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Irrigation Management of Greenhouse Marigold Using Tensiometer: Effects on Yield and Water Use Efficiency

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Authors' contributions

This work was carried out in collaboration between the authors. Author ES designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author KS managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Greenhouse is an important structure to minimize biotic and abiotic stress on crops, which could be grown round the year, during off-season and also under extreme conditions and high rainfall areas. It provides a controlled environment inherently free from pests and disease problems that increases the production and productivity per unit area as compared to open field conditions. Irrigation is a crucial practice, but the farmer irrigates relying on their own experience. One of the possible approaches for proper irrigation scheduling is measuring the soil water potential, simple and easy to manage. A study was conducted to draw the characteristics curve and to examine the effect of irrigation schedule based on the use of characteristics curve on yield and water consumption of greenhouse marigold compared with open field grown on sandy loam soil. Drip irrigation was adopted, with tensiometer based irrigation scheduling. The experimental results showed that the marigold performed well under greenhouse with yield of 20.4 t ha^{-1} and water use efficiency was 108.6 kg $ha^{-1}mm^{-1}$ as compared to field experiment.

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1. INTRODUCTION

Protected cultivation is one of the most promising areas of agriculture in the current context. It is an upcoming alternative production system involving high-tech intensive practices to meet the export demands of horticultural and ornamental crops for food, nutrition and economic security. It control atmospheric condition, pest & disease and enables year around production. Tamil Nadu rank first among flower production & occupies about 0.32 lakh ha is covered by floral crops, among which marigold cover 6733 ha with an approximate production of 100995 tonnes with a productivity of 15 t/ha. Marigold is grown as an ornamental crop for its flowers, which are sold in the market as loose flowers in bulk, as specialty cut flowers, or for making garlands. It is also one of the most important natural sources of xanthophylls for use as natural food additive to brighten egg yolks and poultry skin [1]. Moreover, it is also being used effectively to dye fabrics commercially, where its ethanol-based flower extracts produce different colours on fabrics [2]. Demand of marigold as cut flower or as a extracted products is high in many countries (Spain, Mexico, UK, United States, Italy, South Korea, Taiwan, Japan). Hence, Exporting of marigold will increase the economic level. Though the marigold is well grown under open field condition, only the protection environment can enables the off season (year around) production and increases in yield & xanthophyll content.

Water is becoming an economic scarce resource in many areas of the world, especially in arid and semi-arid regions. Agriculture is the largest consumer of global freshwater, accounting for around 70% of withdrawals as irrigation [3]. Increasing the efficiency of water use within agriculture systems is important in order to secure water for agricultural production. Potential water saving strategies has been estimated that, better irrigation scheduling and use of drip irrigation in row crops may save 20% of the water consumption [4].

Proper irrigation scheduling results in increasing water use efficiency (WUE). WUE relates to how much yield is obtained per unit of applied water. Scheduling water application is very critical, as excessive or inadequate irrigations reduce yield, while inadequate irrigation also causes water stress. Several irrigation management systems, although largely investigated and adopted at experimental level, are expensive and difficult to transfer at farm level. It is the case of the approach based on measuring plant water status.

As a more feasible approach, irrigation decision can be based on measurements of soil water status. Soil water status can be referred to soil water content or soil matric potential. This approach is more feasible for application at farm level. Soil water content sensors measure the amount of water in the soil, while matric potential sensors give a measurement of how easy it is for the plants to extract available water from the soil. Measurements of soil water potential in the field are generally performed by tensiometers for relatively low soil water tension or wet range. Tensiometers are rapid, cheap and easy devices for monitoring the water status of soil and useful for irrigation scheduling [5]. Under high frequency drip irrigation, it is possible to maintain a small wetted soil zone sufficient for crop water uptake, while keeping a much larger zone dry [6].

Very limited information is available in India on cultivation of marigold in soil media with drip irrigation under controlled cultivation. Therefore, an attempt has been made in present study was to evaluate the use of the tensiometer to rationalize the supply of irrigation water in the cultivation of marigold in greenhouse in comparison with open field with drip irrigation system, by defining proper water potential to improve yield and WUE.

2. METHODOLOGY

The research was carried out in Agricultural Engineering College and Research Institute, Kumulur, Trichy, which is located at the latitude of 10.7904833 and longitude of 78.7046725.

Soil from the experimental plot was sieved through 2 mm diameter sieve. This sieved soil was used for finding soil texture by international pipette method, Field capacity & Wilting point by pressure plate apparatus method, Soil moisture content by gravimetric method and other physical characteristics such as bulk density, particle density, porosity & water holding capacity by Keen Rackzowski box, soil moisture tension by using tensiometer. Climatic parameter such as temperature, RH & light intensity were measured using the digital hygrometer and lux meter respectively.

Marigold (Maxima Yellow F1) were selected and planted on 10th December 2016 in single row with row to row and plant to plant spacing of 60 cm x 45 cm. The recommended dose of fertilizer 90:90:75 N: P: K kg/ha was applied throughout the cropping period [7]. Total crop duration is 100 days after transplanting. Greenhouse size were 12 meter length X 6 meter width, same size were taken outside greenhouse.

2.1 Calibration of Tensiometer

The tensiometer filled with distilled water and tapped continuously until the air bubbles removed from the tensiometer. Tensiometer was inserted in soil up to the depth of effective root zone, where moisture is to be measured. Tension was noted from the vacuum gauge, attached with the tensiometer. Irrigation was applied till tension reaches ‘0’ atmosphere. Daily the moisture content of the soil was measured by using gravimetric method and respective tension was noted. This process was continued until it reached the permanent wilting point.

Calibration curve was drawn with observed tensiometer reading on X axis and available soil moisture content on Y axis. Tension measurements were useful in deciding when to irrigate. Marigold seedlings were transplanted at the saturation level. Maximum root zone depth of the marigold crop was measured previously for the initial, mid and final growth stage i.e, 10 cm in the end of the initial stage and 13.5 cm in the end of the mid stage after the mid stage there is no root depth development. Tensiometer was inserted in soil up to the corresponding stage rootzone depth and the tension was recorded on daily basis and respective soil moisture content was noted from (Fig. 1). When the soil moisture content reaches 50% of allowable soil moisture depletion (ASMD), the depleted amount of moisture was scheduled as irrigation.

$$Depth\ of water\ depleted, cm = \frac{MC_i - MC_{\ 50\%\ ASDM}}{100}\ x\ D\ x\ As$$

Example calculation for depth of water to be irrigated for respective stage (initial stage)

$$d = \frac{(23.6 - 16.8)\ x\ 1.42\ X\ 10}{100}\ x\ 0.5 = 0.97\ cm = 9.7\ mm$$

MC_i = Initial moisture content after irrigation

$MC_{\ 50\%\ ASMD}$= Moisture content at 50% of allowable soil moisture depletion
D = Depth of root zone (varies with stage)
As = Apparent specific gravity

2.2 Water Use Efficiency (WUE)

Water use efficiency was calculated as the ratio of yield of the crop in kg ha^{-1} and total depth of water utilized in mm

$$WUE = \frac{Y}{D}$$

WUE = Water use efficiency, kg ha^{-1}mm^{-1}
Y = Yield of the crop, kg ha^{-1}
D = Total depth of water utilized, mm

3. RESULTS AND DISCUSSION

Soil texture is a reflection of the particle size distribution of a soil. The textural analysis of the experimental plot as per the triangular diagram showed sandy loam (sand 72.8%, silt 16.1%, clay 10.2%). Analysis of bulk density, particle density, porosity and maximum water holding capacity, field capacity and wilting point of the experimental site is presented in Table 1.

The soil moisture characteristics curve is of great value in precision farming, because it provides a simple means to determine adequate moisture contents required for soil for good plant growth. Hence a study was undertaken to determine the influence of growing media physical properties on characteristics curves and water holding capacity. Available water was held in soil pores by forces that depend on the size of the pore and the surface tension of water. The closely bound particles have the smaller pores and it has stronger attraction between soil and water, thus results in higher water holding capacity of the soil. The maximum water holding capacity of the soil was estimated as 33%.

The atmospheric air temperature, relative humidity and light intensity were measured inside greenhouse (IGH) and outside greenhouse (OGH) tabulated in the table 2. When compared to outside the greenhouse the temperature and relative humidity was highest and light intensity was lowest inside the greenhouse.

[8] reported that an increases in temperature of 1°C promoted yield on an average 4%. The optimum light intensity resulting in high

photosynthetic activity than at a high light intensity [9]. Also, optimum light intensity might have led to optimum stomatal functioning as already reported [10].

3.1 Soil Moisture Characterstics Curve

Soil moisture characterstics curve between available soil moisture content Vs soil moisture tension were drawn for the soil.

Marigold (maxima yellow F1) was grown in the experimental plot during 10 December 2016 to 19 March 2017 at AEC&RI, Kumulur, Trichy. Inside the greenhouse, irrigation was the only source of moisture to the plant. But outside the greenhouse along with irrigation, rainfall was additional source. Outside the greenhouse the effective rainfall was calculated and taken as input. 80.9 mm of rainfall was calculated as effective rainfall from the total rainfall of 100.5 mm occurred during the crop season.

Depth of water application was calculated from the eq. 1 by using the results of physical properties analysis shows 9.7 mm. Soil moisture tension was recorded daily and the respective ASMC were noted from the characteristics curve, when the available soil moisture content reaches 16.8% (50% ASMD) the calculated depth of water were applied as irrigation throughout the cropping period. Depth of water depleted (may be due to crop water uptake or evapotranspiration or depercolation) throughout the crop cycle was recorded through the soil moisture characteristic curve both inside greenhouse and outside greenhouse shown in Figs. 2 & 3. Depth of water depletion was highest in the mid stage (15 to 60 DAT) and lowest in the final stage (60 to 100 DAT) followed by initial stages (1 to 15 DAT) both IGH & OGH.

The research concludes that inside and outside the greenhouse 187.6 mm and 207.1 mm of water were applied as irrigation throughout the cropping period. Additionally the calculated effective rainfall was taken as a crop water use. So totally depth of water utilized was 35% higher when compared with inside the greenhouse.

Biometric observation such as plant height, stem girth, number of branches and plant spread, maximum & minimum number of flower per plant, flower diameter and flower yield per plant & average flower yield per plant were measured and flower yield per hectare was estimated both inside and outside the greenhouse (Figs. 4, 5, 6 & 7).

Figs. 4, 5, 6 & 7 shows the plant height, stem girth and number of branches where highest inside the greenhouse respectively 39.2 cm, 2.2 cm and 22.3 nos. Plant spread was highest in the 60^{th} day 33.5 cm & when plant get matured the plant spread get reduced.

Fig. 8 shows the maximum and minimum number of flower per plant, flower diameter and flower yield per plant were highest inside greenhouse and recorded in the day of 46^{th}, 51^{th}, 56^{th}, 61^{th}, 66^{th}, 71^{th}, 76^{th}, 81^{th}, 86^{th}, 91^{th}, 96^{th} and 100^{th}. First flower bud appears inside the greenhouse in 31^{st} days after transplanting, 38 days were taken to flower bud opening. Flower picking was done after 5 days of bud opens. Totally 12 picking were done inside greenhouse but 10 in case of outside the greenhouse. Maximum & minimum flower yield per plant both IGH and OGH was 0.095 & 0.02 and 0.087 & 0.021 kg respectively. When compared to outside greenhouse, all biometric parameters where recorded highest inside the greenhouse.

Plate 1. Greenhouse

Plate 2. Inside greenhouse during flowering stage

Plate 3. Outside greenhouse during flowering stage

Table 1. Physical properties of the experimental plot

Bulk density, g/cc	Particle density, g/cc	Porosity, %	Maximum water holding capacity, %	Field capacity, % @ 0.33 atm	Wilting point, % @ 15 atm	Available water, %
1.42	2.6	53	33	23.6	10	13.6

Table 2. Climatic parameter of the experimental plot

Experimental plot	Maximum temperature, °C	Minimum temperature, °C	Maximum relative humidity,%	Minimum relative humidity,%	Maximum Light intensity, Lux	Minimum Light intensity, Lux
IGH	40.7	17.4	96	12.5	48100	1100
OGH	37.2	12.5	86.2	10.5	83600	3100

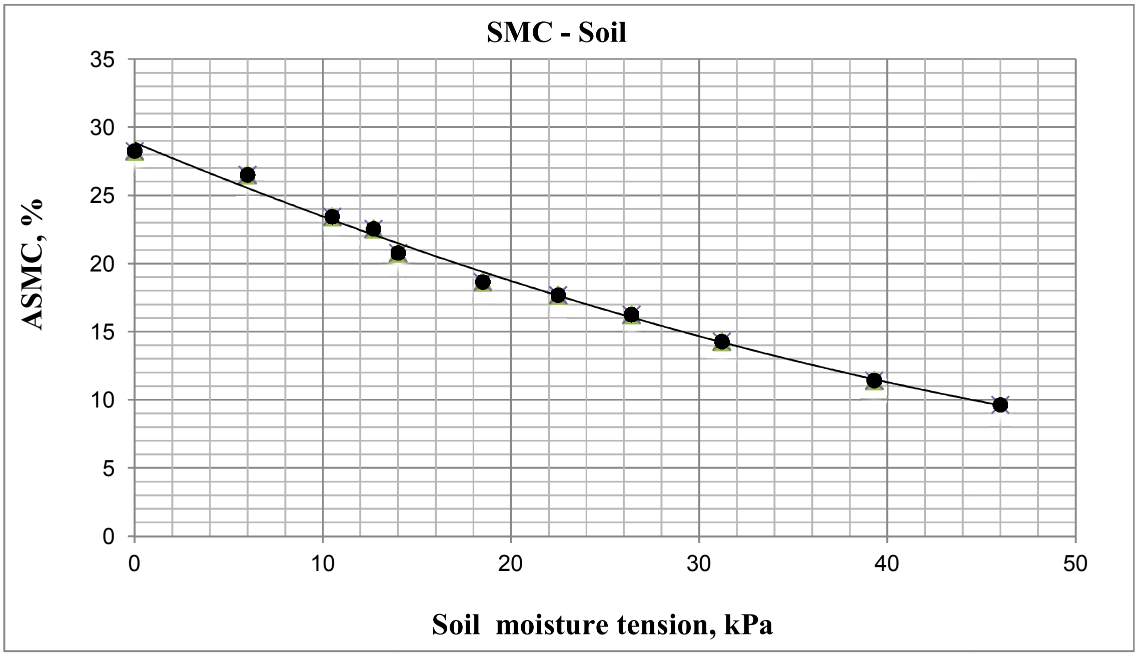

Fig. 1. Soil moisture charateristics curve (SMC) for Soil
ASMC - Available soil moisture content

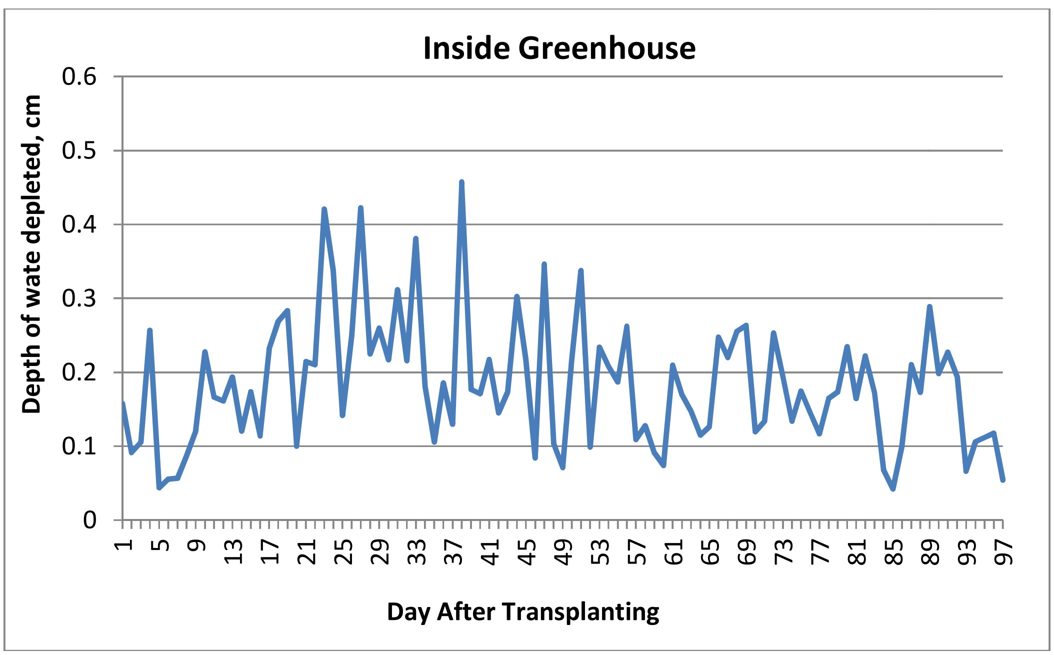

Fig. 2. Depth of water depleted inside greenhouse

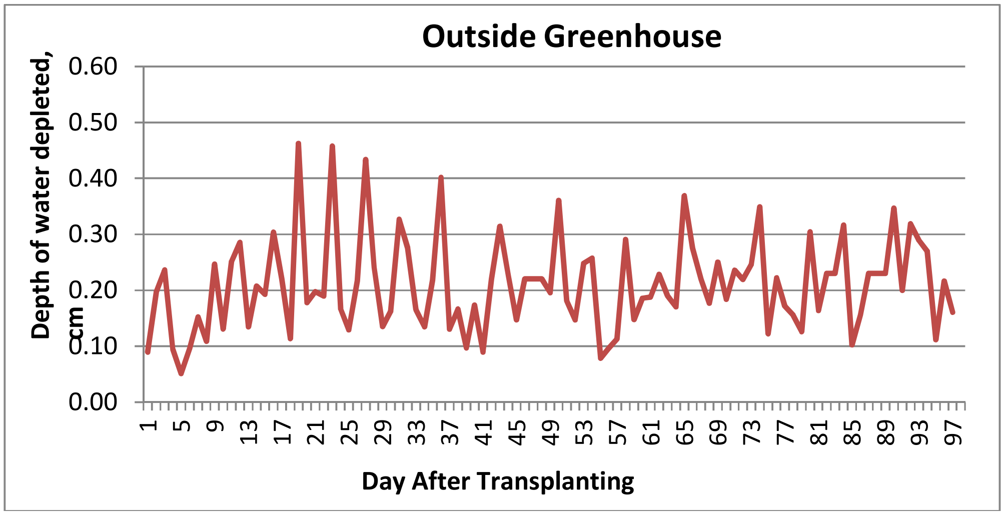

Fig. 3. Depth of water depleted outside greenhouse

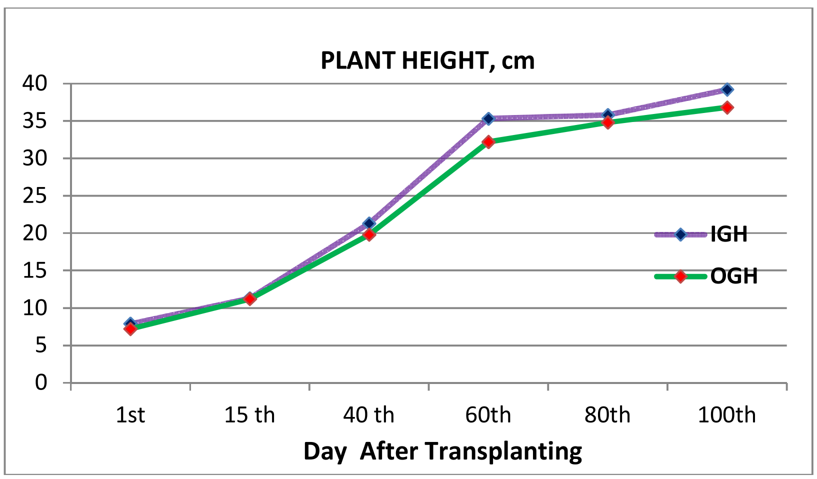

Fig. 4. Plant Height both IGH and OGH

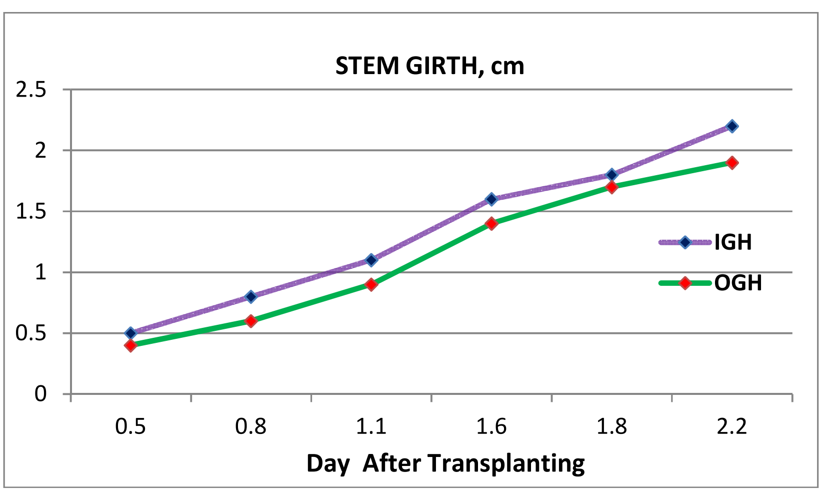

Fig. 5. Stem girth both IGH and OGH

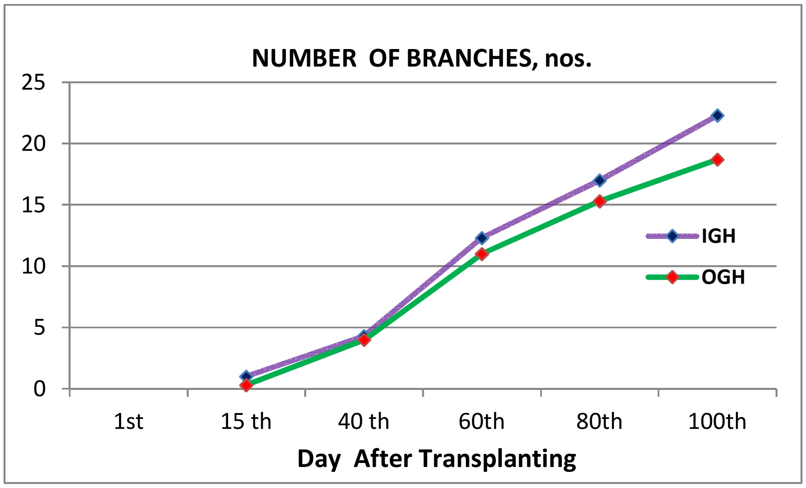

Fig. 6. Number of branches both IGH and OGH

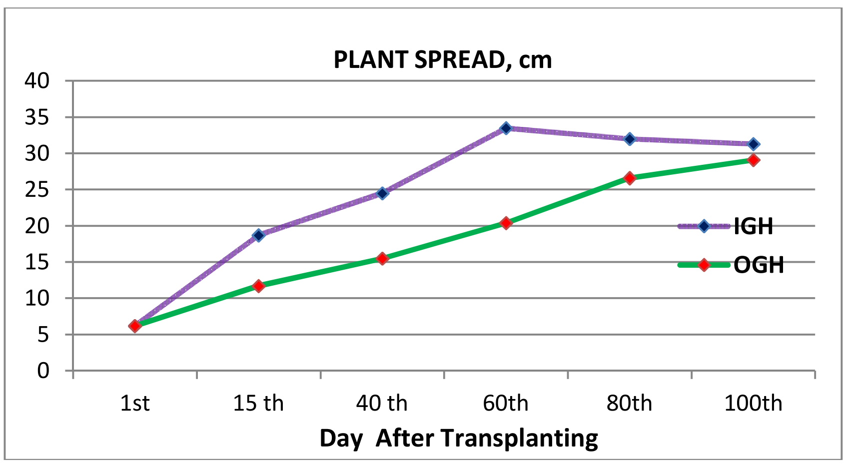

Fig. 7. Plant spread both IGH and OGH

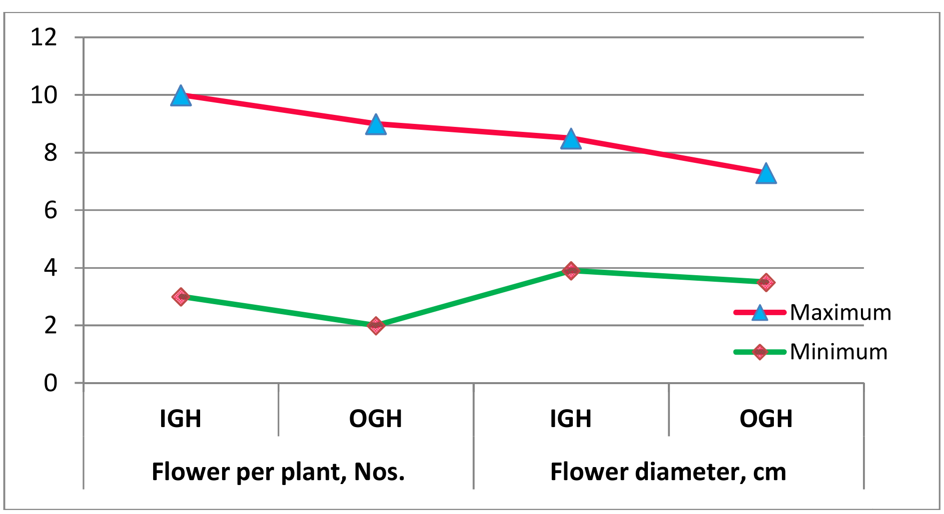

Fig. 8. Flower parameter both IGH and OGH

It was recorded that mean flower yield per plant is 0.55 kg for inside greenhouse and 0.433 kg in case of outside greenhouse. Similarly the flower yield/ha was 20.4 tons for IGH and 17.14 tones for OGH. Water use efficiency was calculated inside and outside the greenhouse as the ratio of yield of the crop in kg ha^{-1} and total depth of water utilized in mm. The highest water use efficiency was recorded as 108.6 kg $ha^{-1}mm^{-1}$ for inside greenhouse compared to outside greenhouse with 59.5 kg $ha^{-1}mm^{-1}$.

4. CONCLUSION

For growing marigold, greenhouse farming system performed better than the open farming system in terms of crop yield and water use efficiency. Irrigation was applied with 50% available soil moisture depletion both inside and outside the greenhouse by using tensiometer. It was observed that biometric parameter were maximum in the greenhouse. It was recorded that mean flower yield per plant is 0.55 kg for inside greenhouse and 0.433 kg in case of outside greenhouse. Similarly the flower yield/ha was 20.4 tons for IGH and 17.1 tones for OGH. Yield was 16% higher compared to outside greenhouse and depth of water utilized was 34% less compared with outside greenhouse.

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COMPETING INTERESTS

Authors have declared that no competing interests exist

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