proved to be adverse for off season cucumber cultivation.
3. Application of drip irrigation @ 80% of ETc with silver black plastic mulch resulted in higher yield (52.25 t ha^{-1}) as compared to all other irrigation treatments under study.
4. The water use efficiency in red shade net house with 50 % shading was highest (204.78 to 92.53 kg/ha-mm) among all other main treatments (S_4). The WUE in green-white shade net was found to vary in range from (43.87 to 192.09), whereas Lowest WUE was observed in control treatment.
5. The fertilizer use efficiency in red shade net house with 50 % shading was highest (168.10) among all other main treatments. The FUE in green-white shade net was found to vary in range from (53.10 to 149.42), whereas minimum FUE was reported in open field.
6. The climatological condition in red shade net house with 50 % shading was found to be optimal for off season production of cucumber crop under semi-arid regions with yield of (52.25 t ha^{-1}).
7. Among the different irrigation treatments the B:C ratio was observed maximum in red shade net house with 50 % shading and application of drip irrigation @ 80% of ETc with silver black plastic mulch. The interaction effect

of shading and irrigation treatments indicated highest B: C ratio for S_4T_5 (2.85). The maximum net income was also observed in red shade net house with 50 % shading, in treatment combination S_4T_6 (Rs. 110481.56/1008 m^2).

8. Overall it is recommended to grow Cucumber in red shade net with 50 % shading with drip irrigation @ 80% of ETc with silver black plastic mulch during summer season under semi-arid condition of Rahuri, district Ahmednagar of Maharashtra State.

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