PERFORMANCE OF GERBERA (*Gerbera jamesonii* Bolus) CULTIVARS UNDER HYDROPONICS

by
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(2014-12-104)

THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Performance of gerbera (*Gerbera jamesonii* Bolus) cultivars under hydroponics"** is a bonafide record of research done by me during the course of study and the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"Performance of gerbera (*Gerbera jamesonii* Bolus) cultivars under hydroponics"** is a record of research work done independently by Arathi C. S. (2014-12-104) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to his.

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We the undersigned, members of the advisory committee of **Ms. Arathi C. S.**, a candidate for the degree of Master of Science in Horticulture, with major in Pomology and Floriculture, agree that the thesis entitled **"Performance of gerbera (*Gerbera jamesonii* Bolus) cultivars under hydroponics"** may be submitted by **Ms. Arathi C. S.**, in partial fulfillment of the requirement for the degree.

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Introduction

1. INTRODUCTION

Gerbera (*Gerbera jamesonii* Bolus ex. Hooker F.) is an internationally important cut flower grown for its colourful, showy and long-lasting daisy like flowers. It is ranked the fifth most commonly used cut flower in the global trade, after rose, carnation, chrysanthemum and tulip (Jacqueline, 2010). It is commonly and broadly used as cut flower for flowery array, interior decoration, gifts for particular occasions, wedding ceremony, bouquets, *etc.*

There are five diverse flower forms in gerbera, primarily based on the rows of petals and how they lie on top: solitary, twice or duplex, crested doubles, full crested doubles and quelled crested doubles (Clay, 1983).The plants are stemless and tender perennial herbs and these plant characters give them an added advantage to grow well in soilless culture and hydroponics.

Floriculture is a fast emerging and highly competitive industry. Commercial cultivation of cut flowers is largely confined to greenhouse systems and gerbera is no exemption. But due to increased industrialization, availability of land for extensive cultivation is less. This has necessitated development of alternative methods for cultivation of commercial crops, in view of the shrinking land area and to ward off biotic and abiotic stresses. Among these, one of the methods is hydroponic culture.

Hydroponics means water working, *i.e.*, growing plants in a nutrient solution without soil. This usually accompanies controlled environment agriculture and has advanced a great deal in ornamental crop production during the last two decades. Combined with controlled environment agriculture, hydroponics is the most intensive method of crop production. It is highly productive with less labour and time, conserves water and land and protects the environment. This also overcomes problems like soil borne diseases, salinity, poor structure and improper drainage.

Land is a valuable but rapidly depleting resource. The per capita availability of land is also less in Kerala. With the spiraling urbanization, the number of flat dwellers has also increased. Simple hydroponic systems can help people grow plants indoors, without the use of soil. Hydroponics could be an answer to sustain agriculture because of its ability to produce larger yields using smaller amount of space.

Continuous flow hydroponic system, in which the nutrient solution flows over the plant roots, is the system commonly used in commercial production. In such a closed system, the roots are directly exposed to the nutrient solution which is later recovered, replenished and recycled. Hydroponics requires less space and labour and can be well tried indoors. Though there are encouraging reports and success stories about the system in vegetables and foliage plants, such reports on flower crops are far too low.

Experimentation and research in the area of indoor and outdoor hydroponic gardening is an ongoing process. With the introduction of hydroponic technology in commercial plant cultivation, studies have been undertaken on numerous economically important ornamental plants such as rose, carnation, gerbera, aster, chrysanthemum, lily, *etc.* With this background, the present study has been undertaken with the following objectives:

1. To assess the suitability of selected gerbera cultivars to hydroponic culture.
2. To compare the growth, yield and vase life of the gerbera cultivars under hydroponic and greenhouse culture.

Review of literature

2. REVIEW OF LITERATURE

Hydroponics, synonymous to soilless culture, is a technology for growing plants in nutrient solutions without the use of soil as a rooting medium. This usually accompanies controlled environment agriculture and has advanced a great deal in ornamental crop production during the last two decades. Combined with controlled environment agriculture, hydroponics is the most intensive method of crop production. It is highly productive with less labour and time requirement, conserves water and land and protects the environment. This overcomes the problems like soil borne diseases, salinity, poor structure and improper drainage.

Continuous flow hydroponic system, in which the nutrient solution flows over the plant roots, is used most commonly for commercial production. Liquid hydroponic systems are closed systems in which the plant roots are directly exposed to the nutrient solution and the solution is recovered, replenished and recycled. Land is a valuable but rapidly depleting resource. The per capita availability of land is also less in Kerala. With increasing urbanisation, the number of flat-dwellers has increased. Simple hydroponic systems can help people to grow plants and flowers in their home without the use of soil. With the area of arable land diminishing each year, hydroponics system may be the answer to sustain world's agriculture because of its ability to produce larger yields in a smaller space.

2.1 History

The origin of soilless culture goes back at least to the 17^{th} century when, in 1666, Boyle attempted to grow plants in "delete space vials containing nothing but water" and reported that one species (spearmint, *Raphanus aquatica*) survived for nine months. A few years later (1699), Woodward grew spearmint in water to which a small quantity of soil had been added.

The development of hydroponics has not been rapid. In the U.S., interest began to develop in the possible use of complete nutrient solutions in about 1925, for large scale crop production. Greenhouse soils had to be replaced at frequent intervals or else be maintained in good condition from year to year by adding large quantities of commercial fertilizers. As a result of these difficulties, research workers in certain U.S. agricultural experiment stations turned to nutrient solution culture methods as a means of replacing the natural soil system with either an aerated nutrient solution or an artificial soil composed of chemically inert aggregates moistened with nutrient solutions (Withrow and Withrow, 1948).

The word hydroponics comes from two Greek words 'hydro' meaning water and 'ponos' meaning labour and was proposed by Setchell. Later Dr. Gericke (1929) used this word while he developed this laboratory technique into a commercial means of growing plants.

Between 1925 and 1935, extensive development took place in modifying the methods of the plant physiologists to large scale crop production. Workers at the New Jersey Agricultural Experiment Station improved the sand culture method (Shive and Robbins, 1937). The water and sand culture methods were used for large scale production by investigators at the California Agricultural Experiment Station (Hoagland and Arnon, 1938). Each of these methods involved certain fundamental limitations for commercial crop production which partially were overcome with the introduction of the sub irrigation system initiated in 1934 at the New Jersey and Indiana Agricultural Experiment Station (Withrow and Withrow, 1948). While there was commercial interest in the use of such systems, hydroponics was not widely accepted due to the high cost in construction of the concrete growing beds. Hydroponics has been reported for vegetable production in non arable or contaminated regions since the World war (Cooper, 1979).

After a period of approximately 20 years, interest in hydroponics was renewed with the advent of plastics. Plastics were used not only in the glazing of greenhouses, but also in lining the growing beds rather than beds made of concrete. Plastics were also important in the introduction of drip irrigation. Numerous promotional schemes involving hydroponics became common with huge investments made in hydroponic growing systems.

Almost another 20 years have passed since the last real interest in hydroponics. There is again a renewed interest in growers establishing CEA/ hydroponic systems. This is especially true in regions where there are environmental concerns in controlling any pollution of groundwater with nutrient wastes or soil sterilants. Today growers appear to be much more critical with regard to site selection, structures, the growing systems, pest control and markets.

2.2 Advantages and disadvantages

Hydroponic culture can be used in places where in-ground agriculture or gardening is not possible (for example, dry desert areas or cold climate regions).

- By this system more complete control of nutrient content, pH and growing environment can be done.
- It reduces the water and nutrient costs associated with water and nutrient recycling.
- Elimination or reduction of soil related insects, fungi and bacteria is possible.
- Crop yields higher
- Because of the reduced area there is no requirement of weeding or cultivation.
- This gives much better working conditions and hence lowers labour costs.

Crop rotation/ fallowing is not necessary and transplant shock is also reduced. On the other hand initial and operational costs are higher than soil culture. And it needs skill and knowledge to operate the hydroponic system properly. Some diseases like *Fusarium* and *Verticillium* can spread quickly through the system. However, many varieties resistant to the above diseases have been bred (Shrestha and Dunn (2008).

2.3 Growing systems

Hydroponic systems can either be liquid or aggregate. Liquid systems have no supporting medium for the plant roots; whereas, aggregate systems have a solid medium of support. Hydroponic systems are further categorized as open (once the nutrient solution is delivered to the plant roots, it is not reused) or closed (surplus solution is recovered, replenished, and recycled).

2.3.1 Liquid hydroponic system

They are closed systems.

2.3.1.1 Nutrient Film Technique (NFT)

Plants are placed in a polyethylene tube that has slits cut in the plastic for the roots to be inserted. Nutrient solution is pumped through this tube. This system delivers a constant flow of nutrients to the plants with a pump, so no timer is required. This system doesn't require a growing medium; the plants are simply suspended in a plastic tray with the roots dangling in a nutrient solution.

2.3.1.2 Floating hydroponics

Plants are grown on a floating raft of expanded plastic.

2.3.1.3 Aeroponics

Aeroponics is a newer and more high-tech method of hydroponic growing. There is no growing medium as like the nutrient film technique. The plants are suspended with the roots in the air and the nutrients and moisture are supplied in the form of a mist. A timer ensures that the pump delivers a new spray of mist every few minutes. Like the nutrient film technique, it is imperative that the pump is always functioning correctly, because even a brief interruption can cause the roots to dry out. Root Mist Technique (RMT) and Fog Feed Technique (FFT) are the two important Aerophonic Hydroponic Techniques in use.

2.3.2 Aggregate Hydroponic System

2.3.2.1 Open system

Rockwool culture is the most widely used medium in hydroponics. Rockwool is ground-up basalt rock that is heated then spun into threads making wool. It is very light and is often sold in cubes. Rockwool can hold water and retain sufficient air space (at least 18 per cent) to promote optimum root growth. And other is sand culture

2.3.2.2 Closed system

In NFT and rockwool, plants are established on small rockwool slabs positioned in channels containing recycled nutrient solution. Instead of rockwool, gravels also can used.

2.3.2.3 Growing medium

The growing medium for hydroponic gardening is an inert medium which does not provide any nutrients to the plant. It only provides the basis for the roots to grow in coco coir fiber, rockwool, perlite, vermiculite, LECA, expanded clay, crushed granite, sand, scoria, gravel are the various types of growing mediums available for growing plants hydroponically. A growing medium allows us to add the correct amount of nutrients and also monitor the pH in a hydroponic system. In addition, using a growing medium other than soil has several advantages that includes, prevention of root infestations, retention of adequate oxygen and water and increased aeration and draining.

2.3.2.4 Nutrient management

The major disadvantage of a closed system is the difficulty of nutrient management. Four main techniques are commonly utilized.

2.3.2.4.1 Technique 1

Water addition, pH and electrical conductivity (EC) control are all automatic. The pH is a measure of the acidity of the substrate and controls the availability of mineral nutrients; whereas, the EC gives an estimate of the nutrient content.

The recommended pH for hydroponic culture is between 5.0 and 6.0 because overall availability of nutrients is optimized at a slightly acidic pH, and the EC level should be 1.5 to 3 dS m^{-1}.

2.3.2.4.2 Technique 2

The water makeup of the holding tank is automatic, usually by float valve, *i.e.*, the tank level is held steady. Here both water and nutrients are being taken, but only water is being replaced. Therefore, the EC will fall until the tank solution is brought up to strength by nutrient addition. The EC is periodically checked and adjusted to the required value by adding nutrient to the tank by hand. The pH is adjusted if necessary by adding acid (dilute sulfuric acid) to lower the pH or an alkali (dilute sodium hydroxide (NaOH) solution) to raise the pH.

2.3.2.4.3 Technique 3

The holding tank is partly or completely run down then refilled as a batch by adding water and/ or nutrient. The important aspect of this technique is that the effects of the addition are checked.

2.3.2.4.4 Technique 4

The holding tank is partly or completely run down then refilled using a standard strength nutrient solution. However, the resultant EC in the system is not checked or adjusted. This technique can lead to disaster.

The use of nutrient solutions in hydroponic cultures may be a valuable system to grow plants and minimize other factors that affects plant growth (Eymar *et al.*, 2001). Nutrient solutions with different NO_3^-/ NH_4^+ ratios, as opposed to fertilization exclusively with NO_3^- have been used successfully by many authors in horticultural crops. Conifers show their higher production with a 55/45 (%) NO_3^-/ NH_4^+ ratio in nutrient solution (Sanchez *et al.*, 2000). A study was conducted by Martin *et al.* (2007) to obtain total N concentration and the best NO_3^-/ NH_4^+ ratio in the nutrient solution in hydroponic culture to fertigate three species of ornamental shrubs in Spain. Results from the experiment suggest that strawberry tree (*Arbutus unedo* L.) and to a little extent tobir (*Pittosporum tobira*) could regulate the N- NH_4^+ absorption independently of the external concentration and reduce the toxic effects of N- NH_4^+.

In soilless culture, most plants perform better when nitrate is the dominating N form. But a minor part of nitrogen is supplied as ammonium (Kirkby and Mengel, 1967; Errebhi and Wilcox, 1990; Stensvand and Gisleod, 1992; Chance *et al.,* 1999; Sonneveld, 2002).

It gets importance for protected vegetable crops and ornamentals. Hydroponics has been recognised as a viable method of producing vegetables (tomatoes, lettuce, cucumbers and peppers) as well as ornamental crops such as herbs, roses, freesias and foliage plants. The expansion of hydroponics nowadays all over the world may be attributed to their ability to be independent of all the soil related problems like the decline of soil structure and fertility or high salinity (Raviv *et al.*, 2002). According to Savvas (2003), the cultivation of greenhouse crops and the achievements of high yields and good quality is possible with hydroponics even in saline or sodic soils or non-arable soils with poor structure, which represent a major proportion of cultivable land throughout the world.

Most commercial hydroponic growers combine hydroponic technology with a controlled environment to achieve the highest quality produce. Within a green-house structure, it is possible to provide temperature control, reduce evaporative water loss, reduce disease and pest infestations and protect crops against wind and rain, allowing growth on a year-round basis (Singh, 2013). According to Mugundhan *et al.* (2011), inside the greenhouse, yields with hydroponic techniques have averaged around 20 to 25 per cent higher than in conventional soil cultivation. Commercial hydroponic growing techniques are also less demanding of chemicals for root zone sterilization and control of pests, weeds, *etc.*

Experimentation and research in the area of indoor and outdoor hydroponic gardening is an ongoing process. With the introduction of hydroponic technology in commercial plant cultivation, studies have been undertaken on numerous economically important ornamental plants such as rose, carnation, gerbera, aster, chrysanthemum, lily, *etc.*

2.4 Hydroponics

Gerbera (*Gerbera jamesonii* Bolus) is one of the leading cut flowers ranking fifth in the global trade. Traditionally, gerbera cultivation has been done in soil and the major problem that the growers face is collar rot, which is a soil borne disease. The work done to evaluate the performance of gerbera cultivars both under hydroponics and greenhouse are reviewed here.

According to Fakhri *et al.* (1995), the flower diameter and fresh weight was maximum in gerbera grown in soil, followed by peat and perlite.

Chobe *et al.* (2010) evaluated the performance of gerbera cultivars under polyhouse conditions and recommended the cultivars Sonata, Entourage, Baston, Danelli, Frishel, Onedine and California for commercial cultivation. The cultivar Sonata performed better in number of leaves/ plant, plant spread and flower yield while the cultivar Martique produced flower with highest diameter and the cultivar Danelli with maximum flower stalk length and the cultivar Baston recorded maximum vase life.

Barreto and Jagtap (2006) assessed the suitability of substrates in pot culture for commercial production of gerbera under protected cultivation. Coco peat combined with compost (1:1) and coco peat (60 %) + perlite (20 %) + rice husk (20 %) produced flowers with the highest net returns (Rs. 28.77 and 28.76, respectively). The substrates, coco peat and vermicompost were found to be cheaper and produced comparatively bright coloured flowers. All the coco peat combinations were found to be cheaper than the peat combinations for better yield and quality flowers.

Cabellero *et al.* (2009) observed that, the maximum number of flowers per plant in gerbera was produced when grown in spent mushroom compost mixed with peat in a 1:1 volume ratio.

The performance of gerbera was commercially advantageous when plants under rainfed open condition in June and July plantings. (Keditsu, 2013).

Several authors suggested the production of gerbera in hydroponic systems (Pisanu *et al.,* 1994; Maloupa and Gerasopoulos, 1999); which results improved inflorescence quality (Maloupa *et al.,* 1993) and profitability (Mattas *et al.,* 2000) through economical use of water and space. Nevertheless, these studies were search of optimal nutritional conditions for gerbera cultivation and in attention with the comparison of substrates as well as recycling of nutrient solutions. The effects of salinity on the performance of flower crops such as gerbera, carnation, rose, aster, bouvardia and lily grown in closed soilless culture systems was conducted by Sonneveld *et al.* (1999). The salinity threshold values obtained indicated that EC values of solutions in the root environment higher than2 dS m^{-1} soon caused growth reduction for all the tested flower crops.

Mascarini *et al.* (2001) reported that soilless production techniques are increasingly resorted to by gerbera growers since healthier crops, earlier harvests, longer and more uniform stalks and flowers with larger diameter were obtained.

Zheng *et al.* (2004) noticed that, nutrient application rates at the final stage (4 to 5 weeks) of the greenhouse gerbera production, in recirculating sub irrigation systems be reduced by at least 50 per cent without any detrimental effect on plant growth or quality.

According to Anjaneyulu (2008), the optimum ions concentration in gerbera leaves ranged from 225 to 287 ppm; Mn, from 88- 126 ppm; Zn, from 56 to 85 ppm and Cu, from 17 to 32 ppm for good flower yield and quality flowers under protected conditions.

Response of different growing media on the growth and yield of gerbera in open system of hydroponic was studied by Khalaj *et al.* (2011) and they found that the media perlite + peat + expanded clay mixture (25 % + 70 % + 5 %) produced significantly maximum number of flowers per plant and improved other quality characteristics as well.

2.5 Nutrient management

Savvas (2003) reported that, low N in the supplied nutrient solution markedly increased the pH in the rhizospere of the gerbera plants, and the pH of the supplied nutrient solution did not affect the leaf nutrient concentrations, when the NH_4^+ supply via the nutrient solution was high. The combination of low N and higher nutrient solution pH reduced the Ca concentration and enhanced the leaf B concentration. The total- N concentration in the analysed plant tissue of gerbera was not effected either by the NH_4^+ supply ratio or by the nutrient solution pH. The leaf Fe, Mn, Zn and Cu concentrations were markedly diminished when the supply of NH_4^+ was low. In the roots, both the low N and the higher pH suppressed the Fe, Mn, Zn and Cu concentrations without any interaction between these two factors. The Mn, Zn and Cu concentrations were strongly depressed by the low ammonium supply in both the stalk and the head of the gerbera flowers. Increasing the supply of NH_4^+ to soilless grown plants prevent the decreasing effect of a low nutrient solution pH on the pH in the root environment. This influence of NH_4^+ with the nutrient solution pH indicates that the pH in the root zone of gerbera grown on inert substrates is most successfully controlled by properly adjusting the NH_4^+ - N/ total- N supply ratio rather than the pH of the supplied nutrient solution.

Albino- Garduno *et al.* (2007) reported the importance of Calcium ions in the hydroponic system of gerbera cultivation. The Calcium level of 6 meq Ca^{2+} L^{-1} reduced the leaf area, plant dry weight, and number of inflorescences produced per plant. The best Calcium dose for gerbera cultivar Amaretto was 12 meq Ca^{2+} L^{-1} and for Darling 9 meq Ca^{2+} L^{-1} which showed the highest dry matter weight, flower production, and quality of the inflorescence, related to high CO_2 net accumulation rates.

The best results of cut flower yield, flower quality and plant growth in gerbera were obtained when nourished with the "Colakoglu- 2" nutrient solution formulation, consisting of 150 ppm N, 31 ppm P, 234 ppm K, 30 ppm Mg, 100 ppm Ca, 15 ppm S, 8 ppm Fe, 5 ppm Mn, 1.5 ppm B, 2 ppm Cu, 3 ppm Zn and 0.2 ppm Mo. The highest value of the number of daughter plants (3.53/ plant) in gerbera was recorded in this nutrient solution formulation (Sirin, 2011).

Savvas and Gizas (2002) suggested the method to prevent nutrient imbalances in closed hydroponic system. They suggested to supply potassium and nitrogen at higher K: (K + Ca + Mg) and NH_4/ total- N ratios than those recommended for open systems. By increasing the relative K, P and Mn supply and correspondingly decreasing that of Ca, Mg and So_4, optimize the nutrient status in the root environment of gerbera plants.

Haghighi *et al.* (2014) suggested that humic acid could be successfully considered as a compound to decrease nutrient input in a hydroponic system without considerable adverse effects on quality and quality of production of gerbera flowers.

Haghighi *et al.* (2016) found that when gerbera was exposed to complete nutrient solution 50 %, and humic acid application. Humic acid increased N, K, Fe uptakes; in medium limited nutrient solution (25%), humic acid improved K and Fe, and in full nutrient solution all the nutrients (N, P, K, Ca, Fe and Zn) increased significantly, except Mg.

Farajollahzadeh *et al.* (2013) introduced a potentially organic hydroponics system for the production of pot gerbera flowers. They found that the fewer and more chlorotic leaves of organic system had better performance than the greener and additional leaves of chemical system. The total weight of whole pots including plants was 20 per cent more in the organic nutrition system.

Materials and methods

3. MATERIALS AND METHODS

The present study to evaluate the performance of gerbera cultivars under hydroponics was conducted at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, Thrissur during the period from June 2015 to May 2016. The materials used and methodology adopted for the investigation are presented in this chapter.

3.1 Location

Vellanikkara is situated at an latitude of 10^0 31' N, longitude of $76^0$13' E, and altitude of 22.25 m above MSL.

3.2 Climate

The experimental site experienced a humid tropical climate with maximum temperature varying from 31.0° C to 36.3° C and the minimum temperature from 23.0° C to 26.2° C during the period of investigation. The mean relative humidity varied from 56 per cent to 83 per cent. The total rainfall recorded during the period of investigation was 1377.07 mm. Weather data during the present study are given in Appendix I.

3.3 Performance evaluation

3.3.1 Treatments

3.3.1.1 Varieties

Tissue cultured plants of five varieties of gerbera namely, Dana Ellen, Goliath, Stanza, Intense and Balance were used to evaluate their performance. The description of the selected varieties are given in Plates 1a, 1b and 1c.

3.3.1.2 Growing conditions

i) Hydroponics – medium culture (quartz sand) (G1)

ii) Hydroponics – solution culture (without solid medium) (G2)

iii) Pot culture - in potting mixture containing 25 % coco peat + 25 % cow dung + 50 % sand (G3)

Dana Ellen

Low growing, leaves dark green, leathery, obovate and deeply lobed. Flowers semi double, full crested type up to 12.0 cm diameter, stalks erect, ray florets yellow, disc florets pale yellowish green.

Goliath

Dark green, obovate and deeply lobed leaves. Flowers semi double, full crested type, up to 12.0 cm diameter, flower stalk erect and thick, ray florets orange, disc florets pale yellowish green.

Plate 1a: Selected gerbera varieties

Stanza

Leaves dark green, obovate and deeply lobed. Flowers semi double and full crested type, up to 13.0 cm in diameter, flower stalk erect, ray florets red, disc florets black.

Intense

Leaves dark green, obovate and deeply lobed. Flowers full crested type, semi double, up to 12.0 cm diameter, flower stalks erect, ray florets cerise (cherry red), disc florets black.

Plate 1b: Selected gerbera varieties

Balance

Leaves dark green, ovate and deeply lobed. Flowers semi double, full crested type, up to 13.0 cm in diameter, and flower stalk erect and thick, ray florets white, disc florets light yellowish green.

Plate 1c: Selected gerbera varieties

Deep Flow Technique (DFT) of hydroponics was followed, which is a closed hydroponic system in which nutrient solution was circulated around the roots by a pump and gravity drain. Closed system of hydroponics was a system in which surplus nutrient solution is recovered, replenished and recycled. The hydroponic system consisted of three 'A' shaped metallic frames supporting 10 horizontally placed PVC pipes. Holes were made in the PVC pipes so as to hold potted plants (pot size 7.5 cm diameter and 8.0 cm height). One PVC pipe could hold 15 pots (Plate 2).

A stock tank of 500 litres capacity was filled with the nutrient solution and connected to the PVC pipes in the hydroponic system. The nutrient solution used was Hoagland solution containing all the macro and micronutrients (Table 1). The PVC pipes were temporarily flooded with the nutrient solution and the solution was drained back into the reservoir. This action was done with a submerged pump that was connected to the timer. Nutrient solution was circulated for three minutes at twenty seven minutes intervals.

3.4 Planting

Two month old plants were used for the study. One set of plants (fifteen plants/ variety) were placed in plastic net pots filled with quartz sand (G1). A piece of net was placed in plastic pots to prevent the media from falling into the nutrient solution in hydroponics.

Another set of plants was washed free of potting media and kept in plastic net pots without media in the nutrient solution in hydroponics (G2).

In addition, gerbera varieties were also kept in plastic pots containing potting mixture (25 % coco peat + 25 % cow dung + 50 % sand) inside the greenhouse (G3).

3.5 Design of experiment

The experiment was laid out in Completely Randomized Design with 5x3 treatments and three replications. There were five pots/ treatment/ replication. A general view of the experimental site is given in Plate 3.

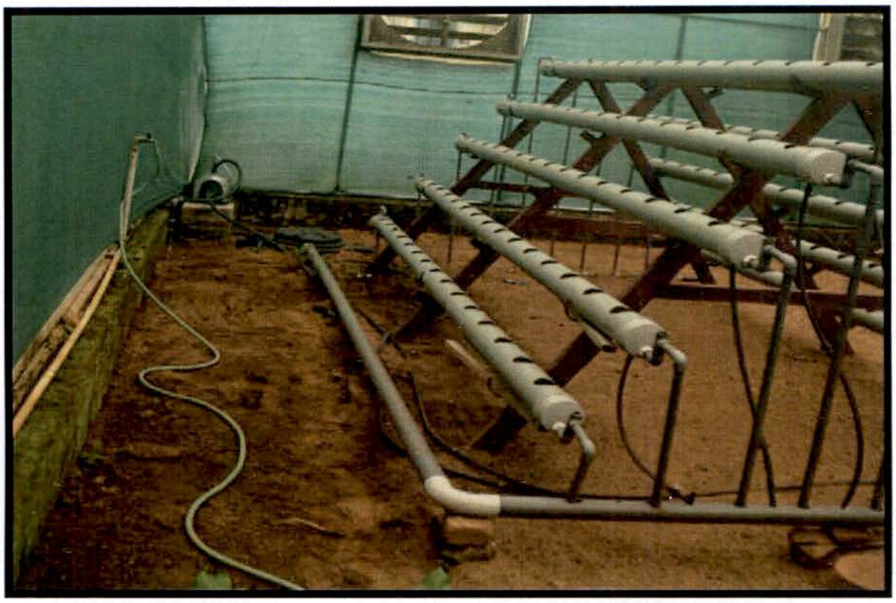

Plate 2: Hydroponic system

Table 1. Hoagland nutrient solution

Component	Stock Solution	mL Stock Solution/1L
Macronutrients		
2M KNO_3	202 g/L	2.5
1M $Ca(NO_3)_2.4H_2O$	236 g/0.5L	2.5
Iron (Sprint 138 iron chelate)	15 g/L	1.5
2M $MgSO_4.7H_2O$	493 g/L	1
1M NH_4NO_3	80 g/L	1
Micronutrients		
H_3BO_3	2.86 g/L	1
$MnCl_2.4H_2O$	1.81 g/L	1
$ZnSO_4.7H_2O$	0.22 g/L	1
$CuSO_4.5H_2O$	0.051 g/L	1
$H_3MoO_4.H_2O$ or	0.09 g/L	1
$Na_2MoO_4.2H_2O$	0.12 g/L	1
Phosphate		
1M KH_2PO_4 (pH to 6.0)	136 g/L	0.5

N	210 mg l^{-1}
K	235 mg l^{-1}
Ca	200 mg l^{-1}
P	31 mg l^{-1}
S	64 mg l^{-1}
Mg	48 mg l^{-1}
B	0.5 mg l^{-1}
Fe	1 to 5 mg l^{-1}
Mn	0.5 mg l^{-1}
Zn	0.05 mg l^{-1}
Cu	0.02 mg l^{-1}
Mo	0.01 mg l^{-1}

(Hoagland and Arnon, 1938)

Plate 3: A general view of experimental site

3.6 Care and management

The nutrient solution was circulated for three minutes at every twenty seven minutes interval. Fresh nutrient solution was added to the tank at fifteen days interval after cleaning. For potted plants, foliar application of soluble NPK (19: 19: 19) fertilizers (Power-19) @ 0.2 per cent was given at fifteen days interval. Need based adoption of plant protection measures was also carried out.

3.7 Harvesting

Flowers were allowed to remain on the plant till starting of wilting and those for vase life studies were harvested at the commercial stage of harvest, *i.e.,* when outer row of disc florets became perpendicular to the stalk.

3.8 Observations

3.8.1 Vegetative characters

The observations were recorded at monthly intervals.

3.8.1.1 Plant height

Standing height of the plant in centimeters was taken as height of the plant.

3.8.1.2 Plant spread

Plant spread was measured in East- West and North- South direction and expressed in centimeters.

3.8.1.3 Number of leaves/plant

Total number of leaves at the time of each observation was counted and recorded as number of leaves.

3.8.1.4 Leaf length

Length of leaf was taken from the base to the tip of the expanded leaf and expressed in centimeters.

3.8.1.5 Leaf breadth

The maximum width of the expanded leaf was measured and recorded in centimeters.

3.8.1.6 Leaf area

Leaf area was derived from the formula 0.43 x Length x Breadth, where 0.43 is a constant.

The constant was calculated using statistical package of non linear regression method (Sankar, 2003). Leaf area was expressed in cm^2.

3.8.1.7 Petiole length

Length of petiole was measured from the base of petiole to the lamina base and expressed in centimeters.

3.8.1.8 Number of lobes/ leaf

Number of lobes on each leaf was counted and recorded.

3.8.1.9 Number of suckers/ plant/ year

The plants did not produce suckers during the period of investigation.

3.8.2 Floral characters

3.8.2.1 Days taken for first flower bud appearance

Number of days from planting to first flower bud emergence was recorded.

3.8.2.2 Days from flower bud emergence to opening of the flower

Days taken from flower bud emergence to flower opening was noted.

3.8.2.3 Number of flowers produced per year

Number of flowers produced on each plant was noted variety wise.

3.8.2.4 Flower longevity

Longevity of flower on the plant was expressed as number of days from opening of flower to starting of wilting.

3.8.2.5 Flower stalk length

Length of stalk from base to flower head was measured and expressed in centimeters.

3.8.2.6 Flower stalk girth

Girth of stalk at 10 cm above the base was measured and expressed in centimeters.

3.8.2.7 Flower diameter

Diameter of the flower was measured and recorded in centimeters.

3.8.2.8 Disc diameter

Diameter of the flower disc was measured and recorded in centimeters.

3.8.3 Post harvest characters

3.8.3.1 Fresh weight of flower

The weight of the individual flower was taken immediately after harvest and recorded in grams.

3.8.3.2 Physiological loss in weight

The loss in weight of the flower in vase was recorded when it showed the sign of wilting/ bending. The loss in weight was calculated by deducting the flower weight at the end of experiment from the initial weight.

3.8.3.3 Water uptake

The flowers were harvested and held in vases with measured quantity of distilled water. The quantity of water left at the end of vase life of flowers was measured. The difference gave the water uptake, expressed in ml.

3.8.3.4 Vase life

The flowers were harvested at the commercial stage of harvest and kept in tap water. Vase life was expressed as the number of days taken for fresh flower to show signs of wilting or bending.

3.9 Meteorological observations

Meteorological observations namely, temperature, relative humidity and light intensity were recorded daily inside the greenhouse.

Temperature and relative humidity were measured using thermohygrometer. Light intensity was recorded using a Lux meter and expressed as Lux.

3.10 Plant analysis

After the experiment, plant samples were analyzed for macro and micronutrient contents.

3.10.1 Total nitrogen

Total nitrogen was determined by Micro Kjeldhal method (Piper, 1942). In this method, all forms of nitrogen in the sample were converted into sulphate of ammonia by digestion with sulphuric and salicylic acid in the presence of sodium sulphate as an electrolyte and selenium as catalyst. The digest was made up to a known volume with distilled water. An aliquot of the resulting solution was distilled with excess of alkali and the distillate was collected in 4 per cent boric acid-indicator mixture. The amount of ammonia evolved was determined by titration with standard sulphuric acid.

The analysis of other nutrients *viz.,* P, K, Ca, Mg, S, Fe, Mn, Zn and Cu was done after diacid digestion of the plant sample. In diacid digestion, the acid mixture was prepared by mixing the nitric and perchloric acid in 9 : 4 ratio. The dried plant sample (0.1 g) was taken in a 50 ml conical flask and 20 ml of diacid was added for predigestion. After the predigestion, samples were heated on a hot plate for digestion until a clear solution was obtained. The digest was transferred to a 25 ml volumetric flask. The digestion flask was washed 2 to 3 times with double distilled water and volume was made up to 25 ml. Aliquots from this solution were taken for the analysis of the nutrient elements.

3.10.2 Total phosphorus

Five mg of the plant digest was pipetted out into a 50 ml volumetric flask. Five ml of Barton's reagent was added to in this, shaken well and made up the volume. This was allowed to stand for 30 minutes for yellow colour development. Then the intensity of the colour was read at 420 nm in spectrophotometer (Piper, 1942). The absorbance value was plotted in the standard graph to obtain the concentration of P in the coloured solution.

3.10.3 Total potassium

Five ml of the plant digest was pipette out into a 25 ml volumetric flask and diluted to 25 ml with distilled water. Aspirated the standards and then the sample to the flame and noted the meter reading and calculated the K content by referring to the standard curve prepared (Piper, 1942).

3.10.4 Total micronutrients

The content of Ca, Mg, Fe, Mn, Zn and Cu were determined using an atomic absorption spectrophotometer (Piper, 1942).

3.10.5 Total sulphur

Five ml plant digest was pipette out into a 25 ml volumetric flask and 1 g Barium chloride crystals was added to each flask and swirled to dissolve. Into that 1 ml of 0.25 per cent gum acacia solution was added and made up the volume with distilled water and shaken well. Within 5 to 30 minutes of development of turbidity, the absorbance was read at 440 nm on a spectrophotometer.

3.11 Incidence of pests and diseases

The plants were observed for incidence of pests and diseases.

3.12 Benefit – cost analysis

Total expenses incurred and profits obtained were estimated and benefit cost ratio was calculated.

3.13 Statistical analysis

Statistical analysis was done by using OPSTAT software developed by the Chaudhary Charan Singh Haryana Agricultural University, Hisar. For obtaining the relationship between various weather parameters, vegetative and floral characters, correlation studies were conducted.

Results

4. RESULTS

Studies were conducted at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during 2015- 2016 to evaluate the performance of gerbera cultivars under hydroponics. Five varieties, *viz.,* Dana Ellen, Goliath, Stanza, Intense and Balance were evaluated to assess the suitability to hydroponic culture and to compare the growth, yield and vase life under selected growing conditions, *viz.,* hydroponic culture with and without media and pot culture (25 % peat + 25 % cow dung + 50 % sand) under a greenhouse. The results are presented in this chapter.

4.1 Vegetative characters

The data pertaining to the vegetative characters of the gerbera varieties as influenced by growing conditions are presented in Tables 2 to 9.

4.1.1 Plant height

Plant height of gerbera varieties as influenced by growing conditions at monthly intervals up to flowering (August to December) are presented in Tables 2a and 2b.

Among the varieties, Intense recorded the maximum plant height (16.94 cm) and was significantly superior to all others except Stanza (15.25 cm). Balance recorded the minimum height (14.36 cm), but was statistically on par with all other varieties, except Intense in the month of December. During the initial months, the variety Dana Ellen recorded the maximum plant height, but at the end of the study (at flowering) the variety Intense had the maximum. Lowest plant height was observed in Balance and the similar situation continued for the rest of the months and at flowering.

Detectable differences were not observed in plant height of the selected gerbera varieties under different growing conditions. During later part of the study (October to December), the varieties grown in G3 (pot culture) recorded maximum

Table 2a. Plant height (cm) in gerbera varieties as influenced by growing conditions

Variety	Plant height (cm)											
	August				September				October			
	Growing conditions				Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	12.67	11.67	10.00	**11.44**	13.78	12.75	11.04	**12.52**	14.07	15.47	15.73	**15.09**
Goliath	10.72	12.11	7.73	**10.19**	11.65	13.05	8.77	**11.15**	15.67	11.33	17.73	**14.91**
Stanza	9.80	9.23	11.13	**10.06**	1079	10.66	12.17	**11.21**	11.53	12.27	16.80	**13.53**
Intense	11.14	10.69	12.27	**11.36**	12.05	11.62	13.29	**13.32**	11.40	13.87	15.60	**13.62**
Balance	6.81	9.33	9.37	**8.50**	8.43	10.33	9.80	**9.52**	8.87	10.63	12.53	**10.68**
Mean	**10.23**	**10.61**	**10.10**		**11.34**	**11.68**	**12.01**		**12.31**	**12.71**	**15.68**	
S. Em ±	**0.96**				**1.07**				**1.04**			
C. D (0.05) for comparing												
Variety	1.61				1.79				1.74			
Growing condition	NS				NS				1.35			
Variety X Growing condition	2.79				NS				3.01			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

Table 2b. Plant height (cm) in gerbera varieties as influenced by growing conditions

Variety	Plant height (cm)							
	November				December			
	Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	15.20	16.23	21.70	**17.71**	9.73	10.53	23.13	**14.47**
Goliath	12.53	11.47	20.40	**14.80**	8.73	11.20	23.47	**14.47**
Stanza	12.77	12.69	21.60	**15.69**	8.33	11.62	25.80	**15.25**
Intense	10.67	8.83	20.27	**13.26**	12.67	11.69	26.47	**16.94**
Balance	10.58	11.67	15.80	**12.68**	9.87	13.60	19.60	**14.36**
Mean	**12.35**	**12.18**	**19.95**		**9.87**	**11.72**	**23.69**	
S. Em±	**1.32**				**1.36**			
C. D (0.05) for comparing								
Variety	2.21				2.21			
Growing condition	1.71				1.71			
Variety X Growing condition	NS				NS			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

plant height which was significantly superior to other growing conditions (G1 and G2) and was statistically on par during October to December.

Interaction between variety and growing conditions showed detectable differences in plant height during August and October only. During August the varieties Dana Ellen in hydroponics with media (G1) recorded maximum plant height (12.67 cm) and was significantly superior to Balance in the same growing condition and Goliath in pot culture (G3) in greenhouse. The other treatment combinations were statistically on par. But the variety Balance in the same growing condition (G1) recorded the minimum (6.81 cm). It followed the same trend in October also. The variety Goliath recorded maximum plant height (17.73 cm) in pot culture (G3) in October and was comparable with Stanza, Dana Ellen and Intense in the same condition (16.80, 15.73 and 15.60 cm, respectively) and Goliath and Dana Ellen grown in hydroponics with medium (G1) (15.67 and 14.07 cm, respectively) and Dana Ellen in hydroponics without medium (G2) (15.47 cm) and significantly superior to all other treatment combinations.

4.1.2 Plant spread

Appreciable differences were observed with regard to plant spread in different gerbera varieties, except in August. Plant spread was maximum (166.76 cm^2) in Dana Ellen during September, followed by Goliath (153.41 cm^2) and was statistically on par. But, in October, Goliath recorded maximum plant spread (348.25 cm^2) and was significantly superior to others. This was followed by stanza and Dana Ellen (279.56 and 269.85 cm^2, respectively) and were on par. Plant spread was minimum (80.16 cm^2) for Intense followed by Balance (137.92 cm^2). But, in November, the variety Balance recorded the maximum (596.73 cm^2) spread and was distinctly superior to others. The minimum plant spread was observed in Intense (358.15 cm^2), followed by Goliath, Dana Ellen and Stanza (433.53, 388.39 and 382.74 cm^2, respectively) and were statistically comparable. Almost similar situation continued in December also.

Distinguishable differences were recorded in plant spread of gerbera varieties under different growing conditions during the entire period of observation, except in August (Tables 3a and 3b). At the beginning (September), plants in hydroponics without media (G2) recorded maximum plant spread (158.55 cm^2), and was on par with hydroponics with media (G1). Minimum plant spread (126.12 cm^2) was recorded in pot culture (G3) in greenhouse. But in October, plants in hydroponics with media (G1) recorded maximum plant spread. By the end of the study period, plants in G3 (pot culture) in greenhouse recorded the maximum plant spread and was distinctly superior to others. Minimum plant spread was recorded by plants in hydroponics without medium (G2).

The interaction between variety and growing conditions on plant spread was not significant.

4.1.3 Number of leaves

Varietal influence on the number of leaves/ plant was clearly evident during the entire period of study (Tables 4a and 4b). During August and September, Dana Ellen recorded significantly more number of leaves (7.16 and 7.29, respectively) and was on par with Stanza, Intense and Goliath. During October, November and December, the leaf number recorded was the highest in Stanza (8.20, 10.37 and 10.40, respectively). The minimum (4.80) number of leaves was in Dana Ellen in October and Intense in November and December (4.34 and 5.49, respectively).

Influence of growing conditions on the number of leaves was distinct only in the later period of study (September, November and December). Among the growing conditions, plants in hydroponic culture with medium (G1) recorded significantly more number of leaves (7.0) in September, whereas the leaf number in other growing conditions were on par. During November and December leaf number recorded was maximum in pot culture (G3) in greenhouse (8.41 and 9.80, respectively). During this

Table 3a. Plant spread (cm^2) in gerbera varieties as influenced by growing conditions

Variety	Plant spread (cm^2)											
	August				September				October			
	Growing conditions				Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	145.48	166.73	106.27	**139.49**	174.30	196.68	129.31	**166.76**	273.20	228.80	307.53	**269.85**
Goliath	142.87	150.17	83.87	**125.63**	169.65	178.18	112.40	**153.41**	436.80	263.07	344.87	**348.25**
Stanza	108.20	116.99	89.03	**104.74**	136.13	139.67	108.53	**128.11**	282.87	209.00	346.80	**279.56**
Intense	73.93	107.51	111.71	**97.72**	96.87	129.95	121.80	**116.21**	88.20	88.13	64.13	**80.16**
Balance	85.15	128.10	133.97	**115.74**	103.60	148.27	158.53	**136.80**	129.40	157.62	126.73	**137.92**
Mean	**111.13**	**133.90**	**104.97**		**136.11**	**158.55**	**126.12**		**242.09**	**189.33**	**238.01**	
S. Em ±	**18.98**				**20.38**				**34.49**			
C. D (0.05) for comparing												
Variety	NS				34.15				57.79			
Growing condition	NS				26.45				44.77			
Variety X Growing condition	NS				NS				NS			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

Table 3b. Plant spread (cm^2) in gerbera varieties as influenced by growing conditions

Variety	Plant spread (cm^2)							
	November				December			
	Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	304.47	348.73	511.97	**388.39**	384.13	375.20	839.93	**533.09**
Goliath	425.33	316.60	558.67	**433.53**	454.60	393.67	850.73	**566.33**
Stanza	353.73	282.08	512.40	**382.74**	346.07	322.03	697.27	**455.12**
Intense	373.47	200.52	500.47	**358.15**	495.73	276.00	804.73	**525.49**
Balance	548.20	344.07	897.93	**596.73**	762.67	540.81	1428.93	**910.80**
Mean	**401.04**	**298.40**	**596.29**		**488.64**	**381.54**	**924.32**	
S. Em±	**61.65**				**80.79**			
C. D (0.05) for comparing								
Variety	103.29				135.37			
Growing condition	80.01				104.86			
Variety X Growing condition	NS				NS			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

Table 4a. Number of leaves/ plant in gerbera varieties as influenced by growing conditions

Variety	Number of leaves/ plant											
	August				September				October			
	Growing conditions				Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	7.73	7.53	6.20	**7.16**	8.00	7.67	6.20	**7.29**	5.00	4.33	5.07	**4.80**
Goliath	7.60	5.80	3.73	**5.71**	8.60	6.80	4.13	**6.51**	5.80	4.73	5.67	**5.40**
Stanza	5.60	5.59	6.17	**5.79**	6.60	6.33	7.13	**6.69**	7.27	6.33	11.00	**8.20**
Intense	5.40	5.20	6.40	**5.67**	6.40	6.20	7.40	**6.67**	8.07	9.33	6.07	**7.82**
Balance	4.53	4.53	4.07	**4.38**	5.40	5.47	4.73	**5.20**	5.67	6.47	4.73	**5.62**
Mean	**6.17**	**5.73**	**5.32**		**7.00**	**6.49**	**5.92**		**6.36**	**6.24**	**6.51**	
S. Em ±	**0.64**				**0.64**				**0.70**			
C. D (0.05) for comparing												
Variety	1.08				1.07				1.67			
Growing condition	NS				0.83				NS			
Variety X Growing condition	1.87				1.85				2.02			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

Table 4b. Number of leaves/ plant in gerbera varieties as influenced by growing conditions

Variety	Number of leaves							
	November				December			
	Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	5.67	5.80	7.33	**6.27**	6.20	6.00	8.13	**6.78**
Goliath	6.07	6.13	9.33	**7.18**	6.80	7.13	10.40	**8.11**
Stanza	8.53	7.03	15.53	**10.37**	8.13	7.00	16.07	**10.40**
Intense	4.67	4.10	4.27	**4.34**	5.60	4.93	5.93	**5.49**
Balance	5.43	4.73	5.60	**5.26**	7.17	7.33	8.47	**7.66**
Mean	**6.07**	**5.56**	**8.41**		**6.78**	**6.48**	**9.80**	
S. Em±	**0.64**				**0.60**			
C. D (0.05) for comparing								
Variety	1.07				1.01			
Growing condition	0.83				0.78			
Variety X Growing condition	1.85				1.74			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

period minimum leaf number was observed in plants in hydroponics with and without medium (G1 and G2) and were on par (5.56 and 6.48, respectively).

The combination effect of variety and growing conditions on the number of leaves showed noticeable differences during the entire period of study. In August, the variety Dana Ellen recorded significantly more number of leaves (7.73) in hydroponics with media (G1) and was followed by Goliath (7.60) under the same growing condition and Dana Ellen (7.53) in hydroponics without medium and were on par. Minimum leaf number (3.73) was recorded by Goliath in pot culture (G3) in greenhouse. The same trend was observed in September also.

During the later period of study (October, November and December), leaf number was maximum in the variety Stanza in pot culture (G3) in greenhouse (11.0, 15.53 and 16.07, respectively) followed by Goliath under same growing condition during November and December (9.33 and 10.40, respectively). In November and December, Intense recorded minimum leaf number (4.10 and 4.93, respectively) in hydroponics without media (G2).

4.1.4 Leaf length

The leaf length of gerbera varieties as influenced by growing conditions is given in Tables 5a and 5b.

The gerbera varieties showed considerable variation in leaf length during August, September, October and December. During August, September and December the variety Balance had maximum leaf length (8.30, 9.10 and 16.24 cm, respectively) and was on par with Intense during August and September. Minimum leaf length was observed in Stanza during August, September and December (6.04, 6.87 and 11.74 cm, respectively).

The growing conditions significantly influenced the leaf length of gerbera during October, November and December only. During these months, plants in pot culture (G3) recorded the maximum (10.80, 17.04 and 20.42 cm, respectively) and was significantly superior to all other growing conditions. Minimum leaf length was

Table 5a. Leaf length (cm) in gerbera varieties as influenced by growing conditions

Variety	Leaf length (cm)											
	August				September				October			
	Growing conditions				Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	8.17	8.63	7.02	**7.94**	9.19	9.82	8.19	**9.06**	9.65	10.13	12.70	**10.83**
Goliath	7.51	8.07	7.17	**7.58**	8.53	9.55	8.21	**8.76**	8.93	9.13	13.27	**10.44**
Stanza	6.35	6.03	5.74	**6.04**	7.24	6.81	6.55	**6.87**	7.97	6.93	11.83	**8.91**
Intense	7.50	8.03	9.02	**8.18**	8.47	8.78	9.83	**9.03**	6.83	6.20	6.53	**6.52**
Balance	8.55	8.17	8.20	**8.30**	9.26	9.05	9.00	**9.10**	7.70	9.00	9.67	**8.79**
Mean	**7.62**	**7.78**	**7.43**		**8.54**	**8.80**	**8.36**		**8.22**	**8.28**	**10.80**	
S. Em ±	**0.43**				**0.47**				**0.65**			
C. D (0.05) for comparing												
Variety	0.73				0.79				1.09			
Growing condition	NS				NS				0.84			
Variety X Growing condition	NS				NS				1.88			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

Table 5b. Leaf length (cm) in gerbera varieties as influenced by growing conditions

Variety	Leaf length (cm)							
	November				December			
	Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	9.80	12.13	16.80	**12.91**	10.27	10.07	18.87	**13.07**
Goliath	9.17	9.23	16.53	**11.64**	10.20	9.67	19.73	**13.20**
Stanza	8.67	7.33	16.19	**10.74**	8.27	7.35	19.60	**11.74**
Intense	11.93	7.83	16.00	**11.92**	14.47	10.18	20.73	**15.13**
Balance	11.02	9.33	19.67	**13.34**	14.43	11.13	23.17	**16.24**
Mean	**10.12**	**9.17**	**17.04**		**11.53**	**9.68**	**20.42**	
S. Em±	**1.23**				**0.88**			
C. D (0.05) for comparing								
Variety	NS				1.47			
Growing condition	1.60				1.14			
Variety X Growing condition	NS				NS			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

observed in hydroponics with medium G1 in October (8.22 cm) and hydroponics without medium (G2) in November and December (9.17 and 9.68 cm, respectively).

Interaction effect of the variety and growing conditions on leaf length was evident only in October (Tables 5a and 5b). The variety Goliath recorded the maximum leaf length (13.27 cm) in pot culture (G3) and was significantly superior to other treatment combinations, except Dana Ellen and Stanza under the same growing condition (12.70 and 11.83 cm, respectively) and were on par. The variety Intense in hydroponic culture without medium (G2) recorded the minimum leaf length (6.20 cm).

4.1.5 Leaf breadth

Distinguishable differences were recorded in leaf breadth of gerbera varieties during October, November and December only (Tables 6a and 6b). During October and November, Dana Ellen recorded maximum leaf breadth (6.86 and 7.02 cm, respectively) and was on par with Goliath and Stanza. Minimum leaf breadth (4.71cm) was recorded in Balance. In December, Balance recorded the maximum leaf breadth (7.28 cm) and was significantly superior to Stanza (5.91 cm) and was on par with all other varieties.

Influence of growing conditions on the leaf breadth was evident only in October, November and December. Maximum leaf breadth was recorded in plants grown pot culture (G3) during these months (6.20, 7.49 and 9.28 cm, respectively).

Interaction effect of variety and growing conditions on leaf breadth was not significant.

4.1.6 Leaf area

Data on the effect of growing conditions in the leaf area of gerbera varieties during the period is given in Tables 7a and 7b. Significant differences were observed in the leaf area among gerbera varieties. The variety Balance recorded maximum leaf area throughout the period of study, except in October. In December, it was on par

Table 6a. Leaf breadth (cm) in gerbera varieties as influenced by growing conditions

Variety	Leaf breadth (cm)											
	August				September				October			
	Growing conditions				Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	5.57	5.82	5.04	**5.48**	6.49	6.81	5.92	**6.40**	6.55	6.67	6.83	**6.68**
Goliath	5.50	5.44	4.75	**5.23**	6.41	6.30	5.37	**6.03**	5.87	5.59	6.90	**6.12**
Stanza	5.43	5.56	5.05	**5.35**	6.24	6.04	5.82	**6.03**	5.84	5.27	6.83	**5.98**
Intense	5.33	5.60	5.47	**5.46**	6.12	6.01	6.37	**6.17**	6.20	5.33	5.67	**5.73**
Balance	5.73	5.67	6.10	**5.83**	6.36	6.43	6.91	**6.57**	6.51	4.67	4.67	**5.28**
Mean	**5.51**	**5.62**	**5.28**		**6.32**	**6.32**	**6.08**		**6.20**	**5.51**	**6.18**	
S. Em ±	**0.24**				**0.26**				**0.45**			
C. D (0.05) for comparing												
Variety	NS				NS				0.76			
Growing condition	NS				NS				0.59			
Variety X Growing condition	NS				NS				NS			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

Table 6b. Leaf breadth (cm) in gerbera varieties as influenced by growing conditions

Variety	Leaf breadth (cm)							
	November				December			
	Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	5.93	6.87	8.27	**7.02**	5.20	6.00	8.93	**6.71**
Goliath	5.65	5.59	8.40	**6.55**	5.80	5.40	9.73	**6.98**
Stanza	5.70	5.41	7.71	**6.27**	5.30	4.28	8.13	**5.91**
Intense	4.83	3.93	6.87	**5.21**	5.92	5.42	10.07	**7.13**
Balance	3.93	4.00	6.20	**4.71**	6.71	5.60	9.53	**7.28**
Mean	**5.21**	**5.16**	**7.49**		**5.79**	**5.34**	**9.28**	
S. Em±	**0.58**				**0.37**			
C. D (0.05) for comparing								
Variety	0.98				0.62			
Growing condition	0.76				0.48			
Variety X Growing condition	NS				NS			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

Table 7a. Leaf area (cm^2) in gerbera varieties as influenced by growing conditions

Variety	Leaf area (cm^2)											
	August				September				October			
	Growing conditions				Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	19.95	22.41	15.12	**19.16**	26.16	29.65	21.03	**25.61**	26.54	29.87	38.40	**31.60**
Goliath	17.91	18.77	15.27	**17.32**	23.75	26.09	20.02	**23.28**	22.75	23.46	40.69	**28.97**
Stanza	15.87	14.79	12.73	**14.46**	20.40	17.94	16.68	**18.34**	20.30	15.90	34.80	**23.67**
Intense	17.56	19.33	21.95	**19.61**	22.80	23.47	27.76	**24.68**	18.79	14.66	16.56	**16.67**
Balance	22.07	20.59	22.00	**21.56**	26.58	25.78	27.39	**26.58**	22.32	18.39	19.57	**20.09**
Mean	**18.67**	**19.18**	**17.41**		**23.94**	**24.59**	**22.58**		**22.14**	**20.46**	**30.00**	
S. Em ±	**1.75**				**2.17**				**2.65**			
C. D (0.05) for comparing												
Variety	2.94				3.63				4.44			
Growing condition	NS				NS				3.44			
Variety X Growing condition	NS				NS				7.69			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

Table 7b. Leaf area (cm^2) in gerbera varieties as influenced by growing conditions

Variety	Leaf area (cm^2)							
	November				December			
	Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	25.19	37.11	61.06	**41.12**	24.25	27.20	75.85	**42.44**
Goliath	22.41	23.48	59.37	**35.09**	25.60	24.25	84.65	**44.84**
Stanza	21.69	17.14	53.94	**30.92**	19.49	13.52	69.29	**34.10**
Intense	25.37	13.08	51.46	**29.97**	37.69	24.76	92.82	**51.76**
Balance	17.85	15.79	53.26	**28.97**	41.70	27.65	95.50	**54.95**
Mean	**22.50**	**21.32**	**55.82**		**29.75**	**23.48**	**83.62**	
S. Em±	**5.68**				**3.63**			
C. D (0.05) for comparing								
Variety	NS				6.08			
Growing condition	7.37				4.71			
Variety X Growing condition	NS				NS			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

with Intense and significantly superior to all other varieties. Minimum leaf area was recorded in Stanza (34.10 cm^2).

The growing conditions significantly influenced the leaf area of gerbera only in the later part of the study (October, November and December). Plants in pot culture (G3) recorded maximum leaf area and was significantly superior to those in other growing conditions. By the end of the study maximum leaf area was recorded in pot culture (83.62 cm^2) and was significantly superior to other growing conditions. Hydroponics without media (G2) recorded the minimum leaf area (23.48 cm^2).

The interaction effect of variety and growing conditions on leaf area was clearly evident only in October. The gerbera variety Goliath recorded maximum leaf area (40.69 cm^2) in pot culture (G3) and was significantly superior to other treatment combinations, but on par with Dana Ellen and Stanza (38.40 cm2 and 34.80 cm^2, respectively) under the same growing condition. The variety Intense recorded minimum leaf area (14.66 cm^2) in hydroponics without media (G2) followed by Stanza (15.90 cm^2) under the same growing condition.

4.1.7 Petiole length

Data on the petiole length of gerbera varieties as influenced by different growing conditions are given in Tables 8a and 8b. Marked variation was noticed in the petiole length of gerbera varieties throughout the study. During August, September and November, the variety Stanza recorded maximum petiole length (8.09, 9.58 and 8.82 cm, respectively). Minimum petiole length was recorded by the variety Balance (6.75, 7.39 and 6.13 cm, respectively). At the end of the study period (December) the variety Intense recorded the maximum (9.44 cm) and was statistically significant to other varieties, which were on par.

Growing conditions influenced the petiole length only during the later part of the study (November and December). Plants in pot culture (G3) recorded maximum petiole length (9.77 and 10.03 cm, respectively) and was significantly superior to

Table 8a. Petiole length (cm) in gerbera varieties as influenced by growing conditions

Variety	Petiole length (cm)											
	August				September				October			
	Growing conditions				Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	7.89	7.47	6.24	**7.20**	8.97	8.48	7.19	**8.21**	9.05	10.30	8.93	**9.43**
Goliath	7.01	7.43	6.23	**6.89**	7.94	8.42	7.12	**7.83**	6.89	8.40	9.33	**8.21**
Stanza	8.53	7.13	8.60	**8.09**	9.50	7.99	11.27	**9.58**	7.57	8.53	8.13	**8.08**
Intense	7.30	8.33	8.20	**7.92**	8.15	9.23	9.07	**8.82**	7.71	7.72	9.00	**8.14**
Balance	6.47	6.71	7.07	**6.75**	7.37	6.89	7.92	**7.39**	10.10	8.40	9.93	**9.48**
Mean	**7.44**	**7.42**	**7.27**		**8.39**	**8.20**	**8.51**		**8.26**	**8.67**	**9.07**	
S. Em ±	**0.61**				**0.69**				**0.66**			
C. D (0.05) for comparing												
Variety	1.02				1.15				1.10			
Growing condition	NS				NS				NS			
Variety X Growing condition	NS				1.99				NS			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

Table 8b. Petiole length (cm) in gerbera varieties as influenced by growing conditions

Variety	Petiole length (cm)							
	November				December			
	Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	7.45	8.47	8.80	**8.24**	8.20	7.73	9.00	**8.31**
Goliath	7.06	8.73	9.72	**8.50**	7.13	7.47	8.40	**7.67**
Stanza	8.31	8.98	9.17	**8.82**	7.20	7.22	9.13	**7.85**
Intense	6.27	5.58	11.80	**7.88**	8.07	7.67	12.60	**9.44**
Balance	4.00	5.07	9.33	**6.13**	6.67	7.13	11.00	**8.27**
Mean	**6.62**	**7.37**	**9.77**		**7.45**	**7.44**	**10.03**	
S. Em±	**0.57**				**0.57**			
C. D (0.05) for comparing								
Variety	0.96				0.96			
Growing condition	0.74				0.74			
Variety X Growing condition	1.66				1.66			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

plants in other growing conditions. During these months the petiole length of plants in other two growing conditions were on par.

Significant differences were noticed in the interaction effect of variety and growing conditions on the petiole length of gerbera during September, November and December. During the later part of the study (November and December), the gerbera variety Intense recorded maximum petiole length (11.80 and 12.60 cm, respectively) and was significantly superior to all other treatment combinations. This was followed Goliath and Balance (9.72 and 9.33 cm, respectively) in pot culture (G3) in November, and Balance and Stanza in December (11.00 and 9.13 cm, respectively) in the same growing condition (G3). The variety Balance in hydroponics with medium (G1) recorded minimum petiole length (4.00 and 6.67 cm, respectively), followed by Balance in hydroponics without medium (G2) (5.07 and 7.13 cm, respectively).

4.1.8 Number of lobes

The data pertaining to the number of lobes on the leaves of gerbera varieties as influenced by growing conditions are presented in (Tables 9a and 9b).

Detectable differences were observed in the number of lobes on the leaves of gerbera varieties during the period of study. The variety Goliath recorded maximum number of lobes throughout the study period and was significantly superior to all others. This was followed by the variety Dana Ellen in all months except November. At the end of the study period (December) the variety Goliath recorded maximum number of lobes on the leaf (6.80) and was significantly superior to all other varieties. This was followed by Dana Ellen (5.22) and Stanza (4.82). The minimum number of lobes (3.37) was recorded by the variety Intense and this was closely followed by Balance (4.29) and were on par.

The different growing conditions also did not influence the number of lobes on the leaves of gerbera. Combined effect of variety with the growing conditions was absent for the number of lobes on the leaves.

Table 9a. Number of lobes/ leaf in gerbera varieties as influenced by growing conditions

Variety	Number of lobes/ leaf											
	August				September				October			
	Growing conditions				Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	1.67	1.80	1.73	**1.73**	2.47	2.20	2.33	**2.33**	3.07	3.07	2.87	**3.00**
Goliath	2.27	2.33	1.80	**2.13**	2.73	2.80	2.80	**2.78**	3.93	4.27	3.77	**3.98**
Stanza	1.40	1.53	1.40	**1.44**	2.00	2.60	2.20	**2.27**	1.80	2.20	1.73	**1.91**
Intense	1.47	1.50	1.53	**1.50**	2.13	2.27	2.27	**2.22**	2.40	2.47	2.60	**2.49**
Balance	1.60	5.60	1.40	**1.53**	2.07	2.07	2.07	**2.07**	2.67	2.60	2.53	**2.60**
Mean	**1.68**	**1.75**	**1.57**		**2.28**	**2.39**	**2.33**		**2.77**	**2.92**	**2.69**	
S. Em ±	**0.23**				**0.23**				**0.21**			
C. D (0.05) for comparing												
Variety	0.39				0.38				0.36			
Growing condition	NS				NS				NS			
Variety X Growing condition	NS				NS				NS			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

Table 9b. Number of lobes/ leaf in gerbera varieties as influenced by growing conditions

Variety	Number of lobes/ leaf							
	November				December			
	Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	3.87	4.07	3.47	**3.80**	5.93	5.27	4.47	**5.22**
Goliath	4.73	4.93	4.33	**4.67**	7.07	6.47	6.87	**6.80**
Stanza	3.60	4.33	4.33	**4.09**	4.27	4.87	5.33	**4.82**
Intense	3.80	3.75	3.80	**3.78**	3.20	3.03	3.87	**3.37**
Balance	3.77	3.67	3.00	**3.48**	4.00	4.40	7.47	**4.29**
Mean	**3.95**	**4.15**	**3.79**		**4.89**	**4.81**	**5.00**	
S. Em±	**0.30**				**0.62**			
C. D (0.05) for comparing								
Variety	0.50				1.04			
Growing condition	NS				NS			
Variety X Growing condition	NS				NS			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

The above discussed characters summarize the vegetative characteristics of the crop so as to have an overall assessment of the crop at this stage, the ranking technique (Arunachalam and Bandyopadhyay, 1984) was adopted (Table 10).

From the Table it is evident that the different varieties had a zigzag way of performance in the whole vegetative phase. When the vegetative phase was nearly over the flowering phase starts.

4.2 Weather conditions during the experimental period

Data on the weather parameters both inside and outside the greenhouse during the crop period under consideration are given in figure 1 to 3.

The mean maximum temperature and the minimum temperature followed the same pattern with relatively lower temperature was recorded inside the greenhouse (Fig. 1). And the light intensity was also following the same pattern (Fig. 3).

But mean relative humidity, was showing a reversal phenomenon in comparison to the mean temperatures and light intensity (Fig. 2).

4.3 Correlation studies

Correlation studies were done by correlating microclimate parameters, viz., maximum and minimum temperature, relative humidity and light intensity with the plant characters namely, height, spread, number of leaves, leaf length, leaf breadth, leaf area, petiole length and number of lobes. This has been done to assess the influence of weather parameter on the performance of selected gerbera varieties and the results are presented in Table 11.

The maximum temperature was found to influence some of the plant characters; plant spread, leaf length and number of lobes positively correlated with maximum temperature, whereas plant height positively correlated only with minimum temperature.

Relative humidity showed significant negative correlation with the plant characters, *viz.*, plant spread, leaf length, leaf area and number of lobes of gerbera

Table 10. Summary of the vegetative characteristics of gerbera varieties under different growing conditions

Growing condition	Variety	August		September		October		November		December	
		Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Hydroponic culture with media (G1)	Dana Ellen	12.0	2	13.0	3	17.5	5	23.0	7	27.5	9
	Goliath	12.5	3	13.0	3	14.5	2	23.0	7	26.0	7
	Stanza	14.5	5	16.5	9	22.0	8	25.0	9	31.0	11
	Intense	15.0	6	16.0	8	24.5	11	25.5	10	27.5	9
	Balance	12.5	3	15.5	7	22.0	8	27.0	11	25.0	6
Hydroponic culture without media (G2)	Dana Ellen	10.5	1	11.5	1	18.0	6	19.5	5	27.0	8
	Goliath	12.5	3	11.5	1	16.5	4	22.5	6	27.0	8
	Stanza	15.0	6	15.5	7	23.5	10	24.5	8	31.0	11
	Intense	13.5	4	14.5	5	24.5	11	28.5	12	31.0	11
	Balance	13.5	4	15.0	6	22.5	9	27.0	11	28.0	10
Pot culture (G3)	Dana Ellen	14.5	5	15.0	6	15.0	3	14.0	2	17.5	5
	Goliath	16.0	7	14.5	5	10.5	1	12.5	1	13.0	1
	Stanza	16.5	8	17.0	10	16.5	4	12.5	1	16.5	4
	Intense	12.0	2	12.5	2	23.5	10	15.5	3	14.5	3
	Balance	12.0	2	14.0	4	21.5	7	17.0	4	13.5	2

Vegetative characters: plant height, plant spread, number of leaves, leaf length, leaf breadth, leaf area, petiole length and number of lobes

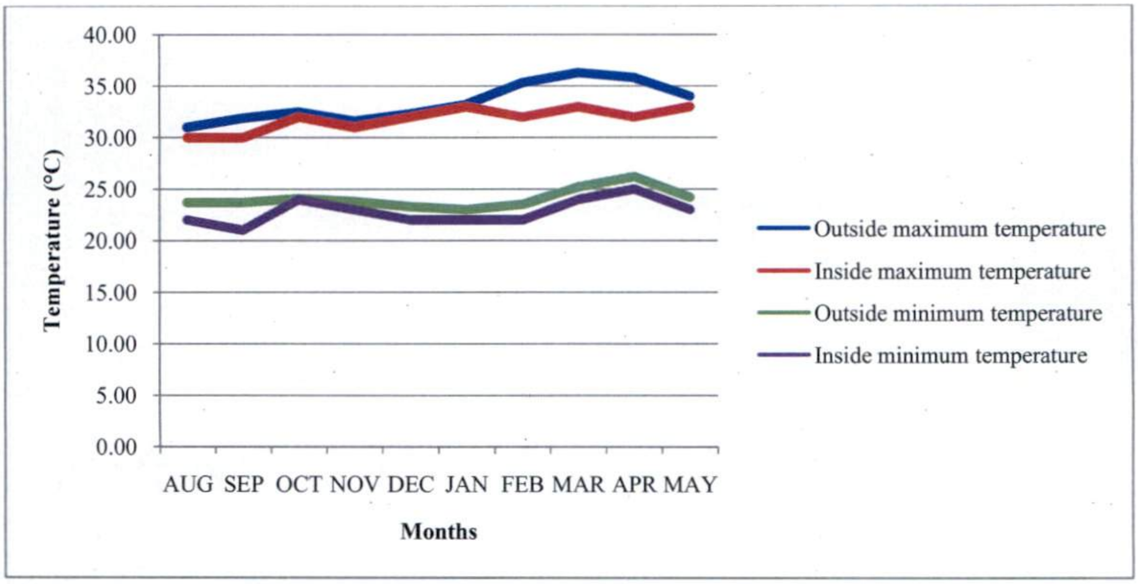

Fig. 1. Temperature inside and outside the greenhouse

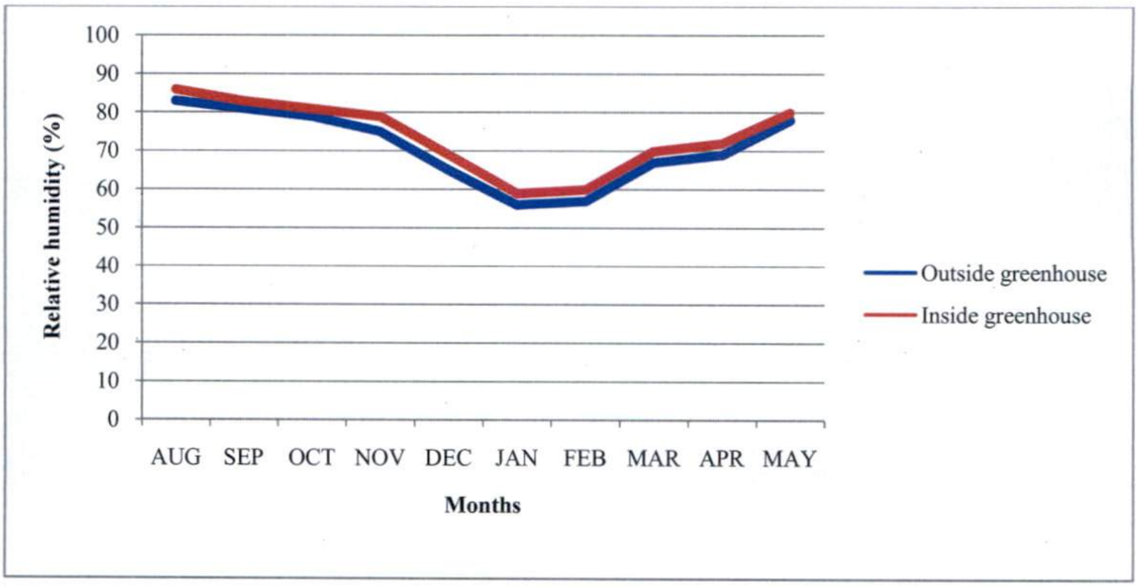

Fig. 2. **Relative humidity inside and outside the greenhouse**

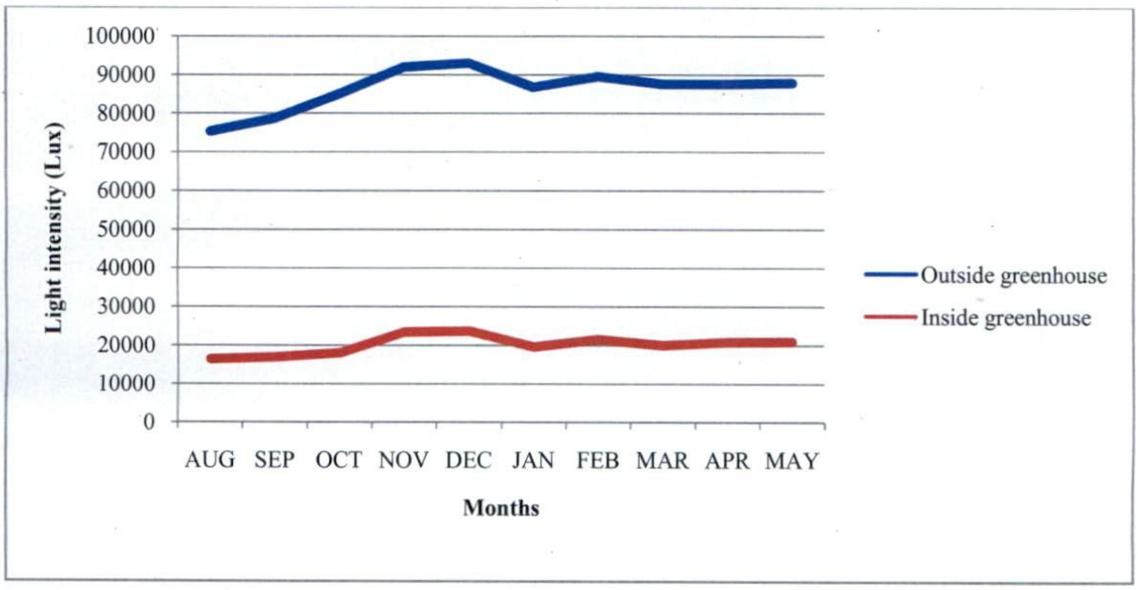

Fig. 3. Light intensity inside and outside the greenhouse

Table 11. Correlation between microclimatic parameters and plant characters

Microclimatic parameters	Plant height	Plant spread	Number of leaves	Leaf length	Leaf breadth	Leaf area	Petiole length	Number of lobes
Maximum temperature	-	0.525**	-	0.272**	-	-	-	0.569**
Minimum temperature	0.216*	-	-	-	-	-	-	-
Relative humidity	-	-0.690**	-	-0.473**	-	-0.307**	-	-0.746**
Light intensity	-	0.722**	-	0.468**	-0.284**	0.207**	-0.243*	0.768**

*Significant at 1% level

** Significant at 5% level

cultivars, whereas light intensity had a positive correlation with these parameters. On the other hand, the leaf breadth and petiole length showed negative correlation with light intensity.

None of the weather parameters showed any influence on number of leaves per plant.

4.4 Floral characters

Data pertaining to the floral characters of the gerbera varieties as influenced by growing conditions are presented in able 12. Statistical analysis of the data were done only for the varieties grown under pot culture.

4.4.1 Days to first flower bud emergence

The varieties showed considerable variation in the duration taken for first flower bud emergence under different growing conditions. Only the variety Balance flowered in the hydroponics with media (G1). It took 125.0 days for emergence of first flower bud, whereas, in hydroponics without media (G2), Balance took 150.7 days for emergence of first flower bud and was followed by Goliath (141.0 days). Others did not flower under these growing conditions.

Significant differences were noticed among gerbera varieties grown in pot culture (G3) with respect to the duration taken for first flower bud emergence. The variety Dana Ellen recorded the maximum duration (131.0 days) for first flower bud emergence followed by Stanza (126.5 days) and were on par. All the other varieties were comparable. Minimum duration (121.0 days) was recorded by the variety Goliath.

4.4.2 Bud emergence to opening of first flower

Variation was noticed among varieties with regard to bud emergence to opening of first flower under different growing conditions (Table 12). The variety Balance took 13.0 days for the opening of first flower in hydroponics with media (G1) whereas, it was 8.0 days in hydroponics without media (G2).

Table 12. Floral characters of gerbera varieties as influenced by growing conditions

Growing condition	Variety	Days to first flower bud emergence	Days to first flower opening	No: flowers/ plant	Flower life in field	Flower stalk		Flower diameter (cm)	Disc diameter (cm)
						Length (cm)	Girth (cm)		
Hydroponic culture with media (G1)	Dana Ellen	NF							
	Goliath	NF							
	Stanza	NF							
	Intense	NF							
	Balance	125.00	13.00	6.30	13.90	33.70	1.30	10.00	2.60
Hydroponic culture without media (G2)	Dana Ellen	NF							
	Goliath	141.00	10.00	8.90	16.30	39.00	1.20	9.00	2.00
	Stanza	NF							
	Intense	NF							
	Balance	150.70	8.00	4.00	15.40	34.00	1.30	9.70	2.00
Pot culture (G3)	Dana Ellen	131.00	16.50	13.00	13.30	61.30	1.40	9.20	1.90
	Goliath	121.00	8.50	15.80	10.80	61.00	1.90	10.10	2.50
	Stanza	126.50	8.30	10.30	14.30	59.30	1.90	8.70	1.90
	Intense	123.30	6.50	10.30	9.50	56.50	1.60	9.70	2.40
	Balance	121.50	6.30	16.80	16.50	58.00	1.90	9.50	2.30
C. D (0.05)		5.81	1.15	1.18	1.37	NS	0.25	NS	0.40

NF – Not Flowered; NS- Not Significant

When varieties grown in pot culture (G3) were compared, the variety Dana Ellen recorded maximum duration for bud emergence to first flower opening (16.5 days) and was significantly superior to all others. The minimum duration was recorded in the variety Balance (6.3 days).

4.4.3 Number of flowers produced/ plant

Differences were noticed in the number of flowers produced/ plant under different growing conditions. In hydroponics with media (G1) and hydroponics without media (G2), the variety Balance produced 6.3 and 4.0 flowers/ plant, respectively. The variety Goliath produced 8.9 flowers/ plant in the hydroponics without media (G2).

Among the varieties, distinguishable differences were noted in the number of flowers produced/ plants in pot culture (G3), Balance produced maximum number of flowers/ plant (16.8) and was on par with Goliath (15.8) and significantly superior to all others.

4.4.4 Flower longevity

Flower longevity on the plant showed variation in growing conditions and the results are presented in Table 12. The variety Balance in hydroponics with media (G1) recorded 13.9 and 15.4 days, respectively.

The varieties in pot culture (G3) showed considerable variation in the longevity of flower on the plant. The variety Balance recorded maximum longevity (16.5 days) and was significantly superior to all others. This was closely followed by the variety Dana Ellen (13.3 days) and Goliath (10.8 days). Minimum flower longevity was recorded by the variety Intense (9.5 days).

4.4.5 Flower stalk length

The flower stalk length was considerably less (33.7 and 34.0 cm, respectively) in the variety Balance in hydroponic culture with media (G1) and without media (G2). Significant variation was not observed among gerbera varieties in pot culture

(G3). The flower stalk length ranged from 56.5 cm (Intense) to 61.3 cm (Dana Ellen) under this growing condition.

4.4.6 Flower stalk girth

The girth of flower stalk varied among the varieties under different growing conditions (Table 12). The variety Balance in hydroponics with media (G1) and without media (G2) recorded 1.3 cm and the variety Goliath in hydroponics without media (G2) recorded 1.2 cm.

When the varieties grown in pot culture (G3) were compared, maximum girth (1.9 cm) was recorded by the variety Goliath, Stanza and Balance and were significantly superior to others. Minimum stalk girth (1.4 cm) was recorded by the variety Dana Ellen, followed by Intense (1.6 cm).

4.4.7 Flower diameter

Significant variation was not recorded in flower diameter among varieties under different growing conditions (Table 12). It ranged from 9.2 cm (Dana Ellen) to 10.1 cm (Goliath) in pot culture (G3) followed by the variety Balance in hydroponics with media (G1).

4.3.8 Disc diameter

Disc diameter recorded in Balance in hydroponics with media (G1) and without media (G2) was 2.6 and 2.0 cm, respectively.

Significant variation was noticed among gerbera varieties in pot culture (G3). Disc diameter was maximum in variety Goliath (2.5 cm) followed by Intense (2.4 cm) and Balance (2.3 cm) and were on par. Minimum (1.9 cm) disc diameter was recorded by the variety Dana Ellen and Stanza.

4.4 Post harvest characters

Data on post harvest characters, namely, fresh weight of flower, flower longevity, water uptake and physiological loss in weight are presented on Table 13.

Table 13. Post- harvest characters of gerbera varieties as influenced by growing conditions

Growing condition	Variety	Fresh weight (g)	Physiological loss in weight (g)	Water uptake (ml)	Vase life (days)	Symptoms of wilting/ loss of freshness
Hydroponic culture with media (G1)	Dana Ellen	NF				
	Goliath	NF				
	Stanza	NF				
	Intense	NF				
	Balance	13.00	4.50	5.00	8.70	Bending of flower stalk
Hydroponic culture without media (G2)	Dana Ellen	NF				
	Goliath	11.30	3.30	5.00	8.00	Bending of flower stalk
	Stanza	NF				
	Intense	NF				
	Balance	12.00	4.00	4.00	9.00	Bending of flower stalk
Pot culture (G3)	Dana Ellen	16.80	7.00	9.50	6.50	Wilting or drooping of flower stalk
	Goliath	16.00	3.80	7.00	5.30	Wilting of ray florets
	Stanza	19.50	6.50	10.30	7.50	Bending of flower stalk
	Intense	14.80	3.80	7.80	4.50	Bending of flower stalk
	Balance	14.40	5.70	10.00	9.30	Breaking of flower stalk and bending
C. D. (0.05)		1.92	1.00	NS	1.00	

NF – Not Flowered; NS- Not Significant

4.4.1 Fresh weight of flower

Fresh weight of flower in the variety Balance varied under different growing conditions. In hydroponics it recorded 13.0 g with media (G1) and 12.0 g without media (G2).

Wide variation was observed in the fresh weight of flower. Among the varieties, Stanza recorded the maximum (19.5 g) fresh weight followed by Dana Ellen (16.8 g) which were on par and significantly superior to all others. Minimum fresh weight (14.4 g) was recorded by Balance, followed by Intense (14.8 g) and Goliath (16.0 g).

4.4.2 Physiological loss in weight (PLW)

Physiological loss in weight also varied among varieties in pot culture (G3) (Table 13) and was maximum (7.0 g) in the variety Dana Ellen followed by Stanza (6.5 g). Minimum (3.8 g) PLW was recorded by the variety Intense and Goliath.

4.4.3 Water uptake

The varieties did not exhibit significant variation in water uptake.

4.4.4 Flower longevity (Vase life)

Data on the flower longevity of gerbera flower under different growing conditions are given in Table 13. Variety Balance recorded maximum flower longevity (9.3 days) in pot culture (G3), followed by hydroponics without media (G2) and with media (G1) recording longevity of 9.0 and 8.7 days, respectively.

When the gerbera varieties grown in pot culture were compared, the variety Balance recorded the maximum (9.3 days) flower longevity and was significantly superior to all others. This was followed by Stanza (7.5 days) and Dana Ellen (6.5 days), which were on par. Minimum flower longevity (4.5 days) was recorded by the variety Intense.

4.5 Nutrient content

Data on the nutrient concentration (N, P, K, Ca, Mg, S, Cu, Fe, Mn and Zn) in gerbera varieties as influenced by growing conditions are given in Tables 14 to 17.

4.5.1 Nitrogen

Data on the nitrogen concentration in gerbera varieties as influenced by different growing conditions are given in Table 14. Significant variation was not observed in the N concentration among the varieties and growing conditions.

Combination effect of varieties and growing conditions was also not significant.

4.5.2 Phosphorus

Data on the phosphorus concentration of gerbera varieties as influenced by growing conditions are given in Table 14.

The P concentration did not show any variation among the varieties.

Significant variation was observed in the P concentration of gerbera under different growing conditions. It was maximum (0.39 %) in plants grown in pot culture (G3) and was significantly superior to others, whereas others were on par.

Significant variation was observed in the interaction effect of variety and growing conditions on P concentration. The variety Goliath recorded maximum P concentration (0.44 %) in pot culture (G3) and was significantly superior to all other treatment combinations, except the varieties Intense, Dana Ellen and Stanza under the same growing condition (G3) and were comparable. The variety Goliath in hydroponic culture with and without media (G1 and G2) recorded the minimum value (0.25 %) and was on par with the variety Dana Ellen (0.26 %) and Intense (0.27 %) in hydroponics with media (G2) and were on par.

4.5.3. Potassium

Data on the effect of growing conditions on the K concentration of the gerbera varieties are given in Table 14.

Table 14. N, P and K concentrations of gerbera varieties as influenced by growing condition

Variety	Nutrient content											
	N (%)				P (%)				K (%)			
	Growing conditions				Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	1.91	2.23	2.19	**2.11**	0.26	0.34	0.38	**0.32**	2.64	1.81	0.63	**1.69**
Goliath	2.12	2.11	1.92	**2.05**	0.25	0.25	0.44	**0.31**	2.39	2.73	0.63	**1.92**
Stanza	2.45	2.37	1.98	**2.27**	0.28	0.33	0.38	**0.33**	2.65	2.89	0.86	**2.13**
Intense	1.75	2.16	1.95	**1.95**	0.27	0.31	0.41	**0.33**	2.49	1.93	0.78	**1.73**
Balance	2.16	2.39	1.97	**2.18**	0.35	0.35	0.36	**0.35**	3.17	3.49	0.67	**2.44**
Mean	**2.08**	**2.25**	**2.00**		**0.28**	**0.31**	**0.39**		**2.67**	**2.57**	**0.72**	
S. Em ±	**0.17**				**0.03**				**0.21**			
C. D (0.05) for comparing												
Variety	NS				NS				0.35			
Growing condition	NS				0.03				0.27			
Variety X Growing condition	NS				0.06				0.60			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

Distinguishable differences were recorded among varieties with respect to the concentration of K. The variety Balance recorded the maximum (2.44 %) and was significantly superior to all varieties except Stanza (2.13 %). The variety Dana Ellen recorded the minimum (1.69 %), which was followed by Intense (1.73 %) and Goliath (1.92 %) and were on par.

Considerable variation was also noticed in the K concentration of gerbera among the growing conditions. Maximum K content (2.67 %) was recorded in plants in hydroponics with media (G1), followed by plants in hydroponics without media (G2) (2.57 %) and were on par. Plants in pot culture (G3) recorded the minimum (0.72 %).

Marked variation was observed in the combination effect of variety and growing conditions in the K concentration. The variety Balance in hydroponics without media (G2) recorded the maximum (3.49 %), followed by hydroponics with media (G1) (3.17 %) and the variety Stanza in hydroponic culture without media (2.89 %) and were on par. The variety Dana Ellen and Goliath in pot culture (G3) recorded the minimum (0.63 %).

4.5.4 Calcium

Data on the Ca concentration of gerbera varieties as influenced by growing conditions are given in Table 15.

Significant variation was not observed in the Ca concentration, among the varieties. However, the growing conditions differed significantly. The plants in pot culture (G3) recorded maximum Ca (2.74 %) and was significantly superior to others which were on par. Plants in hydroponics with media (G1) and without media (G2) recorded a concentration of 1.39 % and 1.72 %, respectively.

Combination effect of variety and growing conditions in the Ca concentration was not significant.

Table 15. Ca, Mg and S concentrations of gerbera varieties as influenced by growing condition

Variety	Nutrient content											
	Ca (%)				Mg (%)				S (%)			
	Growing conditions				Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	1.66	1.19	2.87	**1.91**	1.46	0.63	0.33	**0.81**	1.13	0.79	0.29	**0.74**
Goliath	1.21	1.31	2.62	**1.71**	2.26	1.74	0.33	**1.44**	1.75	1.49	0.22	**1.15**
Stanza	1.72	3.36	2.38	**2.49**	2.02	1.71	0.33	**1.35**	1.41	0.91	0.22	**0.85**
Intense	1.16	1.53	3.30	**2.00**	1.99	0.63	0.34	**0.99**	1.71	0.83	0.33	**0.96**
Balance	1.20	1.19	2.51	**1.63**	2.42	1.84	0.32	**1.53**	2.15	1.62	0.33	**1.37**
Mean	**1.39**	**1.72**	**2.74**		**2.03**	**1.31**	**0.33**		**1.63**	**1.13**	**0.28**	
S. Em ±	**0.54**				**0.34**				**0.14**			
C. D (0.05) for comparing												
Variety	NS				NS				0.23			
Growing condition	0.70				0.45				0.18			
Variety X Growing condition	NS				NS				0.39			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

4.5.5 Magnesium

Marked differences were not observed in the Mg concentration among varieties as evident from the data presented in Table 15.

Growing conditions recorded considerable variation. Concentration of Mg was high (2.03 %) in plants in hydroponics with media (G1) and was significantly superior to others. This was followed by plants in hydroponics without media (G2) and pot culture (G3) (1.31 and 0.33 %, respectively).

The interaction between variety and growing conditions on Mg concentration was also not significant.

4.5.6 Sulphur

Data on the effect of varieties under different growing conditions as the S concentrations are given in Table 15.

Appreciable differences were obtained among gerbera varieties in the concentration of S. Among the varieties, Balance recorded the maximum S concentration (1.37 %) followed by Goliath (1.15 %) and was significantly superior to all others. The variety Dana Ellen recorded the lowest values (0.74 %), followed by Stanza (0.85 %) and, Intense (0.96 %) and were on par.

Influence of growing conditions on the concentration of S in gerbera was significant. The concentration was significantly higher in hydroponics with media (G1). This was followed by plants in hydroponics without media (G2) and pot culture (G3) (1.13 and 0.28 %, respectively).

Combination effect of variety and growing conditions was evident. Among the treatment combinations, hydroponics with media (G1) was a better growing condition for Balance for S concentration (2.15 %) and was significantly superior to all other treatment combinations, whereas other concentrations were on par.

Table 16. Cu and Fe concentrations of gerbera varieties as influenced by growing condition

Variety	Nutrient content							
	Cu (mg l^{-1})				Fe (mg l^{-1})			
	Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	45.44	95.13	23.08	**54.55**	188.84	324.14	170.75	**227.91**
Goliath	40.40	26.93	14.00	**27.11**	222.04	213.48	149.30	**194.94**
Stanza	32.87	48.72	10.87	**30.82**	236.01	262.02	122.71	**206.91**
Intense	38.47	31.99	25.96	**32.14**	264.70	264.85	128.39	**219.32**
Balance	41.23	94.06	22.32	**52.54**	177.09	254.98	181.35	**204.47**
Mean	**39.68**	**59.37**	**19.25**		**217.74**	**263.89**	**150.50**	
S. Em±	**9.84**				**24.34**			
C. D (0.05) for comparing								
Variety	16.48				NS			
Growing condition	12.77				31.59			
Variety X Growing condition	28.55				70.64			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

4.5.7 Copper

Concentration of Cu in gerbera varieties under different growing conditions are given in Table 16. Concentration of Cu in gerbera varied significantly with respect to varieties and growing conditions.

The variety Dana Ellen recorded the maximum Cu concentration (54.55mgl^{-1}) was significantly superior to the variety Goliath (27.11 mg l^{-1}) whereas all other varieties were on par. Concentration of Cu was significantly higher (59.37 mg l^{-1}) in gerbera in hydroponics without media (G2).

Interaction effect of variety and growing conditions was evident. Among the combination treatments, hydroponics without media (G1) was the better growing condition for Cu concentration and the variety Dana Ellen and Balance recorded maximum values (95.13 and 94.06 mg l^{-1}, respectively) and were significantly superior to all other treatments. The variety Stanza in pot culture recorded lower values (10.87 mg l^{-1}), followed by Goliath, Balance, Dana Ellen and Intense under the same growing condition (14.00, 22.32, 23.08, 25.96 mg l^{-1}, respectively).

4.5.8 Iron

The Fe concentration of the varieties as influenced by growing conditions are given in Table 16. Appreciable differences were not obtained among varieties in the concentrations of Fe. Influence of growing conditions on the concentration of Fe was significant.

Hydroponics without media (G1) was the better growing condition recorded the maximum (263.89 mg l^{-1}) and was significantly superior to other growing conditions.

Interaction between variety and growing conditions was significant. Hydroponics without media (G2) was the better growing condition for the variety Dana Ellen for Fe concentration followed by Intense (324.14 and 264.85 mg l^{-1}, respectively). Lower values were recorded by the variety Stanza (122.71 mg l^{-1}),

Table 17. Mn and Zn concentrations of gerbera varieties as influenced by growing condition

Variety	Nutrient content							
	Mn (mg l^{-1})				Zn (mg l^{-1})			
	Growing conditions				Growing conditions			
	G1	G2	G3	Mean	G1	G2	G3	Mean
Dana Ellen	89.46	270.24	26.45	**128.72**	31.63	39.42	25.84	**32.30**
Goliath	94.50	110.00	22.57	**75.69**	29.76	30.39	25.44	**28.53**
Stanza	139.24	156.54	27.31	**107.70**	28.29	29.76	22.75	**26.94**
Intense	63.98	112.43	44.03	**73.48**	27.42	30.03	25.99	**27.81**
Balance	82.47	166.74	44.72	**97.97**	29.43	32.10	27.18	**29.57**
Mean	**93.93**	**163.19**	**33.02**		**29.31**	**32.34**	**25.44**	
S. Em±	**12.95**				**2.36**			
C. D (0.05) for comparing								
Variety	21.69				NS			
Growing condition	16.80				3.07			
Variety X Growing condition	37.57				NS			

NS – Not Significant

G1 – Hydroponics with media

G2 – Hydroponics without media

G3 – Pot culture

followed by Intense, Goliath and Dana Ellen (128.39, 149.30 and 170.75 mg l^{-1}, respectively) in pot culture (G3).

4.5.9 Manganese

Concentration of Mn in gerbera varied significantly with respect to varieties and growing conditions (Table 17). The variety Dana Ellen recorded the maximum Mn concentration (128.72 mg l^{-1}) followed by Stanza (107.70 mg l^{-1}) and were significantly higher than all other varieties. The variety Intense recorded the minimum (73.48 mg l^{-1}).

Among the growing conditions Mn concentration was significantly higher (163.19 mg l^{-1}) in hydroponics without media (G2) whereas plants in pot culture (G3) recorded lower values (33.02 mg l^{-1}) followed by hydroponics with media (G1) (93.93 mg l^{-1}).

Combined effect of variety and growing conditions was significant. The hydroponics without media (G1) (270.24 mg l^{-1}) was the better growing condition for the variety Dana Ellen for Mn concentration. The variety Goliath recorded lower value for Mn concentration (22.57 mg l^{-1}) in pot culture (G3) and this was on par with all other varieties under the same growing condition (G3).

4.5.10 Zinc

The concentration of Zn in gerbera varieties, as influenced by different growing conditions are given in Table 17.

Distinguishable differences were not recorded among varieties with respect to the Zn concentration.

The concentration of Zn in gerbera as influenced by was significantly different. Zn concentration was maximum in gerbera (32.34 mg l^{-1}) in hydroponics without media (G2), followed by hydroponics with media (G1) (29.31 mg l^{-1}) and were on par and significantly superior to other growing conditions. Minimum Zinc concentration (25.44 mg l^{-1}) was recorded in the plants in pot culture (G3).

Combination effect of variety and growing condition was not evident.

4.6 Incidence of pests and diseases

There was no incidence of pest and diseases in any of the plants during the experiment period.

4.7 Benefit – cost analysis

Only one variety *i.e.,* Balance flowered under hydroponics during the study period. Hence B: C ratio was not calculated.

Discussion

5. DISCUSSION

In the modern world of commercial floriculture, gerberas are well known for their wide spectrum of colours and shapes. Besides, in view of the excellent vase life and ease in handling, gerbera is widely used in flower arrangement and bouquets. The popularity of this flower is still on the increase. Over the last few years, it has earned a stable place in the top five of the most cultivated varieties in the world. Commercial cultivation of gerbera is so far restricted to hi- tech greenhouse system in the country, mostly in the subtropical regions.

Various growing systems have been tried in crops in view of the shrinking land area and to ward off biotic and abiotic stresses. Hydroponics is one of such systems of growing in soilless media, which requires less space and labour and can be well tried indoors. Though there are encouraging reports and success stories about the system in vegetables and foliage plants, such reports on flower crops are far too low.

In order to evaluate the performance of gerbera cultivars under hydroponics, a study was conducted at the Department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Vellanikkara, during 2015- 2016. Five gerbera varieties, *viz.,* Dana Ellen, Goliath, Stanza, Intense and Balance were used for the study. The varieties were grown under three conditions; hydroponics with media, hydroponics without media and pot culture under greenhouse. The performance of the system was evaluated by observing the vegetative, floral and postharvest characters and subjecting the data to statistical analysis. The results generated from the studies are discussed hereunder.

5.1 Vegetative characters

The vegetative characters such as plant height, plant spread, number of leaves, leaf length, leaf breadth, leaf area, petiole length and number of lobes were recorded in order to understand the influence of the treatments on these, which in turn would reflect on flowering and floral characters.

Vegetative characters of gerbera varieties showed significant variation during the entire period of the study (from planting till flowering). Performance of gerbera cultivars varies with the region, season and other growing condition (Horn *et al.*, 1974). Considering the plant height, it was observed that the variety Intense was on par with variety Stanza and these two were significantly superior to other varieties under the study. Among the three growing conditions evaluated, significant differences were observed only towards the end of the experiment, during October to December. It was also observed that pot culture was the best growing condition favouring the plant height (Fig. 4)

The effect on plant height as an interaction between variety and growing condition revealed that, the effect was significant only during August and October and was the highest in variety Goliath under pot culture. The variation expressed in the variety may primarily be due to the genetic differences among the varieties as supported by various researchers (Dhane *et al.*, 2004; Akali *et al.*, 2010 and Thakur *et al.*, 2013). The effect of growing media showed significant differences which can be attributed to the textural differences among the media. The varietal interaction with the media also contributed to the performance of the variety.

During the initial period of the study, both the variety and the growing condition did not show any variation in plant spread. But in the later stages, *i.e.*, at the flowering period, the plant spread of variety Balance was significantly higher than that of the others (Fig. 5). In case of growing condition, pot culture showed significant difference. The interaction effect on plant spread by variety and growing condition was not significant. The variation in plant spread could be due to the additive gene effects, as suggested by Vidalie *et al.* (1985).

The entire duration of study showed varietal variation on number of leaves per plant. During the flowering period, the variety Stanza recorded the highest number of leaves per plant and Intense, the lowest. These two differed significantly. But the growing conditions showed variation only during the later period of study, *i.e.*, during

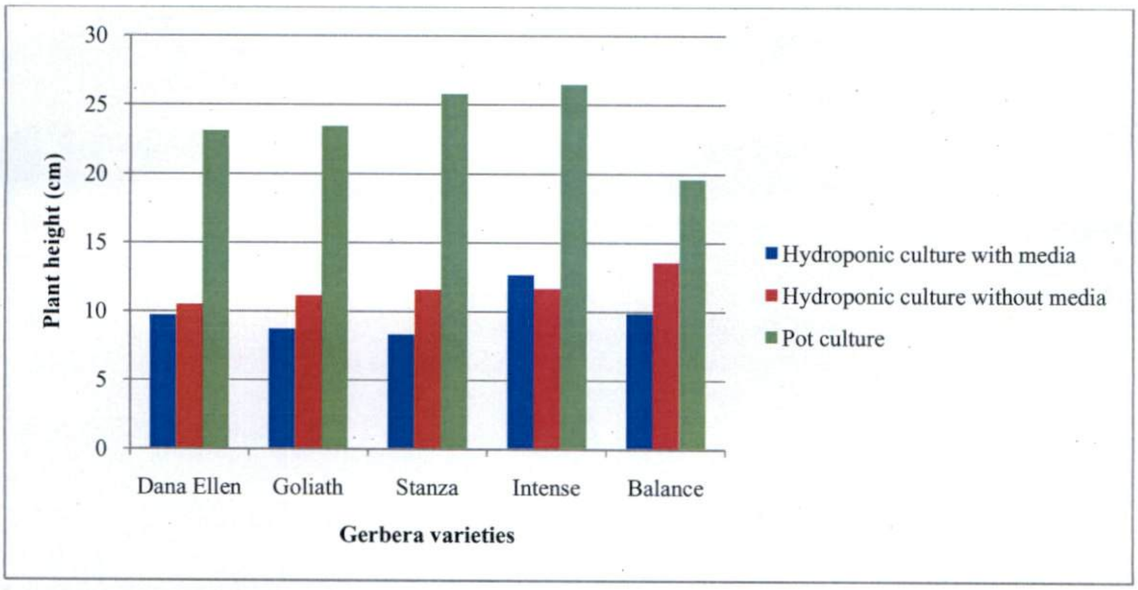

Fig. 4. Effect of growing conditions on plant height (cm) of gerbera varieties

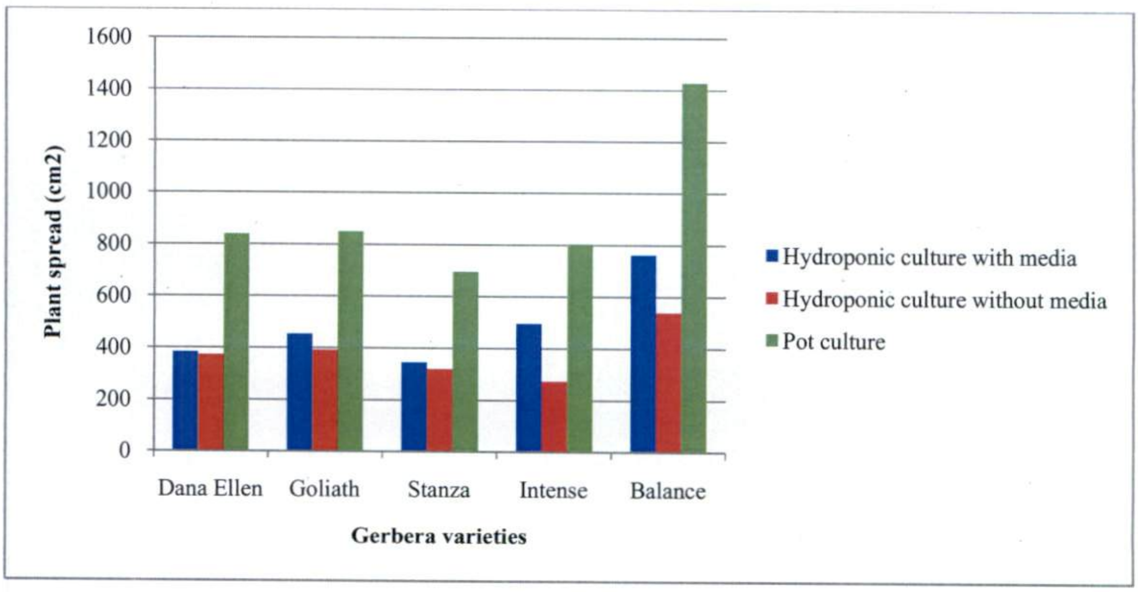

Fig. 5. Effect of growing conditions on plant spread (cm^2) of gerbera varieties

September to December. It was the pot culture that showed significant superiority over other growing conditions (Fig. 6). The interaction effect between variety and growing condition was significant during the entire period of study. Among the interactions, Stanza under pot culture showed highest leaf number, followed by Goliath, under hydroponic culture without media. The lowest leaf number was recorded in Intense under the hydroponic culture without media. The main effect of flooding is a decrease of oxygen availability for the roots, which affects respiration and electron transport (Reid and Wample, 1982). This could also increase the acidity of the medium. Bailey and Hammer (1986) reported a linear increase of shoot dry weight and leaf number of petunia seedlings when pH was reduced from 6.4 to 5.6. Consequently, physiological and metabolic changes occur, and, in most species, growth is inhibited and roots die. In addition to inhibiting growth, flooding can induce wilting and rolling of leaves, adventitious root formation, and stem hypertrophy. Secondary symptoms of flooding include leaf water deficits and inhibition of photosynthesis (Save and Serrano, 1986).

The leaf characters, *viz.,* leaf length, leaf breadth and leaf area, showed a significant variation in the variety Balance (Fig. 7, Fig. 8, Fig. 9). Among the growing conditions, pot culture exhibited significant variation. Considering the interaction between the variety and growing condition, the effect on leaf length and leaf breadth was significant only during October. The variety Goliath under pot culture showed superiority to the variety Intense under hydroponic culture, without media. But the leaf breadth did not have any significance in the interaction effect of variety and growing condition. The results are in accordance with the findings of Nair *et al.* (2002) in gerbera under protected condition. Naik *et al.* (2006) also have reported that, leaf production of any crop decides the spread of plant; leaves are the prime important functional units for photosynthesis, which greatly influence the growth and flower yield.

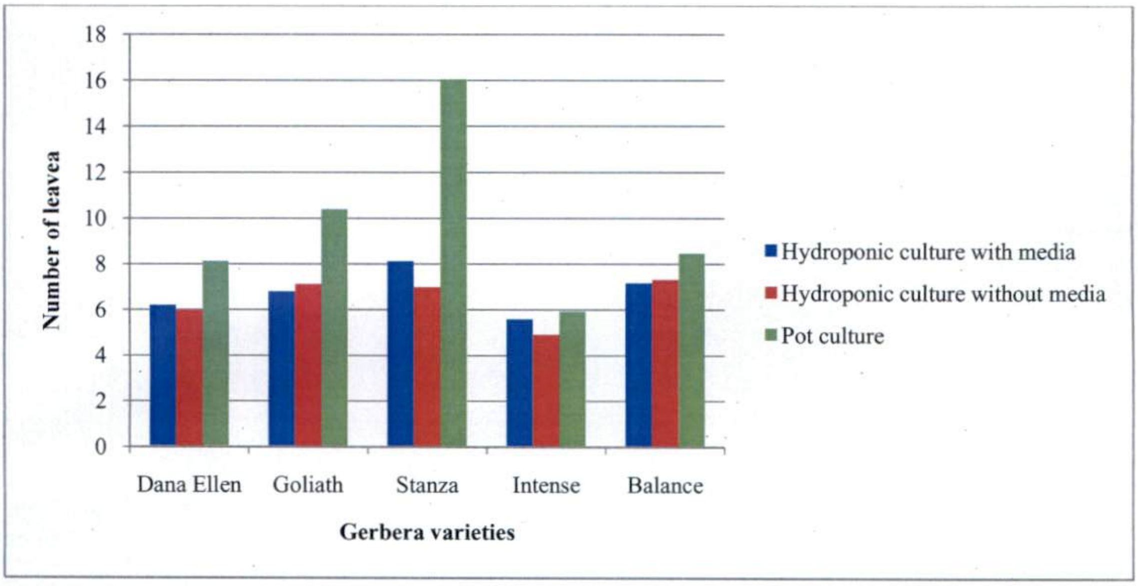

Fig. 6. Effect of growing conditions on number of leaves of gerbera varieties

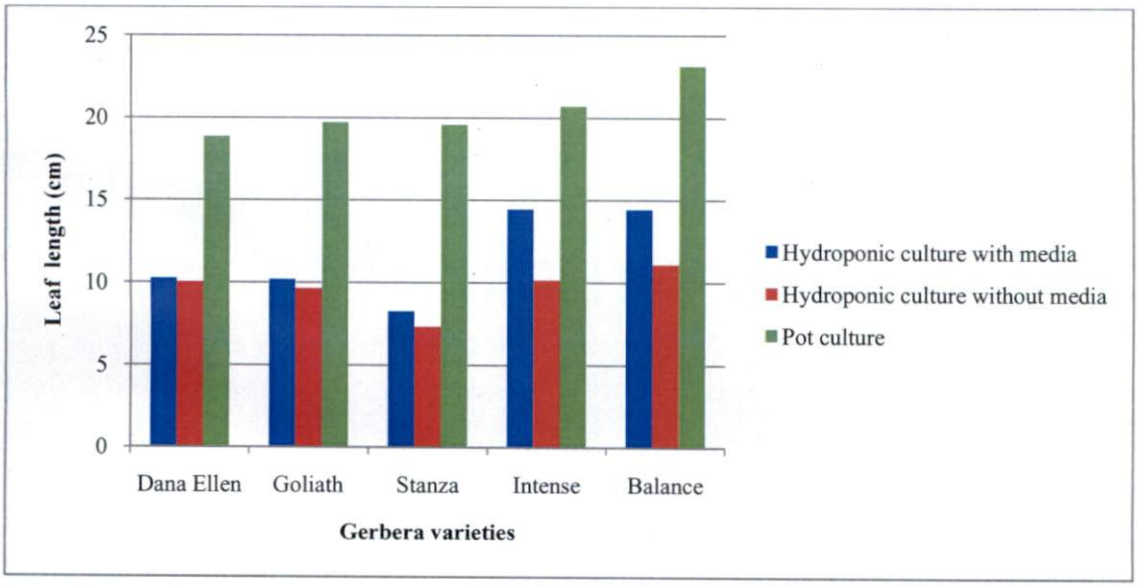

Fig. 7. Effect of growing conditions on leaf length (cm) of gerbera varieties

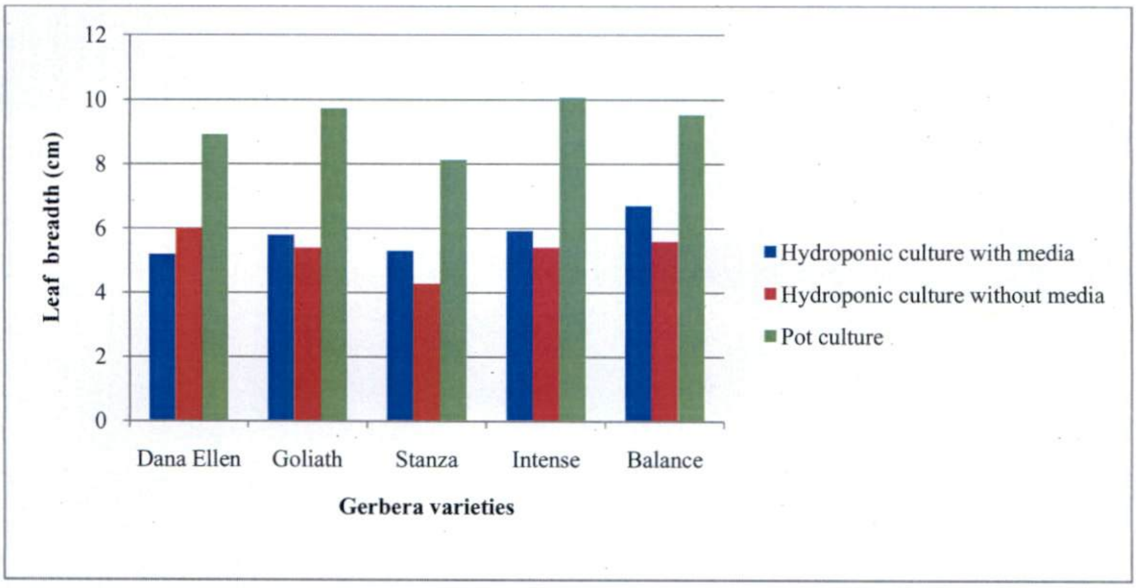

Fig. 8. Effect of growing conditions on leaf breadth (cm) of gerbera varieties

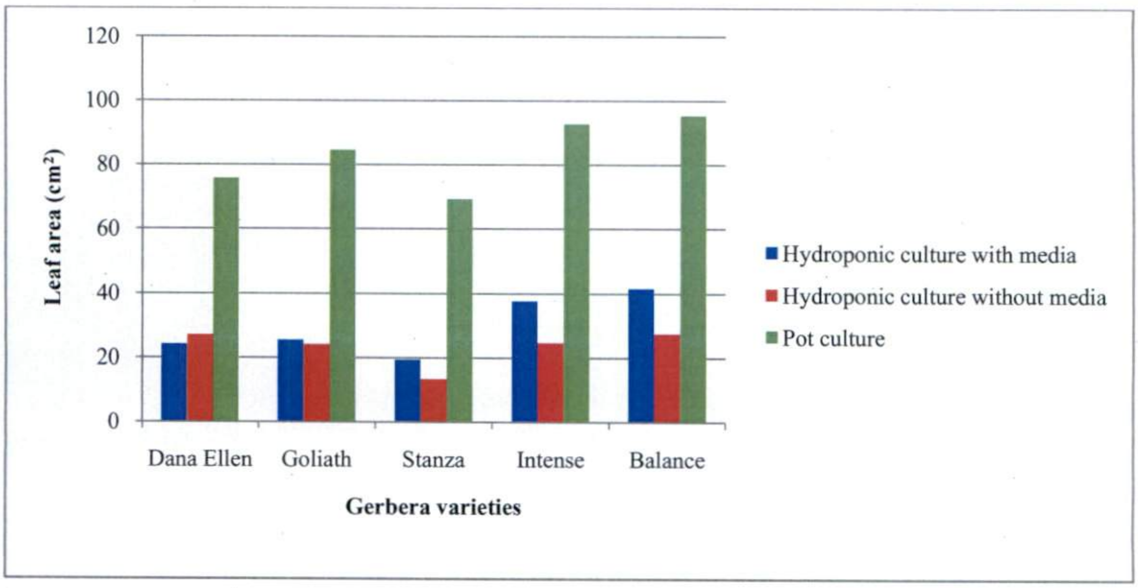

Fig. 9. Effect of growing conditions on leaf area (cm^2) of gerbera varieties

Leaf petiole length showed significant variation on in the varieties during entire study period. The variety Intense recorded highest petiole length and was significantly superior to all others (Fig. 10). But considering the growing condition and interaction effect, it was significant only during the later period of study. The petiole length was better in pot culture and the interaction was better under the same condition with variety Intense. It was significantly superior to variety Balance under hydroponic culture with media.

Significant variation in the number of lobes on the leaf was recorded only among the varieties, during the entire period of study. The variety Goliath had the highest number of lobes and it was significantly superior to all others (Fig. 11)

The varietal difference expressed with respect to the various characters studied can be attributed to the genetic makeup of the varieties (Hemlata *et al.*, 1992). Such variation in vegetative growth parameters of gerbera cultivars has also been reported earlier (Biradur and Khan, 1996; Singh and Ramachandran, 2002). Similar results on vegetative characters have also been reported by Behera *et al.* (1992) in chrysanthemum and in gerbera and Mishra (1997) in gladiolus.

For vegetative characters, pot culture showed better results and this may be due to the large particle size as compared to other condition. Large particles are often added to growing media to improve their air storage and gas exchange properties (Caron *et al.*, 2001). If these particles are very coarse, platy or disc shaped and gas impermeable, they may create a barrier for gas diffusion even if they improve air storage. In the pot culture one composition part is peat. The peat fragments are porous particles (Nkongolo and Caron, 1999) and they can also help in better aeration of the media. Good quality peat has air capacity of 20- 30 per cent and water capacity of 65-75 per cent (De Boodt and Verdonck, 1972). Reinikainen (1993) commented that, a growing medium must have a structure that allows the roots to penetrate widely into the material. Nowak and Strojny (2004) reported a decrease in the yield of gerbera simultaneously with a decrease of the total pore space in the growing medium.

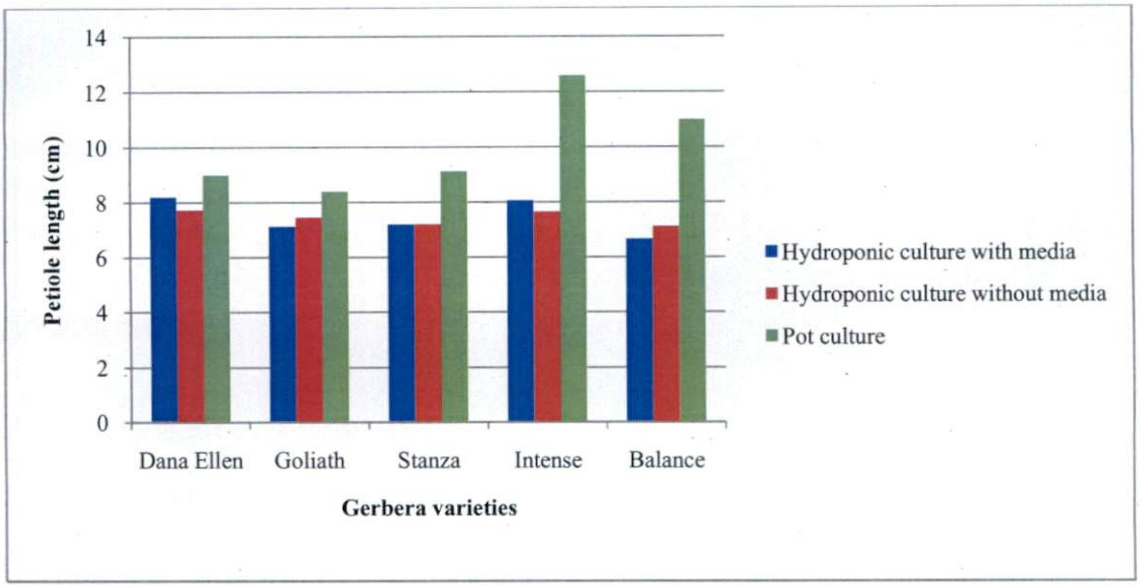

Fig. 10. Effect of growing conditions on petiole length (cm) of gerbera varieties

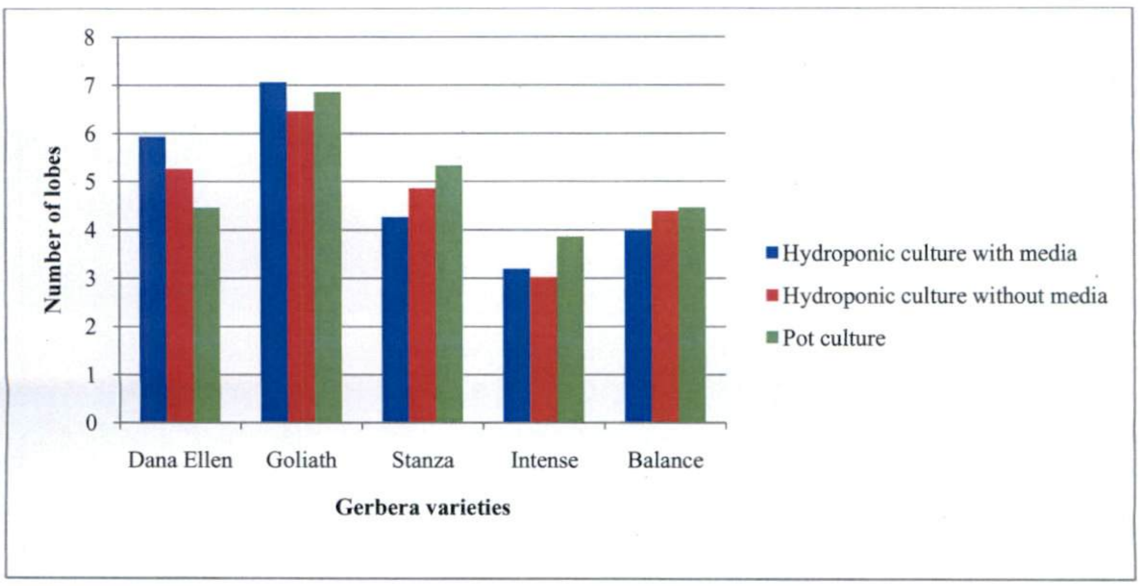

Fig. 11. Effect of growing conditions on number of lobes of gerbera varieties

Comparing the pot culture with other two growing conditions, the irrigation frequency also may be an important factor. The report of Weerakkody *et al.* (2012) that less frequent irrigation providing more aeration, favour shoot and root growth of pot gerbera plants compared to more frequent irrigation schedules under prevailing greenhouse climate supports this inference. Olivella *et al.* (2000) has also reported that, the markedly low tolerance of gerbera plants to flooding was indicated by physiological and growth parameters. These results indicate that irrigation management of this species is complicated. Thus a good combination of physical substrate properties and irrigation scheduling is required. Substrates must have high porosity to allow good drainage and maintain high oxygen levels. Irrigation must be applied in short pulses in order to maintain the oxygen content of the substrate.

5.2 Floral characters

Floral characters such as days to first flower bud emergence, days to first flower opening, number of flowers per plant, flower life in field, flower stalk length and breadth, flower diameter and disc diameter were recorded to analyze the performance of gerbera as a cut flower under different growing conditions.

The floral characters of gerbera varieties showed significant variation among themselves. Only one variety, Balance, flowered under all the three growing conditions. Next to that the variety Goliath flowered in hydroponic culture without media and also in pot culture. All the varieties performed very well under pot culture. In the flowered varieties further floral characters were recorded and analyzed.

The varieties and growing conditions showed significant variation in the duration taken for flower bud emergence. Early flowering was noticed in the varieties Goliath and Balance under pot culture. It may be due to better aeration, higher porosity, higher moisture and fertilizer retention of this medium as well as better vegetative growth of plants in these medium which results in higher accumulation of carbohydrate that ultimately results in early flowering. Late flowering was observed in these varieties, under hydroponic culture without media. The duration from flower bud emergence to opening showed significant variation, both among the varieties and the growing conditions. Considering the interaction between varieties and growing conditions, the variety Dana Ellen took minimum days for flower opening under pot culture whereas the variety Balance took maximum days for flower opening, under hydroponic culture with media.

Number of flowers per plant and life of flowers on plant showed significant variation, both in the varieties and growing conditions. The variety Balance produced the highest number of flowers under pot culture and possessed the longest field life. Balance under hydroponic culture without media showed the least number of flowers per plant. Field life of flower was the lowest in the variety Intense under pot culture. Leffring (1975) has reported that in gerbera, the flower production was influenced by total number of leaves produced per plant and the increase in flower yield may be due to accelerated flower bud development caused by enhanced carbohydrate production, although the lateral shoot formation may have been depressed due to the extended photoperiod (Janne, 1998). From these studies it can be deduced that high light intensity changes the hormonal balance of the shoot tip, which then affects the sink activity of the developing flower. With gerbera it seems that high light intensity and short photoperiod were excellent combination of light factors with respect to number of inflorescence.

The varieties and growing conditions exhibited considerable variation in flower stalk length and girth. Kandpal *et al.* (2003) also reported the variation in stalk length among the genotypes due to the genetic characters of particular genotype. The variety Dana Ellen under pot culture showed lengthy stalk and the variety Balance under hydroponic culture with media showed short stalk. The stalk girth was highest in the varieties, Goliath and Stanza under pot culture condition, but the lowest was in Goliath under hydroponic culture without media. The lowest performance under hydroponic culture may be due to the monotonous nutrient and growing condition. Caballero *et al.* (2009) has reported that, plants at different growth stages required different growing conditions; adequate nutrient accumulation of the plant during the seedling stage is essential for the flowering. Papadopoulos *et al.* (1999) reported that, maximum flower stalk length of 69 cm was attained by using the mixture of perlite and peat in equal volume.

Flower and disc diameter, both among the varieties and growing conditions, showed significant variation following a similar pattern. The flower diameter and disc diameter were highest in the varieties Goliath under pot culture and in Balance under hydroponic culture with media. Nutrient availability is one of the most vital factors influencing flower quality of gerbera in soilless cultivation (Caballero *et al.*, 2007). The flower and disc diameter indicated the total flower size. Naik *et al.* (2006) observed that, the increase in flower size was due to bigger ray florets in the cultivars. Apart from that Aswath and Padmanabha (2004) reported that, electrical conductivity of medium had significant influence on stalk length, stalk thickness and flower diameter of gerbera.

Better performance of varieties for floral characters under pot culture may be due to the positive correlation of water holding capacity, EC, organic carbon and available N, P and K to flower stalk length, girth of flower stalk, flower diameter, weight of cut stem, number of petals per flower, vase life and number of flowers per plant (Panj *et al.*, 2014). The increase in flower yield may be attributed to the greater leaf area index and more number of leaves per plant as well as plant spread, which would have favoured the production and accumulation of maximum photosynthates, resulting in the production of more number of flowers of increased size.

5.3 Post- harvest characters

Postharvest characters are crucial for the acceptance of flowers in the cut flower market. Among the post harvest characters, the fresh weight was highest in the variety Stanza grown under pot culture and lowest in the variety Goliath under hydroponic culture without media. This could be due to the higher temperature available for the plants in pot culture, which is supported by Jia *et al.* (2015), who reported that, the fresh weight of the above ground part increased with the increase of temperature.

The highest physiological loss in weight was observed in Goliath under hydroponic culture without media, whereas lowest physiological loss was recorded in the same variety under pot culture.

The varieties and growing conditions showed a significant variation in the water uptake and vase life of flowers. Considering the water uptake it was highest and lowest in the variety Balance in two different conditions *i.e.,* pot culture and hydroponic culture without media, respectively. The most important cut flower quality parameter, vase life, was longer in the variety Balance and shorter in the variety Intense, under pot culture. The varieties which exhibit longer shelf life and vase life might possess better water uptake capacity and higher accumulation of metabolic sugars (reducing and non- reducing) in the plant as well as in the petal cells (Deka and Talukdar, 2014).The vase life was directly related to dry matter production as well as size of flowers. De Jong (1978) found that, gerbera flowers with strong stalk were maintained the turgor pressure by that vase life also increased.

Differences in cut flower quality characters may be due to inherent characters of the individual cultivars. These findings are also in line with those of Singh and Ramachandran (2002) and Biradur and Khan (1996), who have reported wide difference in quality parameters among gerbera cultivars.

5.3 Nutrient analysis

Macro (N, P, K, Ca, Mg, S) and micro (Cu, Fe, Mn, Zn) nutrient elements were analyzed and recorded to understand the influence of the treatments on varieties and growing conditions.

Gerbera demands high level of nitrogen during the entire growth period and hence considered as a type of nitrophilous plant (Jia *et al.,* 2015). But in the present study, the concentration of nitrogen was neither significantly related to variety or growing condition nor the interaction effect of both these characters. However, the mean nitrogen content in plants was to the tune of above 2 per cent.

The concentration of phosphorus showed significant variation as influenced by the growing condition. The interaction between variety and growing conditions was also significant. Among the growing conditions, pot culture showed better growth and it was significantly superior to other two conditions. The interaction effect between variety and growing condition on the concentration of phosphorus was also significantly higher in the variety Goliath, under pot culture. This was on par to the varieties under same growing condition. Nowak (2001) reported that, phosphorus level in the medium can influence a significant decrease in leaf length and width in African daisy (*Osteospermum* sp.).

The variety Balance under hydroponic culture without media showed poor performance compared to other growing conditions and varieties. The plant height increased with increase in nutrition up to certain level. This result is in line with the finding of Scagel *et al.* (2007). Lowering the levels of macronutrients lengthened the duration and lowered the production. These nutrients improve the growth and development of gerbera by providing essential macronutrients (*i.e.*, NPK). The results are in conformity with those of Baumgrarat (1997), Roy *et al.* (1995) that gerbera require balance nutrition at early stages of growth. Khosa *et al.* (2011) reported that, balanced concentration of macronutrients significantly increases the number of branches per plant. Therefore macronutrients improve growth and flowering production of gerbera. High dose of macronutrients (NPK) resulted in maximum number of leaves which is in confirmed by the finding of Javaid *et al.* (2005), Qasim *et al.* (2003) and Gohar *et al.* (2007). Application of macronutrient solution decreases the number of days for flower emergence, increases the flower diameter and flower quality (Bhallaeharyee, 1985; Poole and Greave, 1989; Ahmad *et al.*, 2007; Khosa *et al.*, 2011).

The concentration of potassium as influenced by varieties and growing conditions varied significantly. The variety Balance showed highest potassium concentration and it was significantly superior to the variety Dana Ellen. Considering the growing condition the trend of all the above characters slowly changed from here onwards, *i.e.,* hydroponic culture with media showed significantly higher concentration of potassium to pot culture. Influence of interaction effect was also showed significant variation. The variety Balance in hydroponic culture without media showed highest concentration of potassium and the variety Goliath under pot culture showed the lowest potassium concentration. Phosphorus and potassium played an important role in the metabolism of the plant (Khosa *et al.,* 2011), and low concentration of these two elements might cause the weakness of the plant in low temperature.

The Ca and Mg levels showed significant variation only with respect to growing condition. The level of Ca was the highest in pot culture and the lowest in hydroponic culture with media. These results are in conformity with those of Frett *et al.* (1995), who have reported the highest branch length by the use of macro nutrient in combination with calcium. But in case of Mg, the trend was just the opposite.

The concentration of sulphur recorded significant variation on variety, growing condition and its interaction also. The variety Balance recorded the highest concentration of sulphur, which was significantly superior to the variety Dana Ellen. Among the growing conditions, hydroponic culture with media showed significantly higher concentrations than pot culture. The interaction effect of the variety and growing condition on sulphur concentration varied significantly. The highest concentration was observed in the variety Balance under hydroponic culture with media and lowest concentration in the variety Stanza under pot culture.

Considering the micronutrient concentration and its effect on varieties and growing conditions, hydroponic culture without media showed significantly higher concentration of micronutrients than the pot culture plants. In the case of varieties, only the Cu and Mn showed the influential variation, *i.e.,* significantly higher concentration in the variety Balance. As to the interaction effect, the variety Dana Ellen under hydroponic culture without media showed highest concentration of Cu, Fe and Mn, and, in pot culture, the highest concentration was in the variety Stanza.

The observations agreed well with the findings of Sawan *et al.* (2001) in cotton and El-Naggar (2009) in carnation, where they used the balanced fertilizer levels to improve the flower quality. Giuffrida *et al.* (2002), on the other hand, reported that the yield was negatively affected by cultivating plants under the closed systems, the reduction in the yield level being around 15 per cent.

For a hydroponic culture nutrient solution is the major part. Whatever nutrients are supplied, the absorption capacity of plants may differ and it may influence the performance also. Nutrient availability is one of the most important factors influencing flower quality of gerbera in soilless cultivation (Caballero *et al.,* 2007), which is affected by the temperature variation (Su *et al.,* 2001). The nutrient absorption capacity is influenced by concentration of nutrients, inter relation of supplied nutrients, growing conditions, weather, technical side of the hydroponic system and varietal characteristics also. But this procedure improves nutrient utilization and lower environmental pollution through reducing the amount of fertilizers added to soil (Bashir *et al.,* 2013). It is also noteworthy that in case of sulphur and micronutrient, solution culture assured steady and sufficient supply when compared to those with growing media; probably because of avoiding adverse nutrient interaction in soil restricting the availability.

Based on the foregoing discussion, it was observed that gerbera varieties vary in response to the growing conditions. In overall comparison between gerbera varieties and growing conditions with regard to vegetative characters, plants in pot culture were found to be more vigorous in terms of plant height, spread, number of lobes, leaf characters, *viz.,* length, breadth, leaf area and petiole length. The variety

Balance in hydroponics with and without media was comparable with that of pot culture and it was the only variety that flowered under all the growing conditions. Thus, further investigations are necessary to evaluate more varieties for commercial exploitation under Kerala condition. The scope of indoor vertical gardening based on hydroponics using pollution tolerant plants like *Chlorophytum, Syngonium, Philodendron etc.* may be exploited to provide cleaner air to improve living environment.

Summary

6. SUMMARY

Evaluation of the performance of gerbera cultivars under hydroponics was conducted at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during 2015- 2016. The main objective was to assess the suitability of gerbera cultivars to hydroponics culture and to compare the growth, yield and vase life under hydroponics and greenhouse culture.

The varieties exhibited wide variation in both vegetative and floral characters. The salient findings of the study are summarized here.

- Maximum plant height was recorded in gerbera variety Intense (16.94 cm), followed by Stanza (15.25 cm) while it was minimum in Balance (14.36 cm).
- When growing conditions were compared, not much difference was noticed with respect to plant height.
- The interaction between variety and growing conditions was evident in plant height of gerbera varieties. The gerbera variety Goliath in pot culture had maximum plant height (17.73 cm), followed by Stanza, Dana Ellen and Intense. The variety Balance recorded the minimum height (8.87 cm) in hydroponics with media culture.
- Appreciable differences were observed with regard to plant spread among varieties. Maximum plant spread was observed in variety Balance (596.73 cm^2) and the minimum (358.15 cm^2) in Intense.
- Among the growing conditions, plants in pot culture recorded maximum plant spread (924.32 cm^2) and were distinctly superior to others, whereas minimum plant spread (381.54 cm^2) was in hydroponics culture without media.
- Variability among varieties could be noted in the number of leaves. Maximum number of leaves was observed in Stanza (10.40) and the lowest (5.49) in Intense.
- When growing conditions were compared, highest leaf number (9.80) was in pot culture and minimum (5.56) in hydroponic culture with media.

- The combination effect of variety and growing conditions was significant with regard to leaf number. The variety Stanza recorded maximum leaf number (16.07) in pot culture and minimum was recorded by Intense (4.93) in hydroponic culture without media.
- The gerbera varieties exhibited wide variation in leaf length, breadth and area. Among the varieties, Balance recorded highest leaf length, breadth and area (16.24 cm, 7.28 cm, 54.95 cm^2, respectively) and Stanza the minimum (11.74 cm, 5.91 cm and 34.10 cm^2, respectively).
- The growing conditions were also found to have influence on leaf characters, *viz.,* length, breadth and leaf area, for which plants in pot culture recorded the maximum.
- Interaction effect of variety and growing conditions on leaf characters was clearly evident. It was maximum in the variety Goliath in pot culture, whereas Intense recorded the minimum in hydroponic culture without media.
- Variability among varieties could be noticed in petiole length and number of lobes in the leaves. Maximum petiole length was observed in the variety Intense (9.44 cm) and number of lobes in Goliath (6.80 cm) whereas petiole length was minimum in Goliath (7.67 cm) and number of lobes was minimum in Intense (3.37 cm).
- The growing conditions were also found to have influence on petiole length of gerbera wherein pot culture recorded the maximum petiole length (10.03 cm) and minimum (7.44 cm) was in hydroponic culture with media.
- Not much difference was noticed in the number of lobes in the leaf under different growing conditions.
- In overall comparison between gerbera varieties and growing conditions with regard to vegetative characters, plants in pot culture were found to be more vigorous in terms of plant height and spread, number of lobes in leaves, leaf length, breadth, leaf area and petiole length.

- Significant negative and positive correlation was found between microclimatic weather parameters (relative humidity and light intensity, respectively) and vegetative characters (plant spread, leaf length, leaf area and number of lobes).
- Significant negative correlation was obtained between light intensity and vegetative characters, namely, leaf breadth and petiole length.
- Gerbera varieties differed in the time taken for first flower bud emergence and opening of first flower under different growing conditions. Balance was the only variety that flowered under all the three growing conditions. It took (125.0) days for emergence of flower bud in hydroponic culture without media.
- Among the gerbera varieties in pot culture, Goliath recorded minimum days (121.0) to first flower bud emergence and Dana Ellen the maximum (131.0 days).
- There was considerable variation in the flower stalk length and girth among the varieties. Flower stalk length was maximum (61.30 cm) in the variety Dana Ellen and girth (1.90 cm) in Goliath and Stanza in pot culture.
- Flower stalk characters of gerbera, *viz.,* length and girth were considerably less in plants grown in hydroponic culture with and without media.
- Significant variation was not observed in the flower diameter among varieties. It varied from 8.70 cm (Stanza) to 10.10 cm (Goliath) in pot culture and Balance had the maximum flower diameter (10.00 cm) in hydroponic culture with media.
- The flower disc diameter also followed the same trend.
- Distinguishable differences were noticed with respect to the longevity of flower on the plant. The variety Balance recorded the maximum longevity (16.5 days) in pot culture, whereas it was 13.9 days and 15.4 days in hydroponic culture with and without media, respectively.

- Maximum number of flowers (16.8) was produced by the variety Balance in pot culture, followed by Goliath (15.8).
- In hydroponic culture with and without media, Balance produced 6.3 and 4.0 flowers, respectively, per plant.
- With respect to the post harvest characters studied, the variety Balance recorded the maximum (9.30 days) spike longevity (vase life) whereas variety Intense recorded the minimum (4.50 days).
- Varietal differences were not significant with respect to the concentration of macronutrients like N, P, Ca and Mg whereas K and S differed. The concentration of K was the highest in Balance (2.44 %) and the lowest in Dana Ellen (1.69 %). The concentration of S was the highest in Balance (1.37 %) and was on par with that of Goliath (1.15 %) and the lowest was in Dana Ellen (0.74 %).
- Influence of growing condition on the concentration of the nutrients P, K, Ca, Mg and S was significant. But in the case of N the difference was not distinct. Among the growing conditions, hydroponic culture with media was significantly superior to other growing conditions with respect to the concentration of K, Mg and S, whereas pot culture significantly enhanced the P and Ca concentration in gerbera.
- Interaction effect varieties and growing conditions with respect to the concentration of the nutrients, P, K and S was significant. The concentration of P was highest in the variety Goliath (0.44 %) in pot culture and lowest in Goliath in hydroponic culture, with and without media. The variety Balance recorded highest K concentration (3.49 %) in the hydroponic culture without media and the varieties Dana Ellen and Goliath recorded the lowest (0.63 %) in pot culture. Hydroponics with media was the better growing condition for Balance for S concentration (2.15 %) and was significantly superior to other treatments.

- Among the micronutrients, Cu and Mn concentration of gerbera varieties varied considerably. Variety Dana Ellen had the highest Cu and Mn concentration (54.55 and 128.72 mg l^{-1}, respectively). With regard to Cu concentration, Goliath recorded the lowest value (27.11 mg l^{-1}). The variety Intense recorded the least (73.48 mg l^{-1}) Mn concentration.
- Growing conditions were also found to have influence on the concentrations of Cu, Fe, Mn and Zn. The concentration of these micronutrients were the highest (59.37, 263.89, 163.19 and 32.34 mg l^{-1}, respectively) in gerbera grown in hydroponic culture without media.
- Interaction between variety and growing condition was evident in gerbera varieties with respect to the concentration of Cu, Fe and Mn. Hydroponic culture without media was the better growing condition for the variety Dana Ellen for Cu, Fe and Mn concentrations (95.13, 324.14 and 270.24 mg l^{-1}, respectively).

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* Original not seen

Appendices

Appendix I. Monthly distribution of weather parameters during the experiment August 2015 – May 2016

Parameters	AUG '15	SEP '15	OCT '15	NOV '15	DEC '15	JAN '16	FEB '16	MAR '16	APR '16	MAY '16
Mean maximum temperature (^{0}C)	31.0	31.9	32.5	31.6	32.3	33.2	35.3	36.3	35.8	34.0
Mean minimum temperature (^{0} C)	23.7	23.7	24.1	23.8	23.3	23.0	23.5	25.2	26.2	24.2
Mean relative humidity (%)	83.0	81.0	79.0	75.0	65.0	56.0	57.0	67.0	69.0	78.0
Rainfall	320.8	242.2	203.8	151.2	88.3	23.8	11.4	9.8	258.0	270.7
Mean light intensity (Lux)	75277.4	78696.7	85077.4	92033.3	93043.4	86803.0	89593.1	87577.4	87620.0	87850.7

Appendix II. Monthly distribution of weather parameters inside greenhouse

Parameters	AUG '15	SEP '15	OCT '15	NOV '15	DEC '15	JAN '16	FEB '16	MAR '16	APR '16	MAY '16
Mean maximum temperature (^{0}C)	30.0	30.0	32.0	31.0	32.0	33.0	32.0	33.0	32.0	33.0
Mean Minimum Temperature (^{0} C)	22.0	21.0	24.0	23.0	22.0	22.0	22.0	24.0	25.0	23.0
Mean relative humidity (%)	86.0	83.0	81.0	79.0	69.0	59.0	60.0	70.0	72.0	80.0
Mean light intensity (Lux)	16471.3	16952.2	18036.8	23513.0	23792.5	19714.7	21628.6	20073.5	20951.7	21048.9

PERFORMANCE OF GERBERA (*Gerbera jamesonii* Bolus) CULTIVARS UNDER HYDROPONICS

by

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ABSTRACT OF THE THESIS

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ABSTRACT

Performance of gerbera cultivars under hydroponics was evaluated at the Department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Vellanikkara during 2015-2016. The main objective was to assess the suitability of gerbera cultivars to hydroponic culture and to compare the growth, yield and vase life under hydroponics and pot culture.

Five gerbera varieties, *viz.,* Dana Ellen, Goliath, Stanza, Intense and Balance were evaluated under three conditions; hydroponics with media, hydroponics without media and pot culture, under greenhouse. Observations were recorded on vegetative, floral and postharvest characters. Macro and micro nutrients of the plant samples were evaluated after the trial.

The varieties exhibited wide variation in both vegetative and floral characters. The plant growth in terms of height and spread was found to be greatly influenced by the variety and the plants of variety Intense were the tallest with more spread at flowering. The growth in terms of plant spread was the least when grown in hydroponic culture without media whereas it was the highest in pot culture. When interaction effect was considered plant spread of the variety Balance in hydroponics was comparable with that of plants in pot culture.

The gerbera varieties exhibited wide variation in leaf characters. The Balance recorded highest leaf length, breadth and area (16.24 cm, 7.28 cm, 54.95 cm^2, respectively) and Stanza the minimum (11.74 cm, 5.91 cm and 34.10 cm^2, respectively). Leaf number was maximum in the variety Stanza (10.40) and petiole length (9.44 cm) in Intense. The growing conditions were also found to have influence on leaf characters, and plants in pot culture recorded the maximum values.

Significant positive correlation was observed between light intensity and vegetative characters namely, plant spread, leaf length, leaf area and number of lobes and negative correlation between leaf breadth and petiole length.

Gerbera varieties differed in the duration taken for flowering under different growing conditions. Balance was the only variety that flowered under all the three growing conditions.

There was considerable variation in the flower characters, *viz.*, stalk length and girth among the varieties. The highest value for flower stalk length (61.30 cm) was in the variety Dana Ellen and for girth (1.90 cm) Goliath and Stanza in pot culture. These two stalk characters were considerably less in plants grown in hydroponic culture with and without media. Significant variation was not observed in the flower and disc diameter among the varieties under different conditions.

Maximum number of flowers (17.6) was produced by the variety Balance in pot culture, followed by Goliath (16.8). The variety Balance produced 6.3 and 4.0, flowers, respectively per plant in hydroponic culture with and without media.

Varietal differences were not significant with respect to the concentration of macronutrients like N, P, Ca and Mg in the plant, whereas K and S differed. The concentration of K and S was the highest in Balance (2.44 %, 1.37 %, respectively) and the lowest in Dana Ellen (1.69 % and 0.74 %, respectively). Among the growing conditions, hydroponic culture with media was significantly superior to others, with respect to the concentration of K, Mg and S, whereas pot culture significantly enhanced the P and Ca concentration. The variety Balance recorded highest K concentration (3.49 %) the hydroponic culture without media.

Variety Dana Ellen had the highest Cu and Mn concentrations (54.55 and 128.72 mg l^{-1}, respectively). The concentration of Cu, Fe, Zn and Mn were the highest (59.37, 263.89, 163.19 and 32.34 mg l^{-1}, respectively) in plants grown in hydroponic culture without media.

In overall comparison between gerbera varieties and growing conditions with regard to vegetative characters, plants in pot culture were found to be more vigorous in terms of plant height, spread, number of lobes, leaf characters, *viz.*, length, breadth, leaf area and petiole length. The variety Balance in hydroponics with and without media was comparable with that of pot culture and it was the only variety that flowered under all the growing conditions.