SPECTRAL MANIPULATION OF GROWTH AND PHYSIOLOGY OF *Gerbera jamesonii* Bolus

by

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(2017-11-136)

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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COLLEGE OF HORTICULTURE
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VELLANIKKARA, THRISSUR- 680656
KERALA, INDIA

2020

DECLARATION

I hereby declare that the thesis entitled "Spectral manipulation of growth and physiology of *Gerbera jamesonii* Bolus" is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara
12/11/2020

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CERTIFICATE

Certified that this thesis entitled **"**Spectral manipulation of growth and physiology of *Gerbera jamesonii* Bolus" is a bonafide record of research work done independently by **Anil A. S (2017-11-136)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associate ship or fellowship to him.

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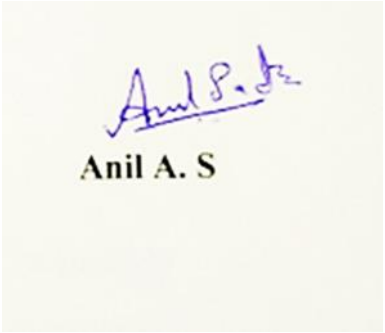

Anil A. S

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Abbreviations

DNA	Deoxyribonucleic Acid
FW	Fresh weight
GA	Gibberellic acid
HPS	High pressure sodium
IAA	Indole-3-actic acid
LED	Light emitting diode
NRA	Nitrogen reductase enzyme activity
PAR	Photosynthetically active radiation
SLA	Specific leaf area
UV	Ultra violet

Dedicated to my family and teachers

Introduction

1. INTRODUCTION

Floriculture has gained an important position in commercial trade. In India the sector has immense potential for small and marginal entrepreneurs. Flowers are intimately associated with many social and religious functions. Production of high value cut flowers has emerged as a profitable agribusiness venture. Gerbera is an important cut flower which ranks 6 th in international trade (Acharya *et al*., 2010). It is widely used in stage decoration and flower arrangements. The flowers are available in a wide range colors as red, white, pink. It has good shelf life and due to its aesthetic value, it is an ideal cut flower for decorative purpose.

Gerbera is a perennial herb native of South Africa and Asia and belongs to the family *Asteraceae.* Of all the recorded species, *Gerbera jamesonii* Bolus is the most popular one under cultivation.

A flower cannot blossom without sunshine. Greenhouse floriculture is gaining a lot of importance worldwide. Gerbera is a heliophyte plant, which prefer high sunshine and cool weather. Gerbera grows well in optimum temperature of 12-25^{0}C and rainfall (500-625 mm). Poor light during rainy season in Kerala adversely affects flower production. The high humidity and excessive rainfall encourage fungal diseases while high temperature during summer season enhances pre harvest stem break. Hence, it is advisable to protect this crop during both summer and rainy season.

Light is one of the most important environmental factors affecting survival, growth and reproduction of gerbera plants. It affects photosynthesis and is related to the accumulation of organic matter and biomass.

Gerbera requires high light intensities for good vegetative growth and flower yield (Kessler 1999). The flower grows well in Kerala climate. The average sunshine hours in open condition in the central zone of Kerala during January to May goes upto 8.1 h/day while during June-September is only 3h/day as per the 33 year mean data

available with the Agro Meteorology Observatory COH, Vellanikkara. This shortage in the sun shine hours can be substituted by the use of external light in net houses. When light is provided at the optimal levels it can significantly increase the growth rate, health and yield of the crop (Darko *et al*., 2014). Thus, growing gerbera with supplementary external light is recommended.

Currently a number of light sources and polyhouse technologies are available for commercial cultivation. High pressure sodium lamp, incandescent lights, fluorescent tube lights are being used in horticulture to control photoperiods (Gomez, 2014). New sources of light for photoperiodic manipulations for horticultural applications, intending to replace high pressure sodium (HPS) lamps or fluorescent tubes, are currently being introduced in the market. Special attention is being devoted to light emitting diodes (LED) technology, which are generally assumed to be more efficient for driving photosynthesis to optimum range (Bergstrand and Schussler 2012).

Similarly, polythene sheets which can filter UV radiation and those which permit UV radiations are also available in the market. UV radiation have adverse effect on growth and development of plants (Stefani *et al*., 2007).

Since LED's are available in different colors, possibility for manipulating growth with different spectral frequency is also possible. Studies by Kessler (1999) has shown that red and blue bands are more important for growth, yield and quality of crop.

Considering the growing interest in green house floriculture the present study was proposed with the following objectives.

1. To understand the effect of UV light on gerbera under polyhouse condition.
2. To study the effect of different spectral radiation on *Gerbera jamesonii*. Bolus

Review of literature

2.REVIEW OF LITERATURE

Tropical climate of Kerala is generally suitable for commercial cultivation of Gerbera. However low light condition during June to September affects flower production. Use of supplementary light sources in polyhouses can serve as a panacea to this problem. The influence of light intensity duration and quality on morphogenesis and quality of plants as well as the effect of using LED's as a supplementary light source on growth and productivity of gerbera is reviewed in this chapter.

2.1 Cultivation of gerbera and its scope as a commercial crop

Among the different flowering plants of the genus of Gerbera, *Gerbera jamesonii* Bolus is the only species under cultivation. Popular gerbera cultivars are hybrids derived from a cross between *Gerbera jamesonii* Bolus and *Gerbera viridifolia* and possibly other varieties (Leffring, 1973). Attavar (1993) reported that fluctuating environmental conditions influence cultivation of gerbera under open condition and suggested polyhouse structures suitable for protected cultivation of the plant. These structures protect gerbera plants from wind, excess precipitation, extensive radiation, temperature extremes, diseases and pests. Protected cultivation facilitates quality improvement and multifold productivity enhancement which helps to compete in global market (Gajanana *et al*., 2003). Gerbera is very fashionable and widely used as a decorative garden flower or cut flower (Kanwar and Kumar, 2008).

2.2 Influence of Light on morphogenesis

Plants react to changes in the electromagnetic radiation spectrum to which they are exposed by altering their morphology and physiological functions which contributes to adaptation to different environmental conditions (Kasperbauer and Hamilton, 1984). To sustain higher photosynthetic capacity or survival, plants modify

their morphology and biomass allocation at different light conditions (Den Dubbleden and Oosterbeek (1995). The diverse responses of plants to light requires sophisticated sensing of its quantity (fluence rate), quality (wavelength, i.e., color), direction, and duration (photoperiod) (Christie and Briggs, 2001). Light is the most important environmental factor affecting yield because plant growth and yield depend on photosynthesis (Yamori, 2016). Plant morphology, physiology, and biochemistry also varies with light source (Macedo *et al.*, 2011). Light spectrum influences photosynthetic process by adjusting stomatal development and movement, photosynthetic pigment level, and photosynthetic protein biosynthesis (Jin *et al*., 2018)

2.2.1 Effect of light intensity

Light intensity is the amount of light reaching the plant canopy and is a critical factor that influences crop physiology and biochemistry (Dorais ,2003). Ghasemzadeh (2011) reported that phenolic acids and flavonoids are absolutely light dependent and their biosynthetic rate is related to light intensity in *Zingiber officinale*. At high light intensity, leaf area and petiole length were smaller than at low light intensity in accessions of *Centella asiatica* (Srithongkul *et al*., 2011). Radusiene *et al*. (2010) reported that increase in light intensity from 800 to 1618 μmol m^{-2} s^{-1} lead to continuous increase in content of bioactive compounds in flowering plant St John‟s wart (*Hypericum perforatum*). Microscopic studies conducted by Cruz *et al*. (2012) showed deposition of anthocyanins in the tissues adjacent to the epidermis and cortex, of *Kalancho brasiliensis* stems increased with light intensity. According to Wu *et al*. (2017) crop plants produce smaller and thinner leaves when exposed to low light conditions as compared to full sunlight.

2.2.2 Effect of Light duration (Seasons)

Leffring (1973) found that there is a strong positive correlation between flower production and the number of lateral shoots in gerbera. Lateral shoot formation in some gerbera cultivars was influenced by photoperiod, short days had a positive influence

on the number of shoots and flower yield. Studies conducted by Rotor (1959) indicated that flowering of *Cattleya sps.* was promoted by exposure to short day length condition. Flowering was induced when the plants were placed under 9 h photoperiod while it was inhibited under 16 h photoperiod. Flower bud development and flowering was accelerated by six weeks in Dendrobium plants which were kept under 9 h photoperiod as compared to plants kept under long day condition (Rogers 1995). Light period exerts the most important effect on altering the growth and essential oil production of Japanese mint (Malayeri *et al.,* 2010)

2.3 Effect of Spectral Quality

2.3.1 Red light

Plants cultivated under red light had extended internodal length (Machin *et al*., 1978). Red light is important for stimulating flowering in long-day plants (Deitzer *et al*., 1979) as well as for promoting internode elongation (Morgan and Smith, 1979). A comparison of photosynthetic rates of strawberry (*Fragaria ×ananassa L*.) leaves with red (660 nm) and blue (450 nm) LED's showed higher quantum efficiencies under red colour (Yanagi *et al*., 1996). Red light induced stomatal opening due to a combination of intercellular reduction of CO_2 concentration and a direct response of the guard cell chloroplasts to red light (Roelfsema and Hedrich, 2005). Red light usually is the basal component in lighting spectra and sole red light is sufficient for normal plant growth and photosynthesis. Light quality and quantity initiate signaling cascade of specific photoreceptors, such as phytochromes, cryptochromes, and phototropins, which alter the expression of a large number of genes (Falciatore and Bowler, 2005). Short term pre-harvest treatment with red 640 nm LED's in controlled environment resulted in enhanced lutein, glucosinolate and sinigrin accumulation in red-leaf cabbages (Lefsrud *et al*., 2008). Red light with wavelength of 640 nm have been reported to increase the total biomass content in *Lactuca sativa L* (Stutte *et al*., 2009). Red light supplemental

(658 nm) for cool white fluorescent lamps resulted in 6% higher phenolics concentration in baby leaf lettuce (Li and Kubota, 2009). Red light (660 nm) applied as sole light source in the controlled environment stimulated anthocyanin accumulation in red leaf cabbages as compared to blue or green LED wavelengths (Olle and Virsile, 2013). Craig and Runkle (2012) concluded that the LED treatment with red wavelength was effective for promoting flowering in petunia and snapdragon but inhibited flowering in marigold. Red light affects stem elongation, leaf extension, bud outgrowth, and photosynthetic apparatus (Wang *et al*., 2016).

2.3.2 Blue light

Blue light has a variety of important photomorphogenic roles in plants such as phototropism (Withrow,1940). According to Machin and Scopes (1978) Chrysanthemum plants grown in blue or high percentage of blue light produced short internodes, large leaves and flowers, foliage appeared thick as compared to the plants grown under natural light.

Blue light was reported to inhibit the hypocotyl elongation in lettuce seedling and had great effect on photo-morphogenesis of plants (Hoenecke *et al*., 1992). Positive effects of blue light, activating cryptochrome system and matching chlorophyll and carotenoids absorption spectra, were demonstrated on green vegetable, growth and photosynthesis (Yanagi *et al*., 1996). According to Shimizu *et al*. (2005) shorter wavelengths, such as the blue spectrum are more energetic. Photosystem 1 and photosystem 2 function as the blue light receptors and are involved in the stomatal response, contributing to increased stomatal conductance (gS) (Doi *et al*., 2004). Wang *et al*. (2016) stated that blue light is known to have numerous effects on plant growth and development including stomata functioning, photosynthesis, carbohydrates status and rate of senescence. Blue light influences leaf thickness, hypocotyl elongation, photosynthesis, biosynthesis and accumulation of secondary metabolites, and stomata development and opening (Hogewoning *et al*., 2010). Orchid seedlings grown under

blue light had longer leaf length and width than cool-white fluorescent lamps (Lee *et al*., 2009). Blue light is reported to promote vegetative growth in leafy vegetables (Okushim *et al*., 2012). Blue LEDs (440−476 nm), used alone or in combination with red LEDs, caused higher chlorophyll ratio in Chinese cabbage plants (Mizuno *et al*. 2011, Li *et al*., 2016). Orchid seedlings grown under blue light had longer leaf length and width than cool-white fluorescent lamps (Lee *et al*., 2009). Blue light is reported to promote vegetative growth in leafy vegetables (Okushima *et al*.,2012).

2.3.3 Green light

Kim *et al*. (2004) summarized the experiments with green supplementary light and concluded that light sources consisting of more than 50% green cause reductions in plant growth. Green light is reported to have a negative impact on physiological and developmental incomes of plants. Green LEDs have reduced photosynthesis and oppose stomatal opening. Reversal by green light of blue-light-stimulated stomatal opening was found across a number of plant species, including leguminous and non leguminous dicots and grass and non grass monocot (Talbott *et al*., 2012). Johkan *et al*. (2012) reported that green LEDs with PAR (300 μmol m^{-2} S^{-1}) are most effective to enhance growth of lettuce. The biomass was observed to be lowest under green LEDs with a decrease in light intensity (Muneer *et al*., 2014).

2.4 Supplementary light source for improving physiological parameters of plants

Growth and physiology of plants are particularly regulated by light signals from the environment**.** Plants grown under blue light exhibit photosynthesis more similar to those grown under red light, such as chlorophyll *a* and *b* ratio (Buschmann *et al.*, 1978) Vogelmann (1998) stated that light perceived bystangenerate a wide range of specific physiological responses. The receptors include phytochromes, cryptochromes and phototropins. Development and physiology of plants are strongly influenced by light spectrum of the growth environment among which red and blue light are involved in a wide range of plant processes such as flowering, phototropism, photo-morphogenesis,

stomatal opening, and leaf photosynthetic functioning (Whitelam and Halliday ,2008). Red and blue lights are important for expansion of leaf and enhancement of biomass (Johkan *et al.,* 2010). Under open condition, plants are adapted to utilize a wide-spectrum of light to control photosynthesis (Kang *et al.,* 2013). Red light components have a great potential for use as a light source to drive photosynthesis. Plant growth and productivity depends on the light conditions and photosynthetic metabolism is detrimentally affected by light intensity (Zavala and Ravetta, 2001).

2.5 Supplementary sources of Lighting

The predominant greenhouse lighting sources are the HPS lamps because of their high efficiency (1.9 mmol $m^{-2}W^{-1}$) in converting energy into photosynthetically active radiation (van Ieperen, 2012). Use of conventional lighting systems with a broad spectrum of wavelengths may generate excessive heat and undesirable effects on plant growth and development due to inadequate protective mechanisms against UV or infrared (IR) radiations (Carvalho and Folta, 2014). Light emitting diodes (LED) technology, was assumed to be more efficient than HSP for driving photosynthesis to optimum range (Bergstrand and Schussler 2012). Chrysanthemum plants provided with additional light intensity of 100 to 200 μmol $m^{-2}s^{-1}$ photosynthetic photon flux density (PPFD) for 14 h per day helped to maximize commercial production of the crop (Ouzounis *et al*., 2016). Various sources of light like high pressure sodium lamp (HPS), incandescent lights, fluorescent tube lights are being used in horticulture for photoperiodic control as well as for production purpose (Bergstrand *et al*., 2016). Traditionally, high pressure sodium (HPS) and metal halide (MH) lamps belonging to high intensity discharge (HID) lamps were commonly used artificial light sources for plant research and greenhouse horticulture (Bergstrand *et al*., 2016). According to Li *et al*. (2016) supplementary lighting is an important horticultural practice and strategy to improve crop growth and to obtain year round, high yield, and quality of produce in greenhouses.

2.6 LED as a light source

The main advantage of LEDs is that they emit pure colours, which can be selected to match the absorption peaks of plant pigments (Bula *et al*., 1991). LED lighting systems for small plant growth chambers were successfully tried several times aboard NASA's space shuttle (Barta *et al*., 1992). Crops tested in this venture included wheat (*Triticumaestivum L*.) and *Brassica rapa* L. potato (*Solanum tuberosum L*.), leaf cuttings (Croxdale *et al*., 1997) and soybeans [*Glycine max (L.) Merr*] (Zhou, 2005). Their small size, durability, long lifetime, cool emitting temperature, and the option to select specific wavelengths for a targeted plant response made LEDs more suitable for plant-based uses than many other light sources (Devlin *et al*., 2007). Light emitting diode (LED) is a unique type of semiconductor diode. The wavelength (colour) of the light emitted depend on the properties of semiconductor material. LEDs can have peak emission wavelengths from UV-C (~250 nm) to infrared (~1000 nm) (Bourget, 2008). As a consequence, LED technology has emerged and developed rapidly in the past decades as alternative light sources (Massa *et al*., 2007). LEDs are easily integrated into digital control systems (Morrow,2008). Large scale use of LED has reduced the cost of the LED lamps which has renewed interest in the use of LEDs as a tool in greenhouse research (Folta and Childers, 2008). Azuma *et al.* (2012) concluded that the light from light emitting diode accelerates anthocyanin accumulation in grape skin. Terfa *et al.* (2012) reported that plants of potted roses grown under light emitting diodes (LED) exhibited higher chlorophyll and anthocyanin content and more thorns than those of grown under HPS. They further reported that the stem and pedicel length were also significantly shorter in LED grown plants compared to high pressure sodium lamp (HPS) grown plants. Schamp *et al.* (2012) also emphasized that the typical discrete spectral properties of LEDs make them highly suitable for flower development at specific growth stages for providing optimal light. They further highlighted forcing the Azaleas with the facilitating complex lighting program like varying intensity or spectral composition over a course of photoperiod or with plant developmental stage

(Yeh and Chung, 2009). Craig and Runkle (2012) concluded that LED lights provide a full spectrum of light designed to mimic natural light, providing plants a balanced spectrum of red, blue and green. Johkan *et al.* (2012) reported that LEDs with PAR (300 μmol m^{-2} S^{-1}) are most effective to enhance the growth of lettuce. Sams *et al.* (2016) reported that plants of *Tagetestenuifolia* in the LED light treatments had greater petal pigment content than plants in the natural sunlight treatment. Burattini *et al.* (2017) opined that light-emitting diodes (LED) are a promising light source for the cultivation of edible vegetables in greenhouses. The spectral radiation of the light sources has an impact on plants physiological parameters, as well as on morphological features.

Materials and methods

3. MATERIALS AND METHODS

The study aims to understand the influence of spectral light intensities on the morphological, phenological, physiological characters, yield and flower quality of gerbera (*Gerbera Jamesonii* Bolus)**.** A pot culture experiment was carried out at Department of Plant Physiology, College of Horticulture, during July 2018 to September 2019.

3.1 General details

3.1.1 Location

The experiment was conducted in polyhouse at College of Horticulture Vellanikkara. The geographical co-ordinates of the location are 10°32 N and 76°16 E with an altitude of 22.5 m above mean sea level.

3.1.2 Season

Crop duration was from July 2018 to September 2019.

3.2 Details of experiment

3.2.1 Plant Material

Tissue culture plants of gerbera variety Julia developed and marketed by LJ International (AVT Biotechnology) was used in this study. The flowers are red with black and yellow center having medium sized flower head.

3.2.2 Design of the experiment

Design: CRD with two factors.

Factor A: Colour of light

- 1. Red
- 2. Yellow
- 3. Blue
- 4. Green
- 5. White
- 6. Control (without any supplementary lighting)

Factor B: UV condition

- 1.With UV
- 2.Without UV

Treatments : 12 (6 ×2)

Exposure rate of light : 200 µmol $m^{-2}s^{-1}$ for 10 h

Replication : 3

No. of plants per replication : 7

Growing conditions: The polyhouses used in the study was modified as per the following specifications given below to effect different treatments.

1- Polyhouse with green net on all four sides of size 21.37 m^2 and height 1.67 m with polythene sheet of 0.25 mm thickness which transmits 80% full spectrum.
2- Polyhouse of size 21.37 m² and 2.13 m height with 0.13 mm thick poly filter, which transmits 85 % of full spectrum radiation and excludes UV-B.

3.2.3 Crop raising and management

Fourty five days old tissue culture plants in two leaf stage were directly planted in the pots of size 9 inches. Soil, sand, vermicomposting, coir pith compost and FYM (2:1:1:1:1) was used as the potting medium. The pots were placed under LED lights of red, blue, green, white and yellow colour kept at a height of one meter from the ground.

Initially twenty-one pots each were placed under each treatment. A set of pots were retained without treatment in each polyhouse as control. To reduce the diffusive effect of light and also to allow uniform distribution of the spectrum in a confined area colored cotton cloth were placed at 1.25 m from ground level as cover for each treatment. Plants were illuminated for 10 hours from 09.00 am to 07.00 pm daily for a period from July 28th to September 25 th (2018 to 2019).

Plants were subjected to pinching and disbudding as per standard practice. Recommended cultural practices were followed to raise the plants to flowering stage.

3.3 Observations recorded

3.3.1 Morphological and phenological observations

Morphological characters such as plant height, plant spread, number of lobes, leaf length, leaf breadth, were measured during the initial growth phase of the plant, which extent from date of plant to flower emergence.

a) Plant height

Height of selected plant was measured in centimetres from the level of soil to the tip of index leaf with the help of meter scale and mean value was calculated. This was recorded at monthly intervals.

Plate 1. View of experimental field

Plate 1(b) . View of experimental field

Plate 2(a). LED treatment on experimental field

Plate 2(b) LED treatment on experimental field

b) Plant spread

Plant spread was calculated by measuring the spread of foliage in East-West and North-south direction. This was recorded at monthly intervals.

c) Number of leaves

Observations on number of leaves were recorded by counting the total number of fully expanded leaves and the mean value was calculated. This was recorded at monthly intervals.

d) Leaf length

Length of the 3 rd leaf from the base of the petiole to the leaf tip was measured and expressed in centimeters.

e) Leaf breadth

Breadth of the 3 rd leaf from middle edge of leaf blade to the next end was measured and expressed in centimeters.

f) Petiole length

Length of the petiole from soil surface to the base of the leaf was measured and expressed centimeters.

g) Number of lobes

Third open leaf was considered as the index leaf and number of lobes of the leaf was counted at monthly intervals.

h) Days to flower initiation

Number of days taken for flower to initiate from the date of planting was noted in each treatment.

Plate 3. Morphological and phenological observations

i) Days to first flower opening

Number of days taken for the flower to fully open was recorded

j) Occurrence of pest and diseases

The incidence of pest and diseases in the experiment were noted.

3.3.2 Physiological observations

Physiological parameters were taken three times. During vegetative stage, before flowering and after flowering

3.3.2.1 Gas exchange parameters

Photosynthetic rate (µ mol $m^{-2}s^{-1}$), transpiration Rate (µ mol $H_2Om^{-2}s^{-1}$) and stomatal conductance (mol H_2O m^{-2} s^{-1}) were recorded using portable photosynthesis system (PPS- Model –LI-6400 of Licor Inc. Lincoln, Nebraska, USA) during vegetative stage, before flowering and after flowering. Readings were made on physiologically active leaf (3^{rd} leaf from top). Three plants were selected from each treatment for measurement and the mean value was computed. Observations were recorded between 9.00 am to 10.30 am.

3.3.2.2 Specific leaf area (cm^2g^{-1})

Specific Leaf Area (SLA) was calculated by dividing the leaf area by total dry weight of the leaf.

3.3.2.3 Stomatal frequency

Stomatal frequency was determined by counting the number of stomata present per unit area of leaf. Abaxial and adaxial leaf epidermal peels were prepared by spreading thin layer of a suitable replica fluid (quick fix) and allowing the replica to dry. The peeled replica was viewed under a light microscope (40X magnification).

Plate 4. Observations on stomatal conductance, photosynthetic and transpiration rate using IRGA

3.3.3 Biochemical characters

Biochemical parameters were estimated at 30^{th}, 60^{th} and 90^{th} day after transplanting in each treatment.

a) IAA content

IAA (indole acetic acid) was estimated by the method proposed by Parthasarathy *et al*. (1970) with little modification using Garden weber reagent. The IAA content was expressed as mg of unoxidised auxin g^{-1} fresh weight.

b) Gibberellic acid content

The method for extraction, purification and estimation of endogenous plant hormone gibberellic acid (GA) was modified from the methodology suggested by Sundberg (1990. Hundred gram of plant sample was homogenized in a mortar and pestle with methanol (ice-cold) and kept at 4^0 C in dark for four hours. The homogenate was centrifuged, filtered and solid residue was further extracted twice with the same solvent.

Methanolic extract was combined and concentrated to a water residue in vacuum at 50^0 C for one hour. Volume was adjusted to 10 ml with phosphate buffer and partitioned in a separating funnel with 10 ml of diethyl ether by stirring for 3 minutes. Ether phase was discarded and the aqueous phase was adjusted to pH 2.7 with 0.4 M HCl. The partitioned aqueous extract was collected twice with 0.4 M $NaHCO_3$. This was then partitioned with 10 ml ethyl acetate. The aqueous phase was decanted and stored at 4^0 C after adding 2 ml of methanol. This was used for gibberellin estimation by adding zinc acetate (2 ml) and potassium ferrocyanide (2ml). It was then centrifuged and the supernatant collected was kept at 20^0 C for 75 minutes after adding 30 per cent HCl. The absorbance was read at 254 nm using a UV- VIS spectro photometer (Spectroquant, Pharo 300, MerckKGaA, Germany). GA content was calculated and expressed in µg g^{-1}.

c) Chlorophyll content

Total chlorophyll, chlorophyll a and chlorophyll b was estimated in physiologically active leaf by the method suggested by Hiscox and Israelstam (1979) using DMSO as extraction reagent. Readings were taken in UV- VIS spectrophotometer (Spectroquant, Pharo 300, MerckKGaA, Germany) at two wavelengths 645 and 663 nm. Formulae used for chlorophyll calculation is given below and the results were expressed in mg g^{-1}fr.wt.

Chlorophyll a = $[(12.7\times A_{663}) - (2.69\times A_{645})] \times V/ 1000\times W$

Chlorophyll b = $[(22.9\times A_{645}) - (4.68\times A_{663})] \times V/ 1000\times W$

Total chlorophyll = $[(20.2\times A_{645}) + (8.02\times A_{663})] \times V/ 1000\times W$

Where A – Absorption at given wavelength

V – Volume of supernatant solution made

W- Weight of the sample

d) Proline content

The proline content was estimated by (Bates *et al.*, 1973) method using acid-ninhydrin as reagent.

e) Pigment composition of flower

i) Xanthophyll

Xanthophyll estimation was done by the method of Neogy *et al.* (2001). Two hundred and fifty mg leaf sample collected from third leaf was macerated with 10 ml of 80% acetone at 4ºC using pestle and mortar. Centrifuged the content for 15minutes at 3000 rpm, the residue re extracted twice and collected the supernatant. Theacetone extract was shaken in separating funnel by adding equal volume of hexane.The xanthophyll was extracted from hexane fraction by repeated washing with 90%ethanol.

The ethanol fraction containing xanthophylls was measured at 450 nm in a UV- VIS Spectrophotometer (Spectroquant, Pharo 300, Merck KGaA, Germany).

Calculation done by the following formula and expressed as A_{45o} µg g^{-1}

$$\frac{\text{Absorbance of sample at 450 nm (µg)}}{\text{Weight of the sample (g)}}$$

ii) Flavanoid content

Flavonoid content was examined spectro photometrically according to Mirecki and Teramara (1984). Five hundred mg leaf sample put in 80% acidified ethanol (methanol: water: HCl 79: 20: 1) and kept overnight in dark. Absorbance was read at a wavelength of 300 nm and flavonoid content was calculated using the following formula and expressed as $A_{3oo}g^{-1}$ fr.wt. of plant sample

$$Y= 16.05xA$$

Where, Y- concentration of UV-B absorbing compound equivalent to Coumaric acid

A - Absorbance at 300nm

iii) Anthocyanin content (mg/g):

Five ml of sample were taken into 100 ml beaker and volume made up to the mark with ethanolic HCL (made by 85 parts 95 % ethanol and 15 parts of 1.5 N HCL) and kept overnight at 4°C. Following morning the mixture was filtered through Whatman‟s No.1 filter paper and residue on the filter paper was washed repeatedly with ethanolic HCL and volume was made up to 100 ml with the same solvent. It was again filtered through fine millipore and 10 ml of aliquot was taken and diluted up to

20 ml with ethanolic Hcl. Then the flask was kept in dark for 2 h after that absorbance was measured at 535 nm wavelength with spectrophotometer. Total anthocyanin content was calculated as follows. (Harborne 1958)

$$\text{Total absorbance for the sample per 100 ml} = \frac{e \times b \times c}{d \times a}$$

Where,

a = Volume of sample

b = Volume made up of the extract used for colour measurement

c = Total volume

d = ml of the extract used

e = Specific O.D Value at 535 nm wave length

1 mg/ml of solution is equivalent to the absorbance of 98.2. Therefore

$$\text{Total anthocyanin (mg/100 ml)} = \frac{\text{Total absorbance for the sample}}{98.2}$$

g) Nitrogen reductase enzyme activity

Nitrgen reductase enzyme activity in the leaf was estimated by the method of Hageman and Flesher (1960). The nitrite formed was estimated by the method described by Nicholas *et al.* (1976), by measuring the absorbance of the pink color at 540 nm using spectrophotometer.

3.3.4 Floral characters

a) Number of flowers per plant

The total number of flowers produced per plant was recorded at monthly interval and average number of flowers per plant was calculated.

a) Stalk length of flower

Length of the stalk was calculated by measuring the length from the base of the stalk to the neck of the flower.

b) Stalk girth

Girth of the stalk at 15 cm from the base was measured and expressed in centimeters.

c) Flower head diameter

Diameter of the flower was measured and recorded in centimeters.

d) Bending percentage

Flowers that showed bending tendancy was noted and expressed in %

e) Vase life of flowers

The flowers were harvested at the commercial stage,they were kept in water. Vase life was expressed as the number of days taken for fresh flower to show sign of wilting.

3.3.5 Weather parameters inside the net houses

a) Photosynthetically active radiation (µ mol $m^{-2}s^{-1}$)

Photosynthetic photon flux density (PPFD) is the intensity of photosynthetically active radiation (PAR) which is expressed in µmol $m^{-2}s^{-1}$. The incident photosynthetically active radiation (PAR) in two growing condition was also measured using quantum light meter (Model- 3415 F, Field scout, spectrum technology, Icn. USA) from 8am to 2pm daily.

b) Temperature (°c)

Daily ambient temperature was taken using digital thermometer (MEXTECH Multi thermometer). Readings were taken at 11 am throughout the growing period. Temperature was expressed as ^{0}c.

c) Humidity (%)

Humidity inside the poly house was observed throughout the crop period using HTC 288-CTH hygro clock. Readings were taken at 11 am throughout the growing period and expressed in percentage.

d) UV ($W/m^{2)}$

Ultraviolet B radiation was measured using UV-B meter (Model- 3414F, Field Scout, Spectrum technology, Icn.USA). Readings were taken at 11: 30 am daily throughout the growing period. Radiation unit was expressed as Wm^{-2}.

e) Lux meter reading (lux)

Light intensity measured at 1 pm using light meter (TES-1332: DIGITAL LUX meter) at top of the canopy in each treatment and in both the locations inside and outside of the polyhouse.

f) Statistcal design

The design was CRD with two factors. First, factor (A) colour of light in five levels and control (without supplementary lighting). Second factor (B) has two levels UV and Non-UV condition. Statistical analysis was done in R-4.0.3 software.

Results

4. RESULTS

The results of the study entitled "Spectral manipulation of growth and physiology of *Gerbera jamesonii* Bolus" are furnished in this chapter. The influence of various spectrally varying LED's and influence of UV on morphological, physiological and biochemical attributes of *Gerbera jamesonii* Bolus were studied. The results are as follows**.**

4.1 Morphological parameters.

Table1. Effect of spectral colours and UV on plant height (cms)

Light Colour	UV	Non-UV	Mean (A)
Red	29.14^{ab}	30.93^{a}	30.03$^{\mathbf{a}}$
Yellow	27.92^{cd}	28.42b^{c}	28.17$^{\mathbf{b}}$
Blue	28.92^{b}	30.82^{a}	29.87$^{\mathbf{a}}$
Green	26.6^{de}	26.86^{de}	26.73$^{\mathbf{d}}$
White	27.81^{cd}	27.87^{cd}	27.84$^{\mathbf{c}}$
Control	25.46^{f}	26.26^{ef}	25.86$^{\mathbf{e}}$
Mean(B)	27.64^{b}	28.53^{a}	
CD (0.05)	A =0.3	B =0.2	(A × B) =0.5

Plant height of *Gerbera jamesonii* Bolus was significantly influenced by spectral colours. Among the spectral colour's plants in red and blue (30.03 and 29.87) shows highest plant height followed by white (27.84), yellow (28.17) and green (26.73). Least plant height was observed under control (25.86) treatment. Plants in Non-UV condition (28.53) had significantly higher plant height as compared to those in UV condition (27.64). From the table it could be inferred that red and blue light in non-UV condition resulted in higher plant height.

Plate 5.Effect of Spectral colors on plant height

Plate 6. Effect of UV plant height

Table 2. Effect of spectral colours and UV on leaf length (cms)

Light Colour	UV	Non-UV	Mean(A)
Red	20.87	21.37	21.13^{b}
Yellow	19.04	19.39	19.21^{c}
Blue	20.94	23.96	22.45^{a}
Green	18.29	18.58	18.43^{e}
White	19.18	19.57	19.37^{c}
Control	18.71	18.9	18.80^{d}
Mean(B)	19.50^{b}	20.29^{a}	
CD (0.05)	A = 1.2	B = 0.7	(A × B) =NS

Leaf length of *Gerbera jamesonii* Bolus was significantly influenced by spectral colours. Among the spectral colours plants in blue spectrum showed highest (22.45) leaf length followed by red (21.13), white (19.37) and yellow (19.21). Least leaf length was observed under green (18.43) which was lower than the control treatment (18.80). Plants in Non-UV condition (20.29) had significantly higher leaf length as compared to those in UV condition (19.50). From the table it could be inferred that blue light in non-UV condition resulted in higher leaf length.

Table 3. Effect of spectral colours and UV on leaf breadth (cms)

Light Colour	UV	Non-UV	Mean(A)
Red	4.85	5.03	4.94[b]
Yellow	3.76	3.99	3.87[d]
Blue	4.83	6.21	5.52[a]
Green	3.25	3.32	3.28[f]
White	3.87	4.83	4.35[c]
Control	3.39	3.42	3.40[e]
Mean(B)	3.99[b]	4.46[a]	
CD (0.05)	A =0.7	B =0.4	(A × B) = NS

Leaf breadth of *Gerbera jamesonii* Bolus was significantly influenced by spectral colours. Among the spectral colours plants in blue spectrum showed highest (5.52) leaf breadth followed by red (4.94), white (4.35) and yellow (3.87). Least leaf breadth was observed under green (3.28) which was lower than the control treatment (3.40). Plants in Non-UV condition (4.46) had significantly higher leaf breadth as compared to those in UV condition (3.99). From the table it could be inferred that blue light in non-UV condition resulted in higher leaf breadth

Table 4. Effect of spectral colours and UV on petiole length of leaves (cms)

Light Colour	UV	Non-UV	Mean(A)
Red	10.12	10.56	10.34[a]
Yellow	8.35	9.43	8.89[c]
Blue	9.77	10.31	10.04[a]
Green	8.12	8.98	8.55[d]
White	8.69	9.55	9.12[b]
Control	7.51	7.76	7.63[e]
Mean(B)	8.76[b]	9.43[a]	
CD (0.05)	A =0.6	B =0.4	(A × B) = NS

Petiole length of *Gerbera jamesonii* Bolus was significantly influenced by spectral colours. Among the spectral colours plants in red and blue spectrum showed highest (10.34, 10.04) petiole length followed by white (9.12), yellow (8.89) and green (8.55) Least petiole length was observed under control (7.63) treatment. Plants in Non-UV condition (9.43) had significantly higher petiole length as compared to those in UV condition (8.76). From the table it could be inferred that red light in non-UV condition resulted in higher petiole length

Table 5. Effect of spectral colours and UV on plant spread (cms)

Light Colour	UV	Non-UV	Mean(A)
Red	167.9	179.67	173.78[b]
Yellow	153.89	161.34	157.61[d]
Blue	172.24	181.81	177.02[a]
Green	135.77	137.57	136.67[f]
White	157.89	163.97	160.93[c]
Control	140.39	146.65	143.52[e]
Mean(B)	154.68[b]	161.83[a]	
CD (0.05)	A = 5	B =3.3	(A × B) = NS

Plant spread of *Gerbera jamesonii* Bolus was significantly influenced by spectral colours. Among the spectral colours plants in blue spectrum showed highest (177.02) plant spread followed by red (173.78), white (160.93) and yellow (157.61). Least plant spread was observed under green (136.67) which was lower than the control treatment (143.52). Plants in non-UV condition (161.83) had significantly higher plant spread as compared to those in UV condition (154.68). From the table it could be inferred that blue light in non-UV condition resulted in higher plant spread

Table 6. Effect of spectral colours and UV on number of lobes (no's)

Light Colour	UV	Non-UV	Mean(A)
Red	10.36	11.57	10.96[a]
Yellow	9.59	9.79	9.69[b]
Blue	9.93	11.43	10.68[a]
Green	7.98	8.19	8.08[e]
White	9.63	9.83	9.73[b]
Control	8.39	8.5	8.44[d]
Mean(B)	9.31[b]	9.88[a]	
CD(0.05)	A =0.9	B =0.5	(A × B) = NS

Number of lobes on leaf of *Gerbera jamesonii* Bolus was significantly influenced by spectral colours. Among the spectral colours plants in red and blue spectrum showed highest (10.96, 10.68) number of lobes on leaf. White (9.73) and yellow (9.69) show similar effect. Least number of lobes on leaf was observed under green (8.08) which was lower than the control treatment (8.44). Plants in non-UV condition (9.88) had significantly higher number of lobes on leaf as compared to those in UV condition (9.31). From the table it could be inferred that red light in non-UV condition resulted in higher number of lobes on leaves.

Table 7. Effect of spectral colours and UV on number of leaves (nos)

Light Colour	UV	Non-UV	Mean(A)
Red	10.79	11.34	11.07[a]
Yellow	8.47	8.86	8.67[d]
Blue	10.46	11.03	10.75[b]
Green	7.41	7.90	7.66[f]
White	9.11	9.84	9.48[c]
Control	7.74	8.22	8.01[e]
Mean(B)	8.94[b]	9.53[a]	
CD(0.05)	A =0.7	B =0.4	(A × B) =NS

Number of leaves of *Gerbera jamesonii* Bolus during winter months was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (11.07) number of leaves followed by blue (10.75), white (9.48) and yellow (8.67). Least number of leaves was observed under green (7.66) which was lower than the control treatment (8.01). Plants in Non-UV condition (9.53) had significantly higher number of leaves as compared to those in UV condition (8.94). From the table it could be inferred that red light in non-UV condition resulted in higher number of leaves.

4.2 Phenological parameters

Table 8. Effect of spectral colours and UV on day to first flower opening (day)

Light Colour	UV	Non-UV	Mean(A)
Red	53.20	46.7	49.75[a]
Yellow	58.48	57.34	57.91[c]
Blue	52.90	47.73	50.31[b]
Green	63.33	61.84	62.58[f]
White	57.96	59.65	58.80[d]
Control	60.89	59.47	60.18[e]
Mean(B)	57.79[b]	55.45[a]	
CD (0.05)	A =0.4	B =1.0	(A × B) = NS

Days to first flower opening of *Gerbera jamesonii* Bolus was significantly influenced by spectral colours. Among the spectral colour's flowers in plants of red spectrum showed least (49.95) days to flower opening followed by blue (50.31), yellow (57.92) and white (58.80). Plants under green light takes more days to open the flower (62.58) which was higher than the control treatment (60.18). Plants in non-UV condition (55.45) had minimum day to first flower opening compared to those in UV condition (57.79). From the table it could be inferred that red light in non-UV condition takes lesser days to flower opening.

Table 9. Effect of spectral colours and UV on first bud to flower initiation (day)

Light Colour	UV	Non-UV	Mean(A)
Red	12.10	11.98	12.04[a]
Yellow	13.29	13.17	13.23[c]
Blue	12.37	12.28	12.33[ab]
Green	13.73	13.44	13.59[c]
White	12.75	12.52	12.64[b]
Control	13.93	13.79	13.86[d]
Mean(B)	13.03[b]	12.86[a]	
CD (0.05)	A = 0.3	B =NS	(A × B) = NS

Days to first flower initiation of *Gerbera jamesonii* Bolus was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum and blue showed lowest (12.04 and 12.33) days to flower initiation from bud followed by white (12.64). Yellow (13.23) and green (13.59) showed similar effect. Highest days to flower initiation was observed under control treatment (13.86).

Table 10. Effect of spectral colours and UV on days to first harvest (days)

Light Colour	UV	Non-UV	Mean(A)
Red	14.67	14.58	14.63[a]
Yellow	15.59	15.47	15.53[b]
Blue	14.40	14.28	14.34[a]
Green	16.23	16.09	16.16[c]
White	15.05	14.82	14.94[b]
Control	16.03	15.74	15.89[b]
Mean(B)	15.33	15.16	
CD (0.05)	A =0.19	B =NS	(A × B) = NS

Days to first harvest of flower was significantly influenced by spectral colours. Among the spectral colours plants in red and blue showed lowest (14.63 and 14.34) days to harvest. White (14.94) and yellow (15.53) show similar effect as control (15.89). Highest days to harvest flower was observed under green (16.16). Plants in non-UV condition and UV condition did not have much influence.

4.3 Physiological parameters.

Table 11. Effect of Spectral colours and UV on photosynthetic rate (µmol $m^{-2}s^{-1}$) during vegetative stage

Light Colour	UV	Non-UV	Mean(A)
Red	9.98[c]	11.98[a]	10.98[a]
Yellow	8.32[d]	8.44[d]	8.38[d]
Blue	9.76[c]	10.76[b]	10.26[b]
Green	6.12[g]	6.33[g]	6.22[f]
White	8.35[d]	8.45[d]	8.4[c]
Control	6.98[f]	7.9[e]	7.44[e]
Mean(B)	8.25[b]	8.97[a]	
CD (0.05)	A =0.22	B =0.13	(A × B) =0.31

Photosynthetic rate of *Gerbera jamesonii* Bolus during vegetative stage was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (10.98) photosynthetic rate followed by blue (10.26), white (8.4) and yellow (8.38) . Least photosynthetic rate was observed under green (6.22) which was lower than the control treatment (7.44). Plants in non-UV condition (8.97) had significantly higher photosynthetic rate as compared to those in UV condition (8.25). From the table it could be inferred that red light in non-UV condition resulted in higher photosynthetic rate.

Table 12. Effect of Spectral colours and UV on photosynthetic rate (µmol $m^{-2}s^{-1}$) before flowering

Light Colour	UV	Non-UV	Mean(A)
Red	12.17	12.35	12.26[a]
Yellow	8.88	9.21	9.04[d]
Blue	10.95	11.49	11.22[b]
Green	8.31	8.45	8.38[f]
White	9.16	9.67	9.56[c]
Control	8.69	8.76	8.72[e]
Mean(B)	9.48[b]	9.98[a]	
CD (0.05)	A =0.3	B =0.1	(A × B) = NS

Photosynthetic rate of *Gerbera jamesonii* Bolus before flowering was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (12.26) photosynthetic rate followed by blue (11.22), white (9.56) and yellow (9.04). Least photosynthetic rate was observed under green (8.38) which was lower than the control treatment (8.72). Plants in non-UV condition (9.98) had significantly higher photosynthetic rate as compared to those in UV condition (9.48). From the table it could be inferred that red light in non-UV condition resulted in higher photosynthetic rate.

Table 13. Effect of spectral colours and UV on photosynthetic rate (µmol $m^{-2}s^{-1}$) after flowering

Light Colour	UV	Non-UV	Mean(A)
Red	14.44[b]	15.17[a]	14.80[a]
Yellow	10.01[g]	10.67[f]	10.34[d]
Blue	12.16[d]	13.51[c]	12.83[b]
Green	9.22[i]	9.55h[i]	9.38[f]
White	11.17[e]	11.92[d]	11.54[c]
Control	9.85[gh]	9.96[g]	9.90[e]
Mean(B)	11.14[b]	11.79[a]	
CD (0.05)	A =0.24	B =0.14	(A × B) =0.35

Photosynthetic rate of *Gerbera jamesonii* Bolus after flowering was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (14.80) photosynthetic rate followed by blue (12.83), white (11.54) and yellow (10.34). Lowest photosynthetic rate was observed under green (9.38) which was lower than the control treatment (9.90). Plants in non-UV condition (11.79) had significantly higher photosynthetic rate as compared to those in UV condition (11.14). From the table it could be inferred that red light in non-UV condition resulted in higher photosynthetic rate.

Table 14. Effect of spectral colours and UV on stomatal conductance (m mole $m^{-2}s^{-2}$) in vegetative stage

Light Colour	UV	Non-UV	Mean(A)
Red	0.53	0.64	0.59^{b}
Yellow	0.32	0.42	0.37^{c}
Blue	0.59	0.69	0.64^{a}
Green	0.19	0.20	0.20^{e}
White	0.37	0.47	0.42^{c}
Control	0.23	0.27	0.25^{d}
Mean(B)	0.37^{b}	0.44^{a}	
CD(0.05)	A =0.07	B =0.04	(A × B) = NS

Stomatal conductance of *Gerbera jamesonii* Bolus during vegetative stage was significantly influenced by spectral colours. Among the spectral colours plants in blue spectrum showed highest (0.64) stomatal conductance followed by red (0.59). White (0.42) and yellow (0.37) show similar effect. Least Stomatal conductance was observed under green (0.20) which was lower than the control treatment (0.25). Plants in non-UV condition (0.44) had significantly higher stomatal conductance as compared to those in UV condition (0.37). From the table it could be inferred that blue light in non-UV condition resulted in higher stomatal conductance.

Table 15. Effect of Spectral colours and UV on stomatal conductance (mmole $m^{-2}s^{-2}$) before flowering stage

Light Colour	UV	Non-UV	Mean(A)
Red	0.60	0.71	0.66^{b}
Yellow	0.39	0.49	0.44^{d}
Blue	0.66	0.76	0.71^{a}
Green	0.26	0.27	0.27^{f}
White	0.44	0.54	0.49^{c}
Control	0.30	0.34	0.32^{e}
Mean(B)	0.44^{b}	0.51^{a}	
CD (0.05)	A =0.07	B =0.04	(A × B) = NS

Stomatal conductance of *Gerbera jamesonii* Bolus before flowering stage was significantly influenced by spectral colours. Among the spectral colours plants in blue spectrum showed highest (0.71) stomatal conductance followed by red (0.66), white (0.49) and yellow (0.44). Least stomatal conductance was observed under green (0.27) which was lower than the control treatment (0.32). Plants in Non-UV condition (0.51) had significantly higher stomatal conductance as compared to those in UV condition (0.44). From the table it could be inferred that blue light in non-UV condition resulted in higher stomatal conductance.

Table 16. Effect of Spectral colours and UV on stomatal conductance (mmole $m^{-2}s^{-2}$) after flowering stage

Light Colour	UV	Non-UV	Mean(A)
Red	0.65^{bc}	0.71^{ab}	0.68^{b}
Yellow	0.44^{ef}	0.49^{de}	0.47^{d}
Blue	0.76^{a}	0.81^{a}	0.79^{a}
Green	0.27^{h}	0.32^{gh}	0.29^{f}
White	0.47^{e}	0.59^{cd}	0.53^{c}
Control	0.35^{fg}	0.39^{ef}	0.37^{e}
Mean(B)	0.49^{b}	0.55^{a}	
CD (0.05)	A =0.5	B =0.03	(A × B) =0.8

Stomatal conductance of *Gerbera jamesonii* Bolus after flowering stage was significantly influenced by spectral colours. Among the spectral colours plants in blue spectrum showed highest (0.79) stomatal conductance followed by red (0.68), white (0.53) and yellow (0.47). Least stomatal conductance was observed under green (0.29) which was lower than the control treatment (0.37). Plants in non-UV condition (0.55) had significantly higher stomatal conductance as compared to those in UV condition (0.49). From the table it could be inferred that blue light in non-UV condition resulted in higher stomatal conductance.

Table 17. Effect of Spectral colors and UV on transpiration rate (m moles $m^{-2}s^{-2}$) on vegetative stage

Light Colour	UV	Non-UV	Mean(A)
Red	7.76	8.95	8.35[a]
Yellow	6.54	7.25	6.89[d]
Blue	8.56	9.35	8.95[b]
Green	4.84	5.33	5.08[e]
White	6.96	7.62	7.29[c]
Control	5.7	6.13	5.91[d]
Mean(B)	6.72[b]	7.43[a]	
CD (0.05)	A =0.3	B =0.2	(A × B) = NS

Transpiration rate of *Gerbera jamesonii* Bolus during vegetative stage was significantly influenced by spectral colours. Among the spectral colours plants in blue showed highest (8.95) followed by red (8.35) ,white (7.29) and yellow (6.89). Least transpiration rate was observed under green (5.08) which was lower than the control treatment (5.91). Plants in non-UV condition (7.43) had significantly higher transpiration rate as compared to those in UV condition (6.72). From the table it could be inferred that red light in non-UV condition resulted in higher transpiration rate.

Table 18. Effect of Spectral colours and UV on transpiration rate (mmoles $m^{-2}s^{-2}$) before flowering

Light Colour	UV	Non-UV	Mean(A)
Red	9.18^{d}	10.19^{b}	9.68^{b}
Yellow	8.04^{g}	8.74^{e}	8.39^{d}
Blue	9.93^{e}	10.81^{c}	10.37^{a}
Green	6.4^{k}	6.84^{j}	6.62^{f}
White	8.44^{f}	9.07^{d}	8.75^{c}
Control	7.24^{i}	7.62^{h}	7.43^{e}
Mean(B)	8.20^{b}	8.87^{a}	
CD(0.05)	A =0.09	B =0.05	(A × B) = 0.13

Transpiration rate of *Gerbera jamesonii* Bolus before flowering was significantly influenced by spectral colours. Among the spectral colours plants in blue spectrum showed highest (10.37) transpiration rate followed by red (9.68), white (8.75) and yellow (8.39). Least transpiration rate was observed under green (6.62) which was lower than the control treatment (7.43). Plants in non-UV condition (8.87) had significantly higher transpiration rate as compared to those in UV condition (8.20). From the table it could be inferred that red light in non-UV condition resulted in higher transpiration rate.

Table 19. Effect of Spectral colours and UV on transpiration rate (mmoles $m^{-2}s^{-2}$) after flowering

Light Colour	UV	Non-UV	Mean(A)
Red	9.37^{d}	10.33^{b}	9.85^{b}
Yellow	8.16^{h}	8.91^{f}	8.53^{d}
Blue	10.06^{c}	10.98^{a}	10.52^{a}
Green	6.53^{l}	6.98^{k}	6.75^{f}
White	8.59^{g}	9.23^{e}	8.91^{c}
Control	7.37^{j}	7.77^{i}	7.57^{e}
Mean(B)	8.34^{b}	9.03^{a}	
CD (0.05)	A =0.09	B =0.05	(A × B) =0.13

Transpiration rate of *Gerbera jamesonii* Bolus before flowering was significantly influenced by spectral colours. Among the spectral colours plants in blue spectrum showed highest (10.52) transpiration rate followed by red (9.85), white (8.91) and yellow (8.53). Least transpiration rate was observed under green (6.75) which was lower than the control treatment (7.57). Plants in non-UV condition (9.03) had significantly higher transpiration rate as compared to those in UV condition (8.34). From the table it could be inferred that red light in non-UV condition resulted in higher transpiration rate

Table :20. Effect of Spectral colours and UV on specific leaf area ($cm^2 g^{-1}$) in vegetative stage

Light Colour	UV	Non-UV	Mean(A)
Red	175.9^{b}	193.99^{a}	184.94^{a}
Yellow	132.64^{g}	123.01^{h}	135.82^{d}
Blue	161.77^{c}	158.12^{cd}	159.94^{b}
Green	112.3^{i}	108.75^{i}	110.52^{f}
White	144.01^{e}	154.12^{d}	149.06^{c}
Control	122.47^{h}	138.01^{f}	130.24^{e}
Mean(B)	141.51^{b}	146.33^{a}	
CD (0.05)	A =3.62	B =2.09	(A × B) =5.13

Specific leaf area of *Gerbera jamesonii* Bolus during vegetative stage was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (184.945) specific leaf area followed by blue (159.94), white (149.06) and yellow (135.82). Least specific leaf area was observed under green (110.52) which was lower than the control treatment (130.24). Plants in non-UV condition (146.33) had significantly higher specific leaf area as compared to those in UV condition (141.51). From the table it could be inferred that red light in non-UV condition resulted in higher specific leaf area.

Table 21. Effect of Spectral colours and UV on specific leaf area ($cm^2 g^{-1}$) before flowering stage

Light Colour	UV	Non-UV	Mean(A)
Red	635.67^{b}	642.31^{a}	638.99^{a}
Yellow	457.77^{f}	442.54^{g}	450.15^{d}
Blue	525.56^{d}	533.56^{c}	529.56^{b}
Green	262.24^{j}	272.3^{i}	267.27^{f}
White	461.54^{f}	482.67^{e}	472.10^{c}
Control	275.45^{i}	282.47^{h}	278.96^{e}
Mean(B)	436.37^{b}	442.64^{a}	
CD (0.05)	A =4.18	B =2.41	(A × B) =5.91

Specific leaf area of *Gerbera jamesonii* Bolus before flowering was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (638.99) specific leaf area followed by blue (529.56), white (472.10) and yellow (450.15). Least specific leaf area was observed under green (267.27) which was lower than the control treatment (278.96). Plants in non-UV condition (442.64) had significantly higher specific leaf area as compared to those in UV condition (436.37). From the table it could be inferred that red light in non-UV condition resulted in higher specific leaf area.

Table 22. Effect of Spectral colours and UV on specific leaf area ($cm^2 g^{-1}$) after flowering stage.

Light Colour	UV	Non-UV	Mean(A)
Red	734.7^{b}	746.3^{a}	740.50^{a}
Yellow	535.89^{h}	544.67^{g}	540.28^{d}
Blue	613.76^{c}	605.56^{d}	609.66^{b}
Green	317.98^{k}	322.78^{j}	320.38^{f}
White	554.89^{f}	588.65^{e}	571.77^{c}
Control	323.56^{j}	337.95^{i}	330.75^{e}
Mean(B)	513.46^{b}	524.31^{a}	
CD (0.05)	A =2.75	B =1.59	(A × B) =3.9

Specific leaf area of *Gerbera jamesonii* Bolus after flowering was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (740.50) specific leaf area followed by blue (609.66), white (571.77) and yellow (540.28). Least specific leaf area was observed under green (320.38) which was lower than the control treatment (330.75). Plants in non-UV condition (524.31) had significantly higher specific leaf area as compared to those in UV condition (513.46). From the table it could be inferred that red light in non-UV condition resulted in higher specific leaf area.

Table 23. Effect of Spectral colours and UV on stomatal frequency in flowering stage.

Light Colour	UV	Non-UV	Mean	UV	Non-UV	Mean(A)
		Adaxial			Abaxial	
Red	453.78^{d}	472.89^{c}	**463.34**^{b}	943.76^{d}	969.90^{c}	**956.83**^{b}
Yellow	368.90^{h}	378.89^{g}	**373.90**^{d}	862.90^{h}	871.98^{g}	**867.44**^{d}
Blue	501.78^{b}	528.64^{a}	**515.21**^{a}	978.75^{b}	995.78^{a}	**987.27**^{a}
Green	244.67^{k}	256.76^{j}	**250.72**^{f}	632.54^{l}	681.67^{k}	**657.11**^{f}
White	401.43^{f}	418.67^{e}	**410.05**^{c}	912.21^{f}	932.67^{e}	**922.44**^{c}
Control	257.78^{j}	298.65^{i}	**278.22**^{e}	689.90^{j}	705.34^{i}	**697.62**^{e}
Mean	**371.39**^{b}	**392.42**^{a}		**836.68**^{b}	**859.55**^{a}	
CD (0.05)	A=2.6	B=1.5	(A ×B) =3	A=3.6	B=2	(A ×B) =5.1

Stomatal frequency in leaves of *Gerbera jamesonii* Bolus after flowering was significantly influenced by spectral colours. Number of stomata in abaxial surface is more compare to adaxial surface. Among the spectral colours plants in blue spectrum showed highest stomatal frequency (515.21 in adaxial and 987.27 in abaxial) content followed by red (463.34 in adaxial surface and 956.83 in adaxial surface), white (410.05 in adaxial and 922.44 in abaxial) and yellow (373.90 in adaxial and 867.44 in abaxial surface), Least stomatal frequency was observed under green treatment (250.72 and 657.11 in adaxial and abaxial respectively) Plants in non-UV condition (392.42 and 859.55 in adaxial and abaxial respectively) had significantly higher stomatal frequency as compared to those in UV condition (371.39 and 836.68 in adaxial and abaxial respectively). From the table it could be inferred that blue light in non-UV condition resulted in higher stomatal frequency.

4.4 Biochemical parameters

Table 24. Effect of Spectral colours and UV on Chlorophyll content before flowering.

	Chlorophyll a			Chlorophyll b			Chlorophyll total		
Light Colour	UV	Non-UV	Mean	UV	Non-UV	Mean	UV	Non-UV	Mean(A)
Red	4.81^{b}	5.01^{a}	**4.91^{a}**	0.67^{b}	0.8^{a}	**0.74^{a}**	5.49^{bc}	5.81^{a}	**5.65**^{a}
Yellow	3.72^{f}	4.22^{e}	**3.97^{d}**	0.51^{e}	0.58^{cd}	**0.55^{d}**	4.23^{f}	4.8^{e}	**4.52**^{d}
Blue	4.7^{c}	4.98^{a}	**4.84^{b}**	0.66^{b}	0.69^{b}	**0.68^{b}**	5.36^{cd}	5.65^{ab}	**5.51**^{b}
Green	3.37^{h}	3.38^{h}	**3.38^{f}**	0.45^{f}	0.46^{f}	**0.45^{f}**	3.82^{h}	3.85^{gh}	**3.84**^{f}
White	4.16^{e}	4.6^{d}	**4.38^{c}**	0.56^{d}	0.61^{c}	**0.59^{c}**	4.72^{e}	5.23^{d}	**4.98**^{c}
Control	3.43^{h}	3.52^{g}	**3.48^{e}**	0.46^{f}	0.49^{ef}	**0.48^{e}**	3.88^{gh}	4.01^{g}	**3.94**^{e}
Mean	**4.03^{b}**	**4.29^{a}**		**0.55^{b}**	**0.6^{a}**		**4.58**^{b}	**4.89**^{a}	
CD(0.05)	A=0.05	B=0.03	AB=0.07	A=0.03	B=0.01	AB=0.04	A=0.1	B=0.06	A×B=0.16

Chlorophyll content of *Gerbera jamesonii* Bolus before flowering was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest chlorophyll content (4.91, 0.74, 5.65) chlorophyll a, b and total respectively followed by blue (4.84, 0.68, 5.51), white (4.38, 0.59, 4.98) and yellow (3.97, 0.55, 4.52). Least chlorophyll content was observed under green treatment (3.48, 0.48, 3.94) which was lower than the control (3.48, 0.48, 3.94). Plants in Non-UV condition ((4.29, 0.6, 4.89)) had significantly higher chlorophyll content as compared to those in UV condition (4.03, 0.55, 4.58). From the table it could be inferred that red light in non-UV condition resulted in higher chlorophyll content in leaves.

Table 25. Effect of Spectral colours and UV on Chlorophyll content after flowering.

	Chlorophyll a			Chlorophyll b			Chlorophyll total		
Light Colour	UV	Non-UV	Mean	UV	Non-UV	Mean	UV	Non-UV	Mean
Red	5.52[b]	5.77[a]	**5.65[a]**	0.73	0.76	**0.75[a]**	6.24[c]	6.56[a]	**6.40**[a]
Yellow	4.46[e]	4.94[d]	**4.7[d]**	0.57	0.63	**0.6[d]**	5.03[h]	5.58[f]	**5.31**[d]
Blue	5.43[b]	5.68[a]	**5.56[b]**	0.71	0.74	**0.73[b]**	6.15[d]	6.43[b]	**6.29**[b]
Green	4.12[f]	4.13[f]	**4.13[f]**	0.51	0.52	**0.52[f]**	4.64[j]	4.65[j]	**4.65**[f]
White	4.86[d]	5.29[c]	**5.08[c]**	0.61	0.69	**0.65[c]**	5.49[g]	5.97[e]	**5.73**[c]
Control	4.14[f]	4.23[f]	**4.19[e]**	0.53	0.54	**0.54[e]**	4.68[j]	4.77[i]	**4.73**[e]
Mean	**4.76[b]**	**5.01[a]**		**0.61[b]**	**0.65[a]**		**5.37**[b]	**5.66**[a]	
CD (0.05)	A=0.09	B=0.05	(A × B) 0.13	A=0.03	B=0.01	NS	A=0.05	B=0.3	(A× B) 0.07

Chlorophyll content of *Gerbera jamesonii* Bolus after flowering was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest chlorophyll content (5.65, 0.75, 6.4) chlorophyll a, b and total respectively followed by blue (5.56, 0.73,6.29), white (5.08, 0.65, 5.73) and yellow (4.7, 0.6,5.31). Least chlorophyll content was observed under green treatment (4.13, 0.52, 4.65) which was lower than the control (4.19, 0.54, 4.73). Plants in Non-UV condition (5.01, 0.65, 5.66) had significantly higher chlorophyll content as compared to those in UV condition (4.76, 0.61,5.37). From the table it could be inferred that red light in non-UV condition resulted in higher chlorophyll content in leaves.

Table 26. IAA content (mg of un oxidized auxin g $^{-1}$FW) in leaf of *Gerbera jamesonii* Bolus as influenced by spectral colour and UV before flowering

Light Colour	UV	Non-UV	Mean(A)
Red	2.15^{e}	2.59^{a}	2.37^{a}
Yellow	1.86^{h}	2.4^{d}	2.13^{e}
Blue	2.09^{f}	2.52^{b}	2.31^{b}
Green	2.11^{ef}	2.45^{c}	2.28^{c}
White	1.92^{g}	2.41^{cd}	2.16^{d}
Control	1.91^{g}	1.81^{i}	1.86^{f}
Mean(B)	1.98^{b}	2.36^{a}	
CD(0.05)	A =0.04	B =0.01	(A × B) = 0.04

IAA content in flower of *Gerbera jamesonii* Bolus before flowering was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (2.37) IAA content followed by blue (2.31) and green (2.28). Yellow (2.13) and white (2.16) show similar results. Least IAA content was observed under control treatment (1.86). Plants in Non-UV condition (2.36) had significantly higher IAA as compared to those in UV condition (1.98). From the table It could be inferred that red light in non-UV condition resulted in higher IAA content.

Table 27. IAA content (mg of un oxidized auxin g $^{-1}$FW) in leaf of *Gerbera jamesonii* as influenced by spectral colour and UV after flowering

Light Colour	UV	Non-UV	Mean(A)
Red	2.19^{c}	2.66^{a}	2.42^{a}
Yellow	1.98^{d}	2.51^{b}	2.23^{d}
Blue	2.18^{c}	2.51^{b}	2.34^{b}
Green	2.18^{c}	2.63^{a}	2.40^{c}
White	1.99^{d}	2.5^{b}	2.24^{d}
Control	2.02^{d}	1.88^{e}	1.95^{e}
Mean(B)	2.07^{b}	2.44^{a}	
CD(0.05)	A =0.03	B =0.01	(A × B) =0.04

IAA content in flower of *Gerbera jamesonii* Bolus after flowering was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (2.42) IAA content followed by blue (2.34) and green (2.40). Yellow (2.23) and white (2.24) showed similar results. . Least IAA content was observed under control treatment (1.95). Plants in Non-UV condition (2.44) had significantly higher IAA as compared to those in UV condition (2.07). It could be inferred that red light in non-UV condition resulted in higher IAA content.

Table 28. GA content (mg g^{-1}) in leaf of *Gerbera jamesonii* as influenced by spectral colours and UV

Light Colour	UV	Non-UV	Mean(A)
Red	19.43^{b}	19.89^{a}	19.56^{a}
Yellow	17.43^{f}	17.85^{e}	17.64^{c}
Blue	18.97^{c}	19.81^{a}	19.49^{a}
Green	16.32^{h}	16.89^{g}	16.60^{d}
White	17.55^{f}	18.42^{d}	17.98^{b}
Control	14.89^{j}	15.29^{i}	15.09^{e}
Mean(B)	17.43^{b}	18.02^{a}	
CD(0.05)	A =0.11	B =0.06	(A × B) =0.16

GA content in flower of *Gerbera jamesonii* Bolus was significantly influenced by spectral colours. Among the spectral colours plants in red and blue spectrum showed highest (19.56 and 19.49) GA content followed by white (17.98), yellow (17.64) and green (16.60). Least GA content was observed under control (15.09) treatment. Plants in non UV condition (18.02) had significantly higher GA content as compared to those in UV condition (17.43). From the table It could be inferred that red light in non UV condition resulted in higher GA content.

Table 29. Nitrate reductase activity (µ moles of NO_2^- formed g^{-1} FW $hr^{-1)}$ in leaf of *Gerbera jamesonii* before flowering as influenced by spectral colours and UV

Light Colour	UV	Non-UV	Mean(A)
Red	35.41^{b}	36.45^{a}	35.93^{a}
Yellow	30.58^{g}	32.47^{e}	31.53^{d}
Blue	34.00^{c}	35.58^{b}	34.79^{b}
Green	27.96^{j}	28.87^{i}	28.42^{f}
White	31.56^{f}	32.87^{d}	32.22^{c}
Control	30.36^{gh}	30.18^{h}	30.27^{e}
Mean(B)	31.65^{b}	32.73^{a}	
CD(0.05)	A =0.29	B =0.17	(A × B) = 0.42

Nitrate reductase activity was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (35.93) nitrate reductase activity in plant followed by blue (34.79), white (32.22) and yellow (31.53). Lowest nitrate reductase activity in plant was observed under green (28.42) which was lower than the control treatment (30.27). Plants in non-UV condition (32.73) had significantly lowest nitrate reductase activity in plant as compared to those in UV condition (31.65). From the table It could be inferred that red light in non-UV condition resulted in highest nitrate reductase activity

Table 30. Nitrate reductase activity (µ moles of NO_2^- formed g^{-1} FW hr^{-1}) in leaf of *Gerbera jamesonii* after flowering as influenced by spectral colours and UV

Light Colour	UV	Non-UV	Mean(A)
Red	39.45^{c}	40.67^{a}	40.06^{a}
Yellow	35.01^{h}	36.61^{f}	35.81^{d}
Blue	38.32^{d}	39.82^{b}	39.07^{b}
Green	32.41^{k}	33.41^{j}	32.91^{f}
White	35.81^{g}	37.31^{e}	36.56^{c}
Control	34.41^{i}	34.61^{i}	34.51^{e}
Mean(B)	35.91^{b}	37.08^{a}	
CD(0.05)	A =0.24	B =0.14	(A × B) = 0.35

Nitrate reductase activity was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (40.06) nitrate reductase activity in plant followed by blue (39.07), white (36.56) and yellow (35.81). Lowest nitrate reductase activity in plant was observed under green (32.91) which was lower than the control treatment (34.51). Plants in non-UV condition (37.08) had significantly lowest nitrate reductase activity in plant as compared to those in UV condition (35.91). From the table It could be inferred that red light in non-UV condition resulted in highest nitrate reductase activity.

Table 31. Proline content (mg g^{-2}) in leaf of *Gerbera jamesonii* before flowering as influenced by spectral colours and UV

Light Colour	UV	Non-UV	Mean(A)
Red	158.97[c]	127.01[g]	142.98[c]
Yellow	136.83[e]	112.45[j]	124.64[e]
Blue	175.31[a]	126.89[g]	151.1[a]
Green	165.67[b]	125.62[h]	145.64[b]
White	131.3[f]	103.67[k]	117.5[f]
Control	149.69[d]	116.76[i]	133.22[d]
Mean(B)	152.96[a]	118.73[b]	
CD(0.05)	A =3	B =1.9	(A × B) = 4.7

Proline content in *Gerbera jamesonii* Bolus before flowering was significantly influenced by spectral colours. Among the spectral colours plants in blue spectrum showed highest (151.1) proline content followed by green (145.64), red (142.98), control (133.22) and yellow (124.64). Least proline content was observed under white (117.50). Plants in UV condition (152.96) had significantly higher proline content as compared to those in non-UV condition (118.73). From the table it could be inferred that blue light in UV condition resulted in higher proline content.

Table 32. Proline content (mg g^{-2}) in leaf of *Gerbera jamesonii* after flowering as influenced by spectral colours and UV

Light Colour	UV	Non-UV	Mean(A)
Red	181.67[b]	138.62[fg]	160.14[c]
Yellow	153.83[d]	127.45[h]	140.64[e]
Blue	189.31[a]	143.89[ef]	166.6[a]
Green	182.97[b]	142.00[ef]	162.48[b]
White	147.33[e]	119.67[i]	133.5[f]
Control	163.69[c]	134.76[g]	149.22[d]
Mean(B)	169.8[a]	134.39[b]	
CD(0.05)	A =3.83	B =2.21	(A × B) =5.4

Proline content in *Gerbera jamesonii* Bolus after flowering was significantly influenced by spectral colours. Among the spectral colours plants in blue spectrum showed highest (166.6) proline content followed by green (162.48), red (160.14), control (149.22) and yellow (140.64). Least proline content was observed under white (133.5). Plants in UV condition (169.8) had significantly higher proline content as compared to those in non-UV condition (134.39). From the table It could be inferred that blue light in UV condition resulted in higher proline content.

Table 33. Floral xanthophyll content (µg g^{-1} fr. wt.) as influenced by UV and spectral colours.

Light Colour	UV	Non-UV	Mean(A)
Red	0.59^{a}	0.44^{c}	0.51^{b}
Yellow	0.42^{cd}	0.35^{ef}	0.38^{d}
Blue	0.63^{a}	0.54^{b}	0.58^{a}
Green	0.27^{gh}	0.25^{h}	0.26^{f}
White	0.31^{fg}	0.29^{gh}	0.3^{e}
Control	0.43^{c}	0.38^{de}	0.40^{c}
Mean (B)	0.44^{a}	0.37^{b}	
CD (0.05)	A =0.03	B =0.01	(A × B) =0.04

Xanthophyll content in flower of *Gerbera jamesonii* Bolus was significantly influenced by spectral colours. Among the spectral colours plants in blue spectrum showed highest (0.58) xanthophyll content followed by red (0.51), control (0.40), yellow (0.38) and white (0.30) Least xanthophyll content was observed under green (0.26). Plants in UV condition (0.44) had significantly higher xanthophyll content as compared to those in non-UV condition (0.37). From the table It could be inferred that blue light in UV condition resulted in higher xanthophyll content.

Table 34. Floral flavonoids content ($A_{300}g^{-1}$ fr. wt.) as influenced by UV and spectral colours.

Light Colour	UV	Non-UV	Mean(A)
Red	30.56^{ab}	27.92^{c}	29.24^{b}
Yellow	25.55^{de}	23.39^{f}	24.47^{c}
Blue	32.36^{a}	28.76^{bc}	30.56^{a}
Green	19.37^{h}	21.28^{gh}	20.32^{e}
White	22.13^{fg}	23.37^{f}	22.75^{d}
Control	25.63^{d}	23.64^{ef}	24.63^{c}
Mean(B)	25.93^{a}	24.72^{b}	
CD (0.05)	A =1.38	B =0.79	(A × B) =1.95

Flavonoid content in flower of *Gerbera jamesonii* Bolus was significantly influenced by spectral colours. Among the spectral colours plants in blue spectrum showed highest (30.56) flavonoid content followed by red (29.24), control (24.63) yellow (24.47) and white (22.75) Least flavonoid content was observed under green (20.32). Plants in UV condition (25.93) had significantly higher flavonoid content as compared to those in non-UV condition (24.72). From the table it could be inferred that blue light in UV condition resulted in higher flavonoid content.

Table 35. Floral anthocyanin content (mg/g) as influenced by UV and spectral colours.

Light Colour	UV	Non-UV	Mean(A)
Red	0.77^{a}	0.62^{cd}	0.70^{b}
Yellow	0.63^{cd}	0.52^{f}	0.58^{c}
Blue	0.81^{a}	0.65^{bc}	0.73^{a}
Green	0.46^{g}	0.31^{h}	0.39^{d}
White	0.62^{cd}	0.57^{e}	0.60^{b}
Control	0.69^{b}	$0.59d^{e}$	0.64^{c}
Mean(B)	0.66^{a}	0.54^{b}	
CD(0.05)	A =0.03	B =0.01	(A × B) =0.04

Anthocyanin content in flower of *Gerbera jamesonii* Bolus was significantly influenced by spectral colours. Among the spectral colours plants in blue spectrum showed highest (0.73) anthocyanin content followed by red (0.70), control (0.64) white (0.60) and yellow (0.58) Least anthocyanin content was observed under green (0.39). Plants in UV condition (0.66) had significantly higher anthocyanin content as compared to those in non-UV condition (0.54). From the table It could be inferred that blue light in UV condition resulted in higher anthocyanin content.

4.5 Floral parameters

Table 36. Effect of Spectral colours and UV on number of flowers per plant (nos) during winter season

Light Colour	UV	Non-UV	Mean(A)
Red	4.97^{c}	5.67^{a}	5.32^{a}
Yellow	4.26^{g}	4.64^{e}	4.45^{d}
Blue	4.36^{f}	5.34^{b}	4.85^{b}
Green	3.34^{j}	3.97^{h}	3.65^{f}
White	4.27^{g}	4.92^{d}	4.59^{c}
Control	3.47^{i}	4.28^{g}	3.87^{e}
Mean(B)	3.98^{b}	4.83^{a}	
CD (0.05)	A =0.03	B =0.01	(A × B) =0.04

Number of flowers in plant of *Gerbera jamesonii* Bolus was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (5.32) no of flowers in plant followed by blue (4.85), white (4.59) and yellow (4.45). Lowest no of flowers in plant was observed under green (3.65) which was lower than the control treatment (3.87). Plants in Non-UV condition (4.83) had significantly lowest no of flowers in plant as compared to those in UV condition (3.98). From the table It could be inferred that red light in non-UV condition resulted in lowest days to flower initiation.

Table 37. Effect of Spectral colours and UV on number of flowers per plant (nos) during summer season

Light Colour	UV	Non-UV	Mean(A)
Red	4.94^{c}	5.24^{a}	5.09^{a}
Yellow	4.01^{f}	4.21^{e}	4.11^{c}
Blue	4.23^{e}	5.11^{b}	4.67^{b}
Green	3.21^{j}	3.54^{h}	3.37^{e}
White	3.95^{f}	4.49^{d}	4.12^{c}
Control	3.37^{i}	3.85^{g}	3.61^{d}
Mean(B)	3.95^{b}	4.40^{a}	
CD(0.05)	A =0.04	B =0.02	(A × B) =0.06

Number of flowers in plant of *Gerbera jamesonii* Bolus was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (5.09) no of flowers in plant followed by blue (4.67). White (4.12) and yellow (4.11) show similar effects. Lowest no of flowers in plant was observed under green (3.37) which was lower than the control treatment (3.61). Plants in Non-UV condition (4.40) had significantly lowest no of flowers in plant as compared to those in UV condition (3.95). From the table it could be inferred that red light in non-UV condition resulted highest number of flowers in plant

Table 38. Effect of Spectral colours and UV on number of flowers per plant (nos) during rainy season

Light Colour	UV	Non-UV	Mean(A)
Red	4.63^{c}	5.03^{a}	4.83^{a}
Yellow	3.82^{g}	4.01^{f}	3.91^{d}
Blue	4.42^{d}	4.9^{b}	4.66^{b}
Green	3.01^{i}	3.33^{h}	3.17^{e}
White	3.93^{f}	4.28^{e}	4.10^{c}
Control	2.74^{j}	2.78^{j}	2.76^{f}
Mean(B)	3.75^{b}	4.05^{a}	
CD (0.05)	A =0.06	B =0.03	(A × B) =0.09

Number of flowers in plant of *Gerbera jamesonii* Bolus was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (4.83) no of flowers in plant followed by blue (4.66) white (4.10) and yellow (3.91). Lowest no of flowers in plant was observed under green (3.17) which was lower than the control treatment (2.76). Plants in Non-UV condition (4.05) had significantly lowest no of flowers in plant as compared to those in UV condition (3.75). From the table it could be inferred that red light in non-UV condition resulted in more number of flowers.

Table 39. Effect of Spectral colours and UV on flower head diameter (cms) in winter months

Light Colour	UV	Non-UV	Mean(A)
Red	11.71^{c}	12.36^{a}	12.04^{a}
Yellow	10.57^{g}	10.90^{f}	10.74^{d}
Blue	11.43^{d}	12.06^{b}	11.75^{b}
Green	9.74^{j}	9.97^{i}	9.86^{f}
White	10.71^{g}	11.26^{e}	10.99^{c}
Control	10.22^{h}	10.31^{h}	10.27^{e}
Mean(B)	10.73^{b}	11.14^{a}	
CD (0.05)	A =0.11	B =0.06	(A × B) =0.16

Flower head diameter of flower of *Gerbera jamesonii* Bolus during winter months was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (12.04) flower head diameter followed by blue (11.75), white (10.74) and yellow (10.99). Least flower head diameter was observed under green (9.86) which was lower than the control treatment (10.27). Plants in Non-UV condition (11.14) had significantly higher flower head diameter as compared to those in UV condition (10.73). From the table it could be inferred that red light in non-UV condition resulted in higher flower head diameter of flower.

Table 40. Effect of Spectral colours and UV on flower head diameter (cms) in summer months

Light Colour	UV	Non-UV	Mean(A)
Red	11.38	12.05	11.72[a]
Yellow	10.22	10.61	10.42[d]
Blue	11.13	11.73	11.43[b]
Green	9.40	9.66	9.53[f]
White	10.40	10.93	10.67[c]
Control	9.91	9.98	9.95[e]
Mean(B)	10.41[b]	10.83[a]	
CD(0.05)	A =0.2	B =0.13	(A × B) = NS

Flower head diameter of flower of *Gerbera jamesonii* Bolus during summer months was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (11.72) flower head diameter followed by blue (11.43), white (10.67) and yellow (10.42). Least flower head diameter was observed under control treatment (9.95). Plants in Non-UV condition (10.83) had significantly higher flower head diameter as compared to those in UV condition (10.41). From the table it could be inferred that red light in non-UV condition resulted in higher flower head diameter of flower.

Table 41. Effect of Spectral colours and UV on flower head diameter (cms) in rainy months

Light Colour	UV	Non-UV	Mean(A)
Red	11.30[c]	11.93[a]	11.61[a]
Yellow	10.15[g]	10.45[f]	10.30[d]
Blue	11.03[d]	11.67[b]	11.35[b]
Green	9.32i	9.58[h]	9.45[e]
White	10.28[fg]	10.82[e]	10.55[c]
Control	9.14i	9.24i	9.19[f]
Mean(B)	10.20[b]	10.61[a]	
CD(0.05)	A =0.13	B =0.07	(A × B) = 0.18

Flower head diameter of flower of *Gerbera jamesonii* Bolus during rainy months was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (11.61) flower head diameter followed by blue (11.35), white (10.55) and yellow (10.30). Least flower head diameter was observed under control treatment (9.19) which was lower than the green light (9.45). Plants in Non-UV condition (10.61) had significantly higher flower head diameter as compared to those in UV condition (10.20). From the table it could be inferred that red light in non-UV condition resulted in higher flower head diameter of flower.

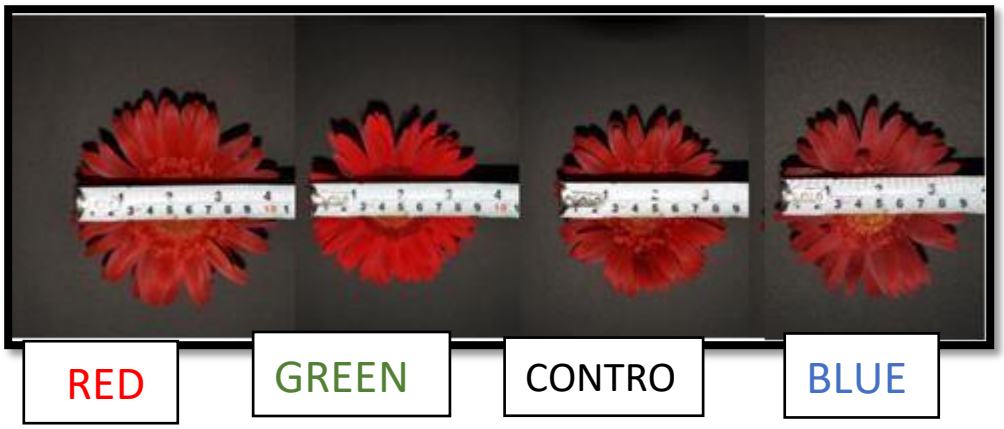

Plate 7. Effect of Spectral colors on flower head diameter

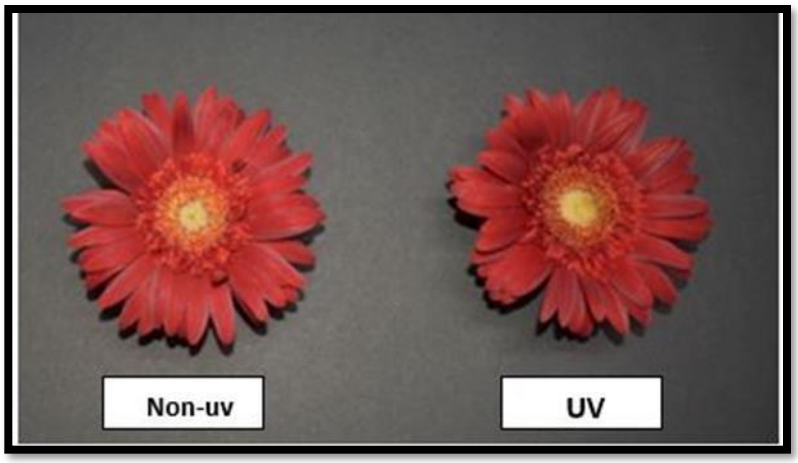

Plate 8 .Effect of UV on flower head diameter

Table 42. Effect of Spectral colours and UV on stalk length (cms) of flower during winter months.

Light Colour	UV	Non-UV	Mean(A)
Red	62.67[c]	64.13[a]	63.40[a]
Yellow	58.71[g]	59.87[f]	59.29[d]
Blue	61.90[d]	63.28[b]	62.59[b]
Green	56.00[k]	56.67[j]	56.33[f]
White	58.87[g]	60.84[e]	59.80[c]
Control	57.14i	57.81[h]	57.47[e]
Mean(B)	59.21[b]	60.43[a]	
CD (0.05)	A =0.14	B =0.08	(A × B) = 0.2

Stalk length of flower of *Gerbera jamesonii* Bolus during winter months was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (63.40) stalk length followed by blue (62.59), white (59.8) and yellow (59.29). Least stalk length was observed under green (56.33) which was lower than the control treatment (57.47). Plants in Non-UV condition (60.43) had significantly higher stalk length as compared to those in UV condition (59.21). From the table it could be inferred that red light in non-UV condition resulted in higher stalk length of flower.

Table 43. Effect of Spectral colours and UV on stalk length (cms) of flower during summer months.

Light Colour	UV	Non-UV	Mean(A)
Red	62.35	63.78	63.07[a]
Yellow	58.34	59.50	58.92[d]
Blue	61.56	62.89	62.23[b]
Green	55.67	56.30	56.00[f]
White	58.50	60.50	59.50[c]
Control	56.78	57.50	57.14[e]
Mean(B)	58.87[b]	60.08[a]	
CD (0.05)	A =0.4	B =0.2	(A × B) = NS

Stalk length of flower of *Gerbera jamesonii* Bolus during summer months was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (63.07) stalk length followed by blue (62.23), white (59.50) and yellow (58.92). Least stalk length was observed under green (56.00) which was lower than the control treatment (57.14). Plants in Non-UV condition (60.08) had significantly higher stalk length as compared to those in UV condition (58.87). From the table it could be inferred that red light in non-UV condition resulted in higher stalk length of flower.

Table 44. Effect of Spectral colours and UV on stalk length (cms) of flower during rainy months.

Light Colour	UV	Non-UV	Mean(A)
Red	61.96[c]	63.35[a]	62.66[a]
Yellow	57.89[g]	59.06[f]	58.48[d]
Blue	61.10[d]	62.44[b]	61.77[b]
Green	55.19[i]	55.88[h]	55.54[e]
White	58.04[g]	60.02[e]	59.03[c]
Control	54.76[j]	55.31[i]	55.04[f]
Mean(B)	58.16[b]	59.34[a]	
CD(0.05)	A =0.2	B =0.1	(A × B) =0.3

Stalk length of flower of *Gerbera jamesonii* Bolus during rainy months was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (62.66) stalk length followed by blue (61.77), white (59.03) and yellow (58.48). Least vase life was observed under control treatment (55.04) which was lower than the green light (55.54). Plants in Non-UV condition (59.34) had significantly higher stalk length as compared to those in UV condition (58.16). From the table it could be inferred that red light in non-UV condition resulted in higher stalk length of flower.

Table 45. Effect of Spectral colours and UV on stalk diameter (cms) of flower in winter season

Light Colour	UV	Non-UV	Mean(A)
Red	2.43	2.62	2.53[a]
Yellow	2.05	2.27	2.16[c]
Blue	2.39	2.51	2.45[b]
Green	1.75	1.83	1.79[e]
White	2.14	2.31	2.26[c]
Control	1.89	1.94	1.92[d]
Mean(B)	2.11[b]	2.25[a]	
CD(0.05)	A =0.17	B =0.11	(A × B) = NS

Stalk diameter was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (2.53) stalk diameter in plant followed by blue (2.45). White (2.23) and yellow (2.16) showed similar effects. Lowest stalk diameter in plant was observed under green (1.79) which was lower than the control treatment (1.92). Plants in Non-UV condition (2.25) had significantly highest stalk diameter in plant as compared to those in UV condition (2.11). From the table it could be inferred that red light in non-UV condition resulted in highest stalk diameter.

Table 46. Effect of Spectral colours and UV on stalk diameter (cms) of flower in summer season

Light Colour	UV	Non-UV	Mean(A)
Red	2.35	2.54	2.45^{a}
Yellow	1.97	2.19	2.08^{c}
Blue	2.31	2.43	2.37^{b}
Green	1.67	1.75	1.71^{e}
White	2.06	2.23	2.15^{c}
Control	1.81	1.86	1.84^{d}
Mean(B)	2.03^{b}	2.17^{a}	
CD(0.05)	A =0.2	B =0.13	(A × B) = NS

Stalk diameter was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (2.45) stalk diameter in plant followed by blue (2.37). White (2.15) and yellow (2.08) showed similar effects. Lowest stalk diameter in plant was observed under green (1.71) which was lower than the control treatment (1.84). Plants in Non-UV condition (2.17) had significantly highest stalk diameter in plant as compared to those in UV condition (2.03). From the table it could be inferred that red light in non-UV condition resulted in highest stalk diameter.

Table 47. Effect of Spectral colours and UV on stalk diameter (cms) of flower in rainy season

Light Colour	UV	Non-UV	Mean(A)
Red	2.30	2.49	2.40[a]
Yellow	1.92	2.14	2.03[c]
Blue	2.26	2.38	2.32[b]
Green	1.62	1.70	1.66[d]
White	2.01	2.18	2.10[c]
Control	1.62	1.67	1.65[d]
Mean(B)	1.96[b]	2.09[a]	
CD(0.05)	A =0.09	B =0.05	(A × B) = NS

Stalk diameter was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (2.40) stalk diameter in plant followed by blue (2.32). White (2.10) and yellow (2.03) showed similar effects. Lowest stalk diameter in plant was observed under green (1.66) and control (1.65) respectively. Plants in Non-UV condition (2.09) had significantly highest stalk diameter in plant as compared to those in UV condition (1.96). From the table it could be inferred that red light in non-UV condition resulted in highest stalk diameter.

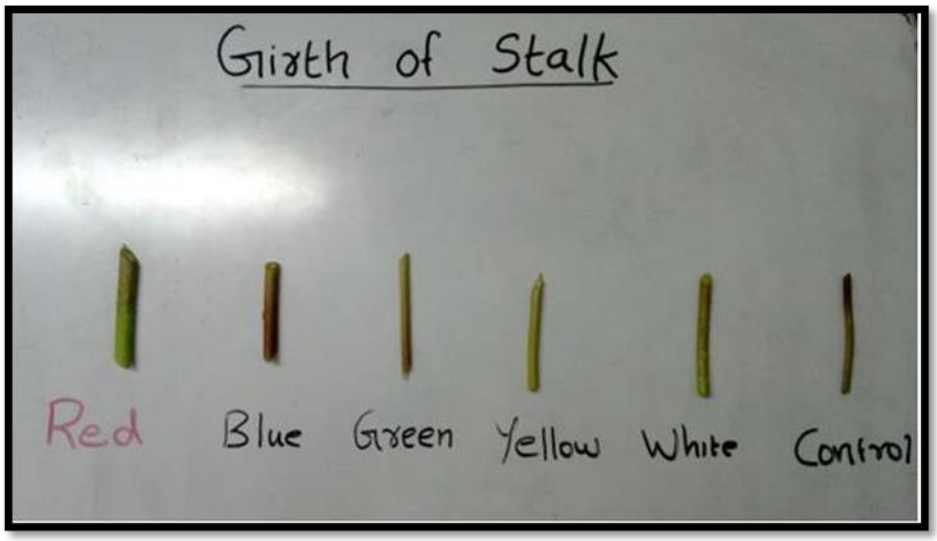

Plate 9.Effect of spectral coloures on girth of stalk

Table 48. Effect of Spectral colours and UV on stalk bending percentage (%)

Light Colour	UV	Non-UV	Mean(A)
Red	21.56^{k}	24.76^{j}	23.16^{f}
Yellow	37.45^{d}	35.89^{e}	36.67^{c}
Blue	26.76^{i}	28.9^{h}	27.83^{e}
Green	61.54^{a}	60.67^{b}	61.10^{a}
White	31.85^{f}	30.67^{g}	31.26^{d}
Control	40.78^{c}	41.34^{c}	41.06^{b}
Mean(B)	36.65^{b}	37.03^{a}	
CD(0.05)	A =0.49	B =0.28	(A × B) =0.70

Flower stalk bending of *Gerbera jamesonii* Bolus was significantly influenced by spectral colours. Among the spectral colours plants in green spectrum showed highest (61.10) flower stalk bending than control treatment (41.06), followed by yellow (36.67), white (31.26) and blue (27.83) Least flower stalk bending was observed under red light (23.16) treatment. Plants in Non-UV condition (37.03) had significantly higher flower stalk bending as compared to those in UV condition (36.65). From the table it could be inferred that green light in non-UV condition resulted in higher flower stalk bending.

Table 49. Effect of Spectral colours and UV on vase life (days) during winter months

Light Colour	UV	Non-UV	Mean(A)
Red	11.91[c]	14.16[a]	13.53[a]
Yellow	10.44[d]	11.56[c]	11.50[c]
Blue	11.76[c]	12.77[b]	12.26[b]
Green	8.51[e]	8.52[e]	8.51[e]
White	10.40[d]	10.55[d]	10.47[c]
Control	8.64[e]	9.97[d]	9.80[d]
Mean(B)	10.28[b]	11.25[a]	
CD(0.05)	A =0.46	B =0.26	(A × B) =0.65

Vase life of flower of *Gerbera jamesonii* Bolus during winter months was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (13.53) vase life followed by blue (12.26), white (10.47) and yellow (11.50). Least vase life was observed under green (8.51) which was lower than the control treatment (9.80). Plants in Non-UV condition (11.25) had significantly higher vase life as compared to those in UV condition (10.28). From the table it could be inferred that red light in non-UV condition resulted in higher vase life of flower.

Table 50. Effect of Spectral colours and UV on vase life (days) on summer months

Light Colour	UV	Non-UV	Mean(A)
Red	11.84	13.01	12.42[a]
Yellow	10.28	10.47	10.37[c]
Blue	11.69	12.68	12.18[b]
Green	8.4	8.42	8.41[e]
White	10.33	10.47	10.40[c]
Control	8.57	8.91	8.69[d]
Mean(B)	10.18[b]	10.64[a]	
CD(0.05)	A =0.52	B =0.30	(A × B) = NS

Vase life of flower of *Gerbera jamesonii* Bolus during summer months was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (12.42) vase life followed by blue (12.18), white (10.40) and yellow (10.37). Least vase life was observed under green (8.41) which was lower than the control treatment (8.69). Plants in Non-UV condition (10.64) had significantly higher vase life as compared to those in UV condition (10.18). From the table it could be inferred that red light in non-UV condition resulted in higher vase life of flower.

Table 51. Effect of Spectral colours and UV on vase life (days) on rainy months

Light Colour	UV	Non-UV	Mean(A)
Red	11.71[c]	12.9[a]	12.30[a]
Yellow	10.16[d]	10.33[d]	10.24[c]
Blue	11.59[c]	12.55[b]	12.07[b]
Green	7.26[f]	8.48[e]	7.87[d]
White	10.18[d]	10.34[d]	10.26[c]
Control	8.19[e]	8.21[e]	8.27[d]
Mean(B)	9.84[b]	10.46[a]	
CD(0.05)	A =0.16	B =0.09	(A × B) =0.23

Vase life of flower of *Gerbera jamesonii* Bolus during summer months was significantly influenced by spectral colours. Among the spectral colours plants in red spectrum showed highest (12.30) vase life followed by blue (12.07), white (10.26) and yellow (10.24). Least vase life was observed under green (7.87) which was lower than the control (8.27). Plants in Non-UV condition (10.46) had significantly higher vase life as compared to those in UV condition (9.84). From the table it could be inferred that red light in non-UV condition resulted in higher vase life of flower.

4.6 Incidence of pest and diseases

4.6.1 Pest incidence

a) **Leaf miner** (*Liriomyza trifolii*)

Small yellow colored flies. Adult Leaf miner lay eggs on upper surface of leaves by making a small puncture. Eggs can be seen as small white specks on the leaves. After hatching, larva mines into the leaf and form a characteristic serpentine tunnel in the leaf. Neem oil 10 ml / liter is used for management.

b) **Thrips (***Frankliniella occidentalis)*

They suck the sap of petals causing brownish streaks and light coloured flower petals.

For controlling thrips, Spinosad 45 % @ 3.0 ml was mixed in 10 litres of water and sprayed in plants.

c) **Mites** *(Tetranychus urticae)*

They mainly occur on the underside of leaves where they pierce the cells and suck out the contents.. Confidor 350 SC @ 0.5 ml in two litres of water was sprayed.

d) **Mealybug**s (*Paracoccus marginatus*)

Soft white bodied insects that are typically found under the leaf and stalk of Gerbera flower. Stunting, chlorosis, defoliation, and wilting of plants occurred. For the control of mealy bugs, malathion at 0.05 % was sprayed on plants.

4.6.2. Disease incidence

a) **Fusarium wilt** (*Fusarium oxysporum*)

Leaves turn yellow and wilt, mostly on one side of the plant. Finally, the whole plant wilts. *Pseudomonas* 10 gm/ litre is sprayed

b) **Botrytis** (*Botrytis cinereal)*

Petioles have long brown spots. Leaves yellow and die. Petals have tan spots. Stems at soil level are killed. Infected tissues become covered with gray fungal growth.Sprint (Mancozeb 50% + Carbendazim 25%) 0.5 gm per litre of water is used for control.

45 days old TC plants

Bud initiation

Red- 49.94 days

Green- 62.58 days

Flower opening

Red-12.04 days

Green-13.86 days

Harvesting stage

Red- 14.63 days

Green- 16.60 days

Vase life

Red 12.38 days Green-7.87 days

Senescence

Fig: 1 Phenophases under different light from planting to harvest

Discussion

5. DISCUSSION

Light is a major environmental resource that affects growth and productivity. It is a major constraint under protected cultivation of gerbera for commercial purpose. The major focus of the study was to compare the effect of UV eliminating polythene sheet to that of UV permitting polythene sheet on the growth parameters of gerbera and also identify the effect of different spectral wavelength on flower production and quality of flowers. The findings of the study are discussed in this chapter.

5.1 Morphological characters as influenced by UV radiation and spectral colours

Early vegetative phase of *Gerbera jamesonii* Bolus var, Juliya extended for four months from date of planting to first flower emergence. Morphological attributes such as plant height, leaf length, leaf breadth, plant spread, number of lobes and petiole length did not show much variation after flowering (Tables 1-6). so mean values for four months alone is given in tables (1-6)

Height of gerbera plants was significantly higher under non-UV condition as compared to UV condition, irrespective of the treatments. This might be due to higher content of growth hormones like IAA and GA under non-UV condition as seen in Tables 27 and 28.

Among the spectral colors, plant height under red and blue spectrum showed significantly higher values as compared to all other colors including white light; lowest height was observed in plants grown under green light which was even lower than control. Generally, plant hormones regulate light-dependent changes in plant morphogenesis (Wu *et al.*, 2017a). Among the endogenous plant hormones, gibberellins (GAs) and auxin [indole-3-acetic acid (IAA)] are reported to mediate differential growth and elongation of plants (Yang and Li, 2017). In the current study,

growth hormones GA and IAA has shown significant variation under different spectral frequencies. Significantly higher content of IAA and GA in red and blue light spectrum might be a major factor that influenced plant height Fig 2.

Leaf characters such as leaf length, leaf breadth, petiole length, number of lobes and plant spread (Tables 2-6) were observed to be significantly higher under non-UV condition as compare to UV condition, while specific leaf area was higher under UV condition than non-UV condition (Tables 20-22). Leaf production was found to be faster in non-UV condition as compared to UV condition. Significant reduction in vegetative characters under UV light has been reported for several crops like *Vigna unguiculata* and *Gossypium hirsutum* (Kakani *et al*., 2003). This has been ascribed to the stress experienced by the plants under high UV-B exposure (Nogues *et al*., 1998). Increase in specific leaf area under UV condition has been indicated as a protective mechanism of plants to prevent UV-B radiation from penetrating into leaf tissues. This has been observed and reported by other workers like (Teramura *et al.*, 1991)

Among the spectral colors, blue light was found to significantly influence vegetative parameters like leaf length, leaf breadth, plant spread, number of lobes and petiole length followed by red light. Rate of leaf production was higher under red light followed by blue light, while it was slow in green light as compared to all other colors. It was seen that stomatal conductance and photosynthetic rate was higher for plants grown under blue light and red light respectively (Table 12-16). Similar findings have been reported by Tennessen *et al*. (1994), where higher biomass production and photosynthetic capacity under blue irradiance were observed. Inhibition of hypocotyl elongation in seedlings has been observed and reported under green light by Folta and Maruhnich, 2007. Yorio *et al.* (2001) reported higher expansion of leaf and increase in biomass of lettuce under red and blue LED, and a reduction in biomass under green LED. Red LED stimulates phytochromes which regulate morphogenesis in plants which might have contribute to earlier leaf initiation as has been reported in spinach by (Burattini *et al*. 2017)

Appearance of flowers in plants marks the reproductive competence of the plants and this is attained only at a certain stage of vegetative development. Vegetative meristems are typically indeterminate, producing organs continuously, whereas flower meristems are determinate, shutting down their growth after reproductive organs are initiated. Flower primordia production starts only after attaining an optimum vegetative stage in plants. From the study, it is seen that flower evocation in gerbera takes place after the emergence of the fifth leaf. Gerbera seedlings planted at two leaf stage in July attained five leaf stage by September, under red and blue LED treatments and these plants came to flower in the same month while those under other spectral treatments came to flowering only by October when they attained five leaf stage.

The current study has clearly brought out the influence of light spectrum on morphogenesis of *Gerbera jamessonii* Bolus. Phenology of the crop under Kerala condition and in polyhouse cultivation using tissue culture plants planted at 2 leaf stage has shown that flower evocation starts at 5^{th} leaf stage, which was attained after 4-5 months of planting. Phenophases under UV and Non-UV condition from planting to harvest are depicted in Fig 1.

Number of days taken for each phenophase was significantly affected by nature of UV exposure and spectral colors. Duration taken for the attainment of each phenophase was shorter for plants grown in non-UV condition than under UV condition, and also it was shorter under red LED while it was highest for plants under green LED, which was even more than those grown without any supplementary lighting (control). Presence of photoreceptors such as phytochromes for red light absorption and cryptochromes and phytotropins for absorption of blue light may be the reason for earliness in morphogenesis under these spectral colors.

5.2 Physiological and biochemical characters affected by UV-B and spectral colours

Evaluation of photosynthetic rate and stomatal conductance under different color regimes indicated that maximum photosynthetic rate was under red light. Fig 3-4. This may be due to activation of phytochrome system and also higher chlorophyll under red light (Table 25).

Stomatal conductance was highest under blue light exposure. Higher stomatal frequency and larger leaf area was observed under blue light as indicated in Tables 16 and 23. Lowest photosynthetic rate and stomatal conductance was under green light which also had the lowest stomatal frequency. Green light is also reported to antagonize some blue light responses, such as stomatal opening (Folta and Maruhnich, 2007), which in turn would be the reason for lower values of stomatal conductance and photosynthetic rate under green light.

Photosynthetic rate, stomatal conductance and transpiration rate was found to be higher before flowering and after flowering as compared to the vegetative phase. According Fujii and Kennedy (1985) photosynthetic rates in flowering or fruiting spur leaves were higher than vegetative spur leaves in *Malus domestica* Bork.

Proline and flavonoid **c**ontents were found to be higher in UV condition as compared to non-UV condition Fig 5-6. As UV-B light imposes stress to plants, accumulation of proline has been reported by (Wagh, 2015). Among the spectral colours, blue light was found to induce reduction of proline and flavanoids in Gerbera. Similar findings have also been reported by Kim *et al.* (2013) in *Solanum lycopersicum* under blue LED treatment. Flavonoids are reported to impart protection to the plants from high UV-B, which has also been observed and reported by other workers like (Ryan *et al*., 2002). Kootstra.1994 observed that flavonoids prevented UV-B-induced DNA damage.

IAA content was found to be higher under red and blue light, compared to other spectral colors both before and after flowering. Higher biosynthesis and transport of IAA has been reported by liu *et al*.(2011) under red light. Similarly, GA content in leaves was higher in plants grown under red and blue light compared to plants grown without supplementary light. Higher levels of bioactive GA_3 and GA_4, was observed in *Solanum lycopersicum* seedlings grown under red colored LED than in those grown under other light conditions (Matsuo *et al.,* 2019). However, both the growth hormones were found to be lower under UV as compared to non-UV condition. According to Tevini and Ros (1995) UV-B causes photooxidative destruction of IAA. This has also been validated by Wagh.(2015).

Nitrate reductase enzyme activity is an indicator of protein synthesis and productivity of crops. In the current study, nitrate reductase enzyme activity was highest under red light followed by blue, which showed higher growth and productivity (Fig 7). Activation of nitrate reductase activity under red light has been reported in *Diplotaxis tenuifolia* even under low nitrogen content by Signore *et al.,* 2020.

5.3 Effect UV and spectral colours on pigment composition of *Gerbera jamesonii* Bolus

The study showed that chlorophyll content in leaves of gerbera was affected by both UV-B radiation and spectral regimes. Plants under non-UV condition had significantly higher a, b and total chlorophyll as compared to non-UV condition. Inhibition of chlorophyll synthesis and break down of structural integrity of chloroplast under UV-B radiation has already been reported by Marwood and Greenberg (1996).

Among the spectral colours, plants under red light showed a 43% higher content of total chlorophyll as compared to control. Blue light exposure contributed to 39% improvement in total chlorophyll. Influence of photoreceptors both red and blue receptor have been reported to control synthesis of chlorophyll by Lopaz-figuroa

(1991) in algal species. High chlorophyll might have contributed to higher photosynthetic efficiency and greater biomass production under red and blue lights.

Anthocyanin and xanthophyll pigments in flower petals were also estimated and the result indicated that under UV condition, both the pigments were higher as compared to non-UV conditions. Studies conducted by hu *et al*., (2020) has shown that UVB radiation activates genes coding enzymes and transcription factors involved in anthocyanin biosynthesis. Among the spectral colours, blue light was found to activate synthesis of anthocyanin; similar results have been reported in Arabidopsis by Noh and Spalding (1998). Activation of transcriptional factors encoding enzymes in anthocyanin biosynthetic pathway has been reported as the reason for this by Outchkourov, *et al.* (2018). Xanthophyll cycle is the mechanism by which plants regulate the energy available for photosynthesis. Under both UV-B and blue light, energy level is higher as compared to other spectral colours. In the current study, higher xanthophyll content in flower petals was observed in the above two situations. Presence of active xanthophyll cycle has also been reported in blue light by Talbott *et al.* (2012) in the orchid *Paphiopedilum.*

5.4 Floral characters as influenced by UV radiation and spectral colours

Number and quality flower production is the major thrust in Gerbera cultivation. The present study shows that there is a seasonal influence on the number and quality of flowers. Under Kerala condition, maximum number of flowers was seen in winter season followed by summer. Least number of flowers was obtained in rainy season. Though the number of flowers in rainy season is slightly reduced under protected cultivation, it can be considered as an all-season crop (Tables 36-38). Seasonal influence on flower production in Gerbera has been reported by Chen *et al*. (2018). Praveen *et al*. (2018) has reported that Gerbera under Kerala condition prefers winter season, which is also evident from the study. Flower quality parameters such as

floral diameter, stalk length, stalk diameter and bending percentage was also found to be superior for plants grown in winter than the other two seasons.

UV exposure and spectral colours also showed significant influence on the number and quality of flowers. There was a significant increase in number of flowers in non-UV condition as compared to UV condition. Floral diameter, stalk length, stalk diameter and bending percentage were found to be negatively influenced by UV exposure. According to Sampson and Cane (1999) enhanced UV-B delayed bloom, reduced flower production and flower quality in *Phacelia campanularia*. However, the contents of anthoyanin, xanthophylls and flavanoid were found to be higher under UV condition than non-UV. Activation of the secondary metabolic pathway by UV exposure might be a reason for the compromise in the quantity (biomass)/ size of the floral organs (Amjath and Girija,2018).

Among the spectral colours, plants under red LED produced maximum number of flowers in all three seasons followed by blue. Flower number under yellow, green and white light was on par and all of them produced more number of flowers than control. Influence of photoreceptors such as phytochromes and cryptochromes under red and blue light respectively might have accelerated growth under these two wavelengths leading to faster growth and more number of flowers as discussed earlier.

Market performance is for flowers with maximum flower head diameter and optimum stalk length without bending as reported by (Sindhu *et al*.,2010). The study indicated that flower quality is enhanced under red light while green light has a negative influence on quality parameters. Flowers were found to have a vase life of 12 days when grown under red light while those under green light and control had a vase life of only 8 days. This also indicates the positive influence of red light on flower quality followed by blue light.

Higher anthocyanin content of petals in blue and red light also accounts for better visual quality of flowers. Lowest anthocyanin pigment was observed in green

light. This also indicates the effect of spectral colours on the metabolism of theplants. Ichimura (1999) has reported that higher anthocyanin pigmentation in flowers improves their vase life. Flowers from plants grown under blue and red light had better vase life which was 3 to 4 days more than control and also from plants grown under green light. Higher content of anthocyanin pigments may be the major factor that accounted for improvement in vase life.

Study on the spectral manipulation of growth and physiology of *Gerbera jamesonii* Bolus showed that under Kerala condition, Gerbera flowers can be obtained throughout the year when grown in polyhouses. Number and quality of flowers is better under non-UV condition and also supplementary lighting with red or blue LED will substantially improve productivity and quality of flowers.

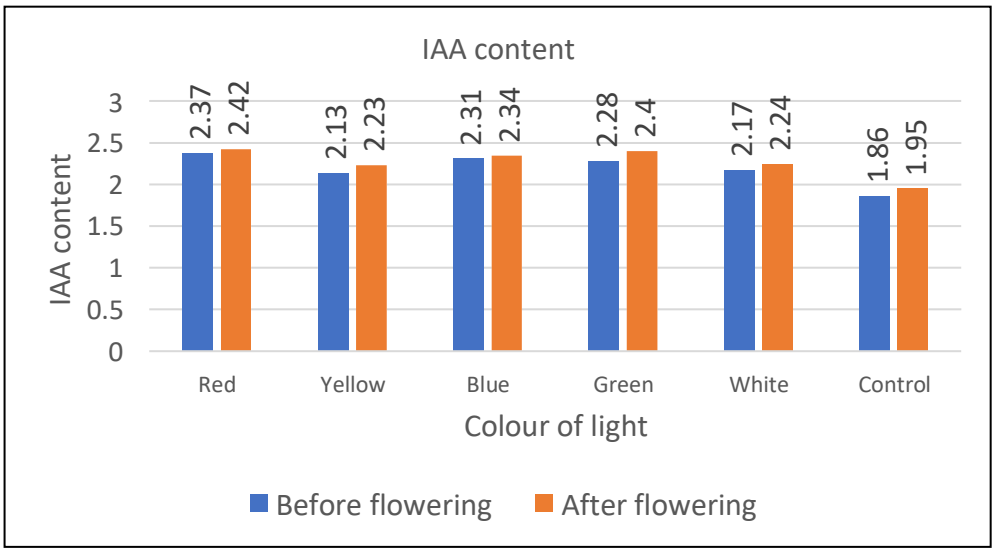

Fig 2. IAA content at different growth phase influenced by spectral colours

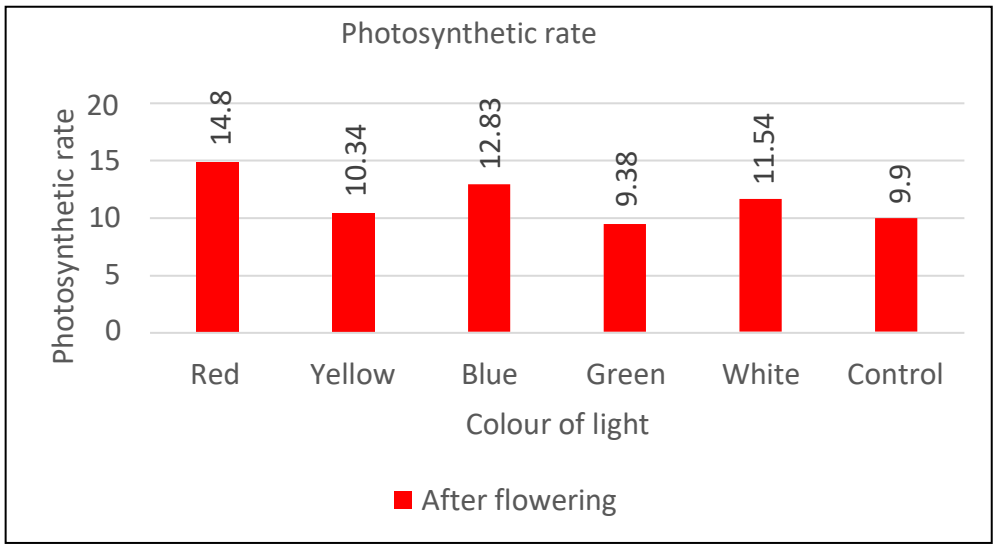

Fig 3. Photosynthetic rate after flowering influenced by spectral colours

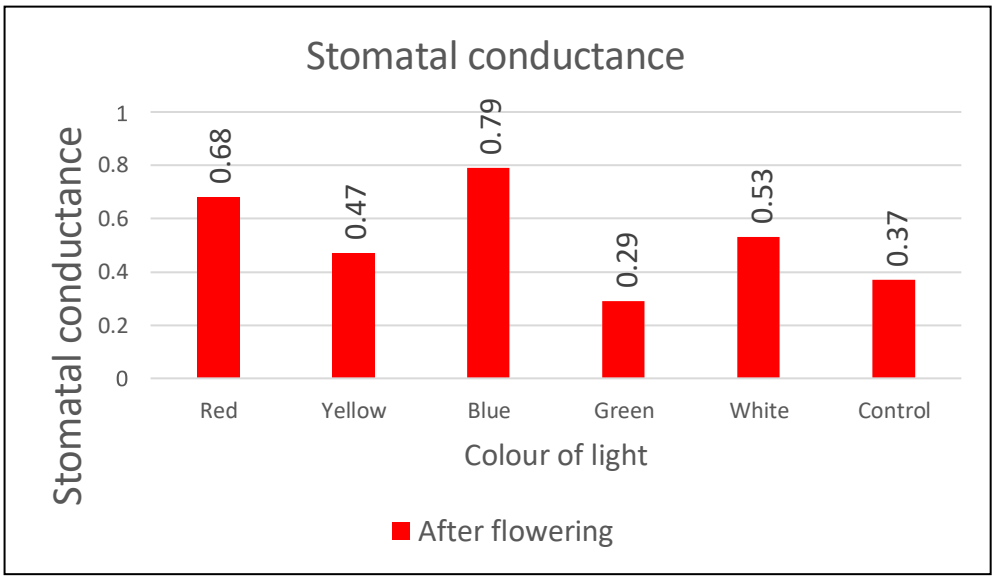

Fig 4. Stomatal conductance after flowering influenced by spectral colours

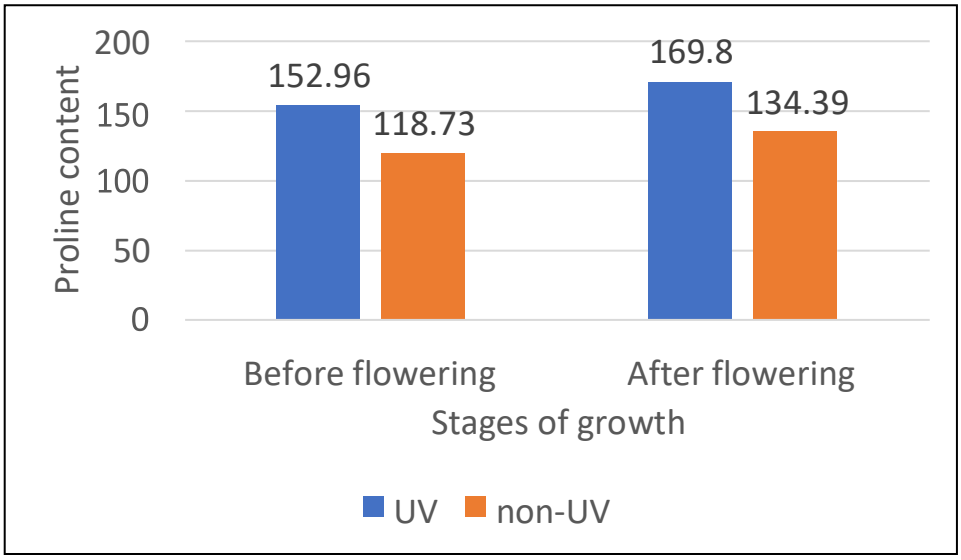

Fig 5. Proline content during flowering influenced by UV.

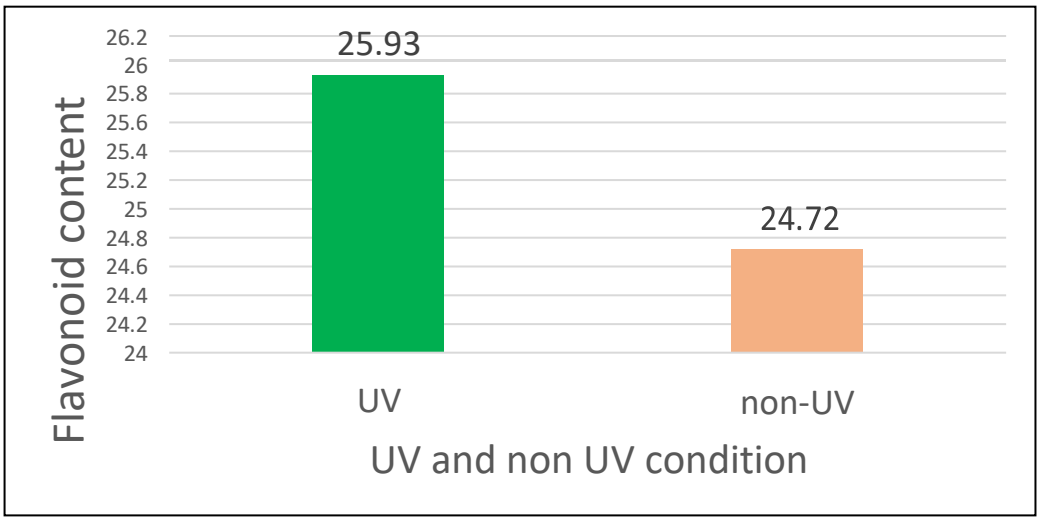

Fig 6. Flavonoid content during flowering influenced by UV.

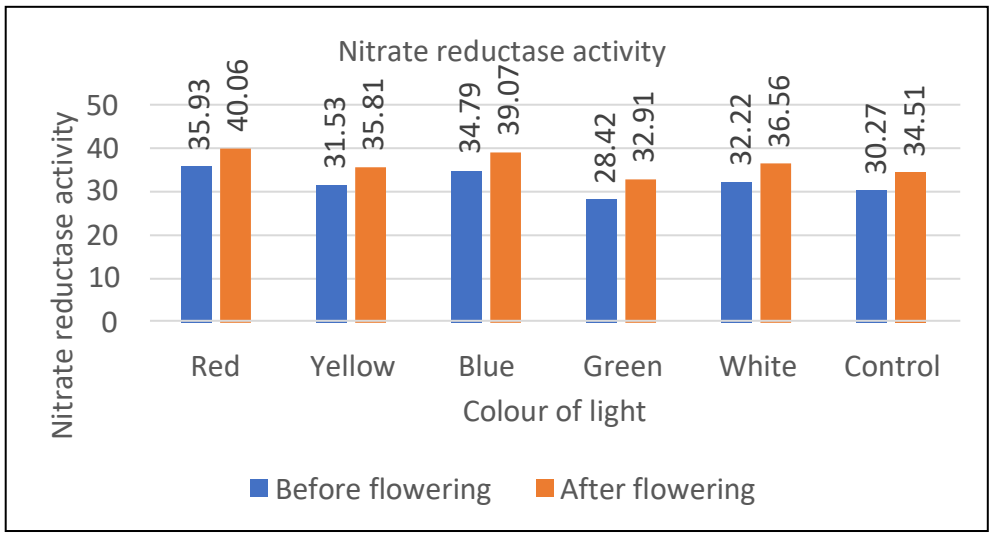

Fig 7. Nitrate reductase enzyme activity at different growth phase influenced by spectral colours

Botrytis

Fusarium wilt

Mealybugs

Thrips

Leaf miner

Mites

Plate 10. Pests and diseases observed

Summary

6. SUMMARY

Gerbera (African daisy) is an important commercial flower cultivated in net houses in Kanthalloor and other parts of Kerala. Gerbera requires high light intensities for good vegetative growth and flower yield. The average sunshine hours in open condition in the central zone of Kerala during January to May goes upto 8.1hr/per day while during June-September is only 3 h/day as per the 33 year mean data available with the Agro Meteorology Observatory COH, Vellanikkara. This shortage in the sun shine hours during rainy season can be substituted by the use of external light in net houses. When light is provided at the optimal levels it can significantly increase the growth rate, health and yield of the crop.

It is important to standardize the quality of the polythene sheet and the spectrum of light that activates growth and productivity. In this context the present study was proposed

The salient features of study are as follows

1. Sunshine hours during rainy season (June 3.72 h, July 1.82 h, and August 1.23 h. respectively) was critically very low compare to winter and summer months.
2. Reduction in sunshine hours, reduces yield attributing characters like number of flowers in plant, flower head diameter, stalk length, and vase life of gerbera during rainy season
3. Gerbera grows well in Kerala condition; maximum number of flowers was seen in winter season followed by summer. Least number of flowers was obtained in rainy season.
4. UV-B radiation reduced many morphological, physiological and floral characters of plant like plant height, number of leaves, photosynthetic rate, number of flowers and vase life of flowers. But it enhances production of some secondary metabolites.

5. Leaf characters such as leaf length, leaf breadth, petiole length, number of lobes and plant spread were observed to be significantly higher under non-UV condition as compare to UV condition.
6. The plant hormones IAA, GA and nitrate reductase were higher in UV-B reduced conditions. Proline and flavonoid **c**ontents were found to be higher in UV condition as compared to non-UV condition.
7. UV exposure and spectral colors also showed significant influence on the number and quality of flowers. There was a significant increase in number of flowers in non-UV condition as compared to UV condition. Floral diameter, stalk length, stalk diameter and bending percentage were found to be negatively influenced by UV exposure.
8. Plants grown under red light exhibits good floral characters like number of flowers per plant, flower head diameter, stalk length, stalk diameter, days to first flower initiation and vase life. Whereas leaf length, leaf breadth, plant spread, petiole length, was recorded maximum under blue light.
9. Flower evocation in gerbera takes place after the emergence of the fifth leaf.
10. Flowers were found to have a vase life of 12 days when grown under red light while those under green light and control had a vase life of only 8 days. Higher content of anthocyanin pigments may be the major factor that accounted for improvement in vase life.
11. Plants grown under red and blue light recorded higher photosynthetic rate as compared to plants grown under yellow, white and green colored LED's. Which was substantiated by an increase in chlorophyll content, stomatal conductance and transpiration rate
12. The increased IAA and GA content in red and blue light enhanced the growth, which resulted in increased plant height, leaf length, leaf breadth and petiole length.
13. Green light contributed to decrease in floral and morphological parameters but increased secondary metabolites like proline, flavonoids and anthocyanin.
14. White and yellow light showed an intermediate effect in morphological, physiological as well as biochemical constituents.

15. Plants grown in non-UV condition with red light irradiation showed improvement in marketable floral parameters such as number of flowers, flower head diameter, stalk length and vase life.

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Appendix

Appendix 1

Weather data 2018-2019

Monthly mean Sunshine hours (h)

Months	Sunshine h
JULY	1.85
AUG	2.2
SEP	7.2
OCT	5.66
NOV	7.11
DEC	6.95
JAN	8.38
FEB	8.72
MAR	8.57
APR	8.02
MAY	6.8
JUN	3.72
JULY	1.82
AUG	1.23
SEP	1.74

Appendix 2

Monthly mean temperature (°c) in open and polyhouse condition

Months	UV	NON UV	OUTSIDE
July	28.20	27.19	25.96
Aug	27.95	26.94	25.71
sep	29.56	28.55	27.32
oct	30.15	29.14	27.91
Nov	30.27	29.26	28.03
Dec	30.02	29.01	27.78
Jan	28.83	27.82	26.59
Feb	31.57	30.56	29.33
Mar	33.03	32.02	30.79
Aprl	33.09	32.08	30.85
May	32.32	30.95	29.72
June	30.11	29.10	27.87
July	29.15	28.36	26.45
Aug	28.54	27.89	26.12
Sep	27.56	26.44	25.89

Appendix 3

Monthly mean UV (W m^{-2}) in open and polyhouse condition

Months	UV	open
July	1.12	1.37
Aug	1.16	1.45
sep	1.25	1.54
oct	1.21	1.35
Nov	1.19	1.47
Dec	1.13	1.39
Jan	1.31	1.62
Feb	1.41	1.74
Mar	2.45	2.76
Aprl	2.37	2.64
May	2.17	2.45
June	1.14	1.42
July	1.02	1.39
Aug	0.98	1.27
Sep	0.96	1.23

Appendix 4

Monthly average humidity (%) in polyhouse and open condition

Humidity	WITH U V	WITHOUT UV	OUTSIDE
July	96.32	97.48	95.81
Aug	96.43	97.87	96.03
sep	92.47	93.58	91.30
oct	90.35	91.46	89.83
Nov	84.76	85.15	83.19
Dec	79.61	80.13	78.16
Jan	72.47	73.70	71.26
Feb	77.36	78.69	76.75
Mar	84.24	85.36	83.84
Aprl	87.37	88.65	86.62
May	87.36	88.47	86.00
June	93.45	94.75	92.70
July	97.12	98.39	96.79
Aug	97.34	98.44	96.93

Appendix 5

Monthly mean PAR (µmolm^{-2}s^{-1} in open and polyhouse condition

Months	UV	non UV
July	549.7	543.36
Aug	538.7	532.36
sep	630.79	624.45
oct	709.66	703.32
Nov	736.73	730.39
Dec	780.6	774.26
Jan	890.7	884.36
Feb	871.7	865.36
Mar	1033.7	1027.36
Aprl	1098.57	1092.23
May	1174.7	1168.36
June	947.7	941.36
July	749.7	743.36
Aug	579.7	573.36
Sep	591.45	580.87

Appendix 6

Monthly mean LUX in UV and non-UV condition

Months	UV	non- UV
July	8850	8600
Aug	12850	12600
Sep	12650	12400
oct	12950	12700
Nov	13250	13000
Dec	13750	13500
Jan	13950	13700
Feb	14150	13900
Mar	15650	15400
Aprl	14950	14700
May	14800	14550
June	13400	13150
July	10550	10300
Aug	10400	10150
Sep	10550	10250

Appendix 7

Monthly average value of number of leaves

Treatment/Months	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sep	AVERAGE
RED UV	4.3	5.89	6.7	9.6	12.8	13.4	14.3	14.89	13.73	13.34	13.44	13.33	12.55	12.59	10.86
RED NU	4.91	6.21	7.31	10.21	13.41	14.01	14.91	15.5	14.34	13.95	14.05	13.94	13.16	13.2	11.41
YELLOW	3.12	4.53	5.34	7.98	9.63	10.78	11.37	11.12	11.78	10.63	10.43	10.11	9.43	9.89	8.54
YELLOW NU	3.53	4.94	5.75	8.39	10.04	11.19	11.78	11.53	12.19	11.04	10.84	10.52	9.84	10.3	8.93
BLUE	4.34	5.43	5.45	9.16	12.54	13.11	14.01	14.37	13.63	13.12	13.21	13.12	12.23	12.16	10.53
BLUE NU	4.96	5.98	6.07	9.78	13.16	13.73	14.63	14.99	14.25	13.74	13.83	13.74	12.85	12.78	11.1
GREEN	3.01	4.11	5.17	6.24	8.33	8.36	9.24	9.36	9.14	10.45	10.33	10.23	8.11	8.16	7.48
GREEN NU	3.53	4.63	5.69	6.76	8.85	8.88	9.76	9.88	9.66	10.97	10.85	10.75	8.63	8.68	7.97
WHITE	3.45	4.14	5.45	7.47	10.67	11.45	12.32	12.35	12.32	12.43	12.54	11.34	11.35	11.78	9.4
WHITE NU	3.98	4.67	5.98	8.21	11.2	11.98	12.85	12.88	12.85	12.96	13.07	11.87	11.88	12.31	9.91
CONTROL	3.56	4.96	5.56	7.68	8.68	9.13	10.02	10.43	9.13	10.23	10.35	9.12	8.23	8.11	7.81
CONTROL NU	4.13	4.98	5.86	8.25	9.25	9.7	10.59	11	9.7	10.8	10.92	9.69	8.8	8.68	8.29

SPECTRAL MANIPULATION OF GROWTH AND PHYSIOLOGY OF *Gerbera jamesonii* Bolus

by

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Abstract of the Thesis

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ABSTRACT

Gerbera (African daisy) is one of the most important commercial flower grown throughout the world under a wide range of climatic conditions. Gerbera requires high light intensities for good vegetative growth and flower yield. The average sunshine hours in open condition in the central zone of Kerala during January to May goes upto 8.1 h/day while during June- September is only 3h/day as per 33 year mean data available with the Agro Meteorology Observatory COH, Vellanikkara. This shortage in the sun shine hours can be substituted by the use of external light in polyhouse. When light is provided at the optimal levels it can significantly increase growth rate, health and yield of the crop.

The experiment was conducted during the period from July 2018 to September 2019 in polyhouses, at, College of Horticulture, Vellanikkara, to study the influence of spectral light intensities and UV on the morphological, phenological, physiological characters, yield and flower quality of Gerbera (*Gerbera Jamesonii* Bolus)

Tissue culture plants of Gerbera variety Julia developed and marketed by LJ International (AVT Biotechnology) in two leaf stage were directly planted in pots of size 9-inch depth at the rate of one plant per pot. The pots were placed under LED lights of red, blue, green, white and yellow colours kept at a height of one meter from the ground. Plants were illuminated for 10 hours from 09.00 am to 07.00 pm daily from July 28th to September 25 th (2018 to 2019).

Observations on morphological characters such as plant height, leaf length, leaf breadth, plant spread, number of lobes, specific leaf area and petiole length were significantly influenced by spectral colors and UV. Among the spectral color's plants under red and blue showed significant higher morphological attributes compared to other colors. Also, plants under non-UV condition showed greater growth characters as compare to UV condition.

Floral evocation was observed when the plants reached five leaf stage. Under red and blue light exposure, plants came to flower in September (49 days from planting) while plants in all other treatments started flowering in October (60 days from planting).

Evaluation of photosynthetic rate under different color regimes indicated that maximum photosynthetic rate was under red light. Gas exchange parameters like stomatal conductance, transpiration rate and stomatal frequencies were higher under blue light followed by red light. Also, plants under non-UV condition showed better physiological characters as compare to those under UV condition. Estimation of GA, IAA and chlorophyll content revealed that all the three components were higher in red light followed by blue under non-UV condition. Nitrate reductase enzyme plays a major role in nitrogen metabolism of plants. In the present study, the nitrate reductase enzyme activity was found to be higher in plants grown under red light in non-UV condition.

Flower pigments like anthocyanin, xanthophyll, flavonoids were found higher in plants grown under blue light and under UV condition rather than non-UV condition. These constituents are products of secondary metabolic pathway in plants. Flower number and flower quality parameters like number of flowers, flower head diameter, flower stalk length, flower stalk girth and vase life was better under non UV condition than UV condition. These quality characters were seen to be better in plants grown under red and blue light.

The study indicated that UV stabilized sheets would be more beneficial than normal polythene sheets and red and blue LED's can be used to supplement light requirement in polyhouses for commercial cultivation of *Gerbera jamesoni* Bolus