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Effect of Different Moisture Regimes on the Yield, Quality and Water Use Efficiency of Chrysanthemum var. Marigold

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A B S T R A C T

The performance and water use efficiency (WUE) of Chrysanthemum var. Marigold was evaluated under two moisture regimes, *i.e.*, 100 % FC and 70 % FC imposed and maintained using gravimetric method. At 100 % FC, the plant height (30.33 cm), average plant spread (38.21 cm), number of primary branches/plant (5.67) and secondary branches/plant (4.67), number of leaves/plant (71.67), number of flowers/plant (136.75), average weight of individual flowers (7.21g), RWC (94.29%), root: shoot ratio (0.42), total fresh bio mass (153.09 g), flower yield (881.67 g / plant) and shelf life of 7.58 days were significantly higher compared to plants grown under 70% FC. The gas exchange characteristics *i.e.* photosynthetic rate, stomatal conductance and transpiration rate were also significantly higher in plants grown at 100 % field capacity compared to 70 % field capacity treatment. However, the water use efficiency (WUE) of chrysanthemum was higher at 70% FC (39.82 g/litter) compared to 100 % FC (22.38 g/litter). The results of the study showed that, the plants maintained under 100 % FC produced a greater number of flowers with enhanced shelf life compared to plants grown under 70 % FC. Hence it is suggesting that Chrysanthemum var. Marigold performed better in higher moisture regime than 70 % FC level.

Introduction

Chrysanthemum (*Dendranthema grandiflora* Tzvelev.) belonging to the family Asteraceae is cultivated for its attractive coloured flowers (Koley and Sarkar, 2013). It is one of the most important commercial flower crops grown in different parts of the world for loose flowers, cut flowers and as potted plant. Among the factors that influence production, proper management of water is a fundamental requirement for cultivation of flowers. Photosynthesis, biomass production and dry matter play a vital role on the visual quality of ornamental plants. One of the most important factors that affects this in plants is water potential (Jones and Tardieu 1998; Peri *et al.*, 2003). Therefore, optimizing water management is an important step to determine the effects of water on the growth period of ornamental plants as well as their visual quality (Carvalho *et al.*, 2005; Lin *et al.*, 2011). Hence, it is obligatory to consider different factors such as soil, plant and water resource in order to irrigate larger areas with the current water resources and to prevent possible efficiency and quality losses. In addition, the amount of plant water consumption under either sufficient or deficient water conditions throughout the growing period of plants need to be understood in order to assess the water-yield relationships. Efficient use of limited water resources and enhanced growth under limited water supply are desirable traits for crops in drought conditions (Jaleel *et al.,* 2008) and also there is a need to sustain production and quality of flowers under water limiting situations. The efficiency for producing dry matter per unit of applied water, and the ability to allocate an increased proportion of the biomass into economic parts are important factors.

Water use efficiency (WUE) is the ability of the crop to produce biomass per unit of water transpired, and harvest index is the fraction of total dry matter harvested as yield. Studies evaluating a plant's response to water are often performed under greenhouse or controlled environmental conditions, with the plants growing in pots to maintain them at certain water stress level through gravimetric method for a limited time or throughout the growing period (Chandi *et al.*, 2013; Chauhan 2013; Chauhan and Johnson 2010; Earl 2003; Sarangi *et al.,* 2015). The widely used direct method is the gravimetric method or thermostat-weight technique for quantification of WUE (Schmugge *et al.*, 1980) and is accurate and inexpensive (Dobriyal *et al.*, 2012). A gravimetrical determination of water consumption provides the exact amount of irrigation water to be applied to the plants (Andersson, 2001).

The majority of the investigations on chrysanthemum are in the level of field evaluation (Jawaharlal *et al.*, 2017; Arif *et al.*, 2015; Janakiram *et al.*, 2006; Sohier *et al.*, 2008 and Ngouajio *et al.*, 2007) and their studies are mainly concentrated on effect different irrigation treatments on yield and quality of chrysanthemum.

Janakiram *et al.*, (2006) reported that overall comparison of growth parameters, yield and quality of flowers were found to be better with less irrigation (40 kPa) in chrysanthemum cv. Yellow Regan. According to Sohier *et al.*, (2008) the maximum plant height (77 cm), number of leaves (60 nos./plant.) and stem dry weight (8.27 g/plant) was observed with 75 % of irrigation water in chrysanthemum cv. Wilson's white. Plants grown under irrigation water of 400 ml at 6 times/day in 140 cm^3 substrates produced the tallest plant of 109.25 cm in chrysanthemum cv. White Regan (Tasweek *et al.*, 2014). Jawaharlal *et al.,* (2017) reported that irrigation scheduled at 0.6 E pan had shown the highest water use efficiency (111.09 kg ha/mm). Turan *et al.*, (2015) revealed that increased amount of irrigation water applied (517.9 mm) to the plants produced maximum yield of 30.09 flowers/plant in chrysanthemum cv. Bacardi. Irrigation management with daily replacements of 175% of the crop evapotranspiration, corresponding to a daily average irrigation depth of 12.25 mm, showed the best results for all evaluated morphological parameters, that is primordial for the increase of the chrysanthemums quality cv. Puritan (Posse *et al.,* 2019). Hence with respect to chrysanthemum no study has been done to quantify water use efficiency by gravimetric method with field capacity-based moisture regimes in pot culture for improved growth, yield and quality of chrysanthemum. Hence, the present investigation was undertaken to study the water use efficiency, growth and yield performance of

Chrysanthemum cv. Marigold with two different moisture regimes under controlled conditions by gravimetric method.

Materials and Methods

The experiment was conducted under controlled condition at ICAR – Indian Institute of Horticultural Research, Bengaluru, to study the growth, yieldand physiological responses of chrysanthemum var. Marigold under two moisture regimes. The experiment was laid out in a completely randomized design. The experiment was carried out by growing plants in12-inch diameter plastic pots. The weight of empty pots was recorded. The Chrysanthemum var. Marigold cuttings were prepared from the maintained mother block and it were planted in portrays for rooting. The rooted cuttings were transplanted to the pots filled with 10 kg of uniform media containing red soil and farmyard manure (FYM) in the 1:1 (v/v) ratio after 30 days. The pots were maintained under protected condition to avoid rain.

Imposing moisture regime treatments

Two moisture regimes at 100% FC and 70% FC were imposed during the period from 30 to 75DAT. The pots were maintained at 70 and 100% FC by gravimetric method for a period of 45 days. Electronic weighing scale was used for weighing the pots and difference in the previous day was considered as the amount of water consumed and it was replenished.

Gravimetric method

The pot mixture (red soil and FYM in the 1:1 (v/v) ratio) was dried, and filled in the pot followed by the initial dry weight was taken. Then the soil was watered to maintain the field capacities *i.e.*100% FC and 70% FC and the wet weight was taken. Then the next day the pot weight was taken to compute the difference between initial weight and final weight of the soil in the pot. The moisture regimes treatments were maintained by the replenishment of moisture based on the difference in the weight of the soil.

Quantification of water use efficiency (WUE)

The cumulative water transpired (CWT) was computed by subtracting the water added to the pots daily and evaporated water from the empty pots, the cumulative water transpired from the plants was summed up daily and expressed in ml. The biomass accumulated during the treatment period (30 and 75 DAT) was estimated as the difference in the initial and final dry biomass and expressed as gram/plant. The average initial biomass was recorded by weighing uniform plants using destructive method at before imposing the treatments. Entire plant sample containing stems, leaves, roots and flowers were taken separately and dried using hot air oven at temperature of 70^0C, it is maintained and dry weight of samples were taken in grams. Total dry matter production was worked out by adding the average weight of different components of the crop and expressed in grams. The quantification of WUE involves the measurement of the dry matter accumulated over a particular period of time and the total water transpired by the plant during the same period. The water use efficiency was estimated by using following formula,

Water Use Efficiency (g/ml) = Total biomass produced by the plant (g) / cumulative water transpired from the plant (ml)

Growth parameters

The plant growth observations like, plant height, plant spread, number of primary and secondary branches/plant, number of leaves/plants were recorded at bud initiation stage.

Yield parameters

Yield parameters like, diameter of the flower head, number of flowers/plant, average weight of individual flowers, yield of flowers/plant and shelf life were recorded at flowering stage.

Gas exchange characteristics

Gas exchange characteristics *i.e.* photosynthetic rate (A) (CO_2 µ mol m^{-2} s^{-1}), stomatal conductance (gs) (m mol H_2O m^{-2} s^{-1}) and transpiration rate (E) (m H_2O m^{-2} s^{-1}) were recorded at 9.00 am to 11.30 am by using Infra-red gas analyzer (IRGA) (Portable Photosynthesis System), Li - COR 6400 at flowering stage.

Relative water content

The relative water content (RWC) was also recorded at flowering stage from the freshly procured leaf samples. The fresh weight (FW) of the leaf samples was taken immediately. Then the samples were stored at dark condition for 2 hrs for taking turgid weight (TW), after that the samples were kept in an oven (at 80°C) for a period of 24 hours. After 24 hours, the dry weight (DW) was taken. The relative water content was calculated by using following formula,

$$RWC (\%) = \frac{FW-DW}{TW-DW} \times 100$$

Results and discussion

Growth parameters

The plants grown at 100% FC recorded highest plant height of 30.3cm compared to plants maintained at 70% FC (19.8 cm). The plant height was affected by the low moisture at 70 % FC (Table 1a). The height of the floral stem plays vital role in chrysanthemum, because it is a measure highly related to the production of the biomass and foliar area (Clement, 1995). According to Spadeto *et al.,* (2018), when investigating the water replenishment levels in the pot chrysanthemum culture, it is observed that the maximum flower stems were found in the treatments in which the crop grown in high moisture condition. The two moisture regimes at 100% and 70 % FC showed significant difference in the number of leaves produced *i.e.*71.67 and 36.67 leaves/plant respectively. The average plant spread (38.21cm) and total number of branches (11.34) also recorded higher in 100 % field capacity. According to Taiz and Zeiger (2009), less moisture condition causes the roots to produce abscisic acid, the hormone responsible for decreased growth and leaf production. The treatment *i.e.* 70% FC with lower volumes of water applied, directly influenced the vegetative growth of chrysanthemum compared to high moisture condition. The high moisture level improved the growth characters of the plant, whereas the low moisture condition retarded the overall growth performances. These results were collaborating with the results found by Pereira *et al.,* (2005) in chrysanthemum.

Physiological parameters

The treatments showed a decrease in fresh biomass with increase in low moisture condition. Plants maintained at 100% FC were tallest, therefore, they produced the greatest fresh biomass (Table 3 and Fig. 1), compared to 70 % FC. In the treatments, the highest total fresh bio mass were recorded in 100 % FC (153.09 g/plant), it was significantly higher than the biomass observed in 70 % FC (141.10 g/plant), It is known that the lowest rates of accumulation of biomass occurs where there is low moisture condition in the soil. The lowest range of accumulation bio mass occurs where there is water deficit in the soil (Loue, 2010). Since biomass production is the result of the photosynthetic activity and photo assimilates accumulation of the leaves, the efficiency with which the photo assimilates are converted. Under low moisture situation, the plants use the mechanism of closure of the stomata to avoid the loss of water, this mechanism also reducing the accumulation of photosynthates through photosynthetic activity, thus compromising the development of the plant, increased shoot (17.75 g/ plant of 100 % FC and 13.29 g / plant of 70 % FC) and root biomass (20.17 g/ plant of 100 % FC and 16.29 g / plant of 70 % FC) was occurs where the moisture content was more, similar results were observed by Chahal *et al*. (2018), Spadeto *et al.* (2018), Sarangi *et al.* (2015) and Farias *et al.* (2005).. Water restriction affected the biomass of leaves, the first operator of the photosynthetic activity (Olfa *et al*. 2018). The decrease in total dry weight may be due to the considerable decrease in overall plant growth, photosynthetic activity and canopy structure, as indicated by leaf senescence during low moisture level in the soil (Nautiyal *et al*. 2002).

Relative water content (RWC) in the leaves is the most appropriate way to measure plant water status. The relative water content was recorded higher in the leaves of plants treated with 100 % FC (94.29%) followed by plants treated with 70 % FC (84.64%) (Table 1b). This is supported with the findings of Jungklang and Saengnil (2012) that the plants grown under 100 % FC was observed higher leaf water potential than the plants grown under 70 % FC.

However, the root/shoot ratio was affected by moisture condition of the soil, indicating that the root/shoot ratio was higher (0.42) in the plants grown under 70 % FC compared to the plants under 100 % FC (0.28) (Table 1b). This is supported with reports, that increase in root/shoot ratio with increased low moisture was observed in the plants extremely sensitive to low water condition and it is strongly influenced by the ability of the roots to grow in water deficit soil and maintain its optimal water status (Tyree and Dixon, 1986) and (Tyree and Alexander, 1993). According to Sobrado and Turner (1986), the similar rate of osmotic adjustment in root and leaf cells explained the similar root/shoot ratio found in low moisture and high moisture grown *Helianthus annuus*. Plants grown under low moisture i.e. 70 % FC showed a significant difference in root length compared to the plants under 100 % FC treatment. This significant difference could be illustrated by enhanced development of a longer root in search of limited amounts of water available in the soil. The root length of the plants under 70 % FC is 34.5 cm and 16.37 cm under 100 % FC (Table 1b). Reduced irrigation enhanced a deeper and more extensive rooting system. This would allow plants to use water and nutrients from deeper soil, thus increase both irrigation and nutrient use efficiency (Ngouajio *et al.,* 2007).

The gas exchange characteristics were influenced by moisture regime treatments. Higher photosynthetic rate (A) (7.56 CO_2 μ mol m^{-2} s^{-1}), stomatal conductance (gs) (0.16 m mol (H_2O) (m^{-2} s^{-1}) and transpiration rate (E) (3.26 m H_2O) (m^{-2} s^{-1}) were observed in plants at 100% FC compared to plants maintained under low moisture regime at 70 % FC which registered photosynthetic rate (A) (5.16 μ mol (Co_2) (m^{-2} s^{-1}), stomatal conductance (Gs) (0.15 m mol (H_2O) (m^{-2} s^{-1}) and transpiration rate (E) (2.22mol H_2O (m^{-2} s^{-1}) (Table 2). The rate of transpiration was higher in the 100 % FC treatment compared to the low moisture treatment plants. The decrease in photosynthesis of leaves is usually caused by stomatal limitation under moderate low moisture conditions (Deglinnocenti *et al.*, 2009; Misson *et al.*, 2010). Low moisture conditions affect primly cell enlargement than cell division. It reduces the plant growth by inhibiting rate of photosynthesis, respiration, translocation, ion uptake, carbohydrates, nutrient metabolism and ultimately the overall growth and development of the plants (Farooq *et al.,* 2009). In this study, the photosynthetic rate (A), stomatal conductance (Gs) and transpiration rate (E), all showed a significant increase with increased field capacity (100%) (Table 2), these results were highly associated with Zang *et al.,* (2010). A reduction in the photosynthetic rate under low moisture conditions could be attributed either to a decrease in stomatal conductance (Jones (1998); Cornic and Massacci (1996)).The maintenance of the photosynthetic rate could be mainly attributed to the maintenance of stomatal conductance in plants (Spence *et al.*, 1986). Low moisture level in the soil decreased the photosynthetic potential and affected the diurnal pattern of gas exchange there by, reducing plant growth. Low water condition was the main limitation to primary, photosynthetic process in lily (Zhang *et al.*, 2010).

Fig.1 Effect of moisture regimes on total dry biomass (g/plant) production in chrysanthemum var. Marigold

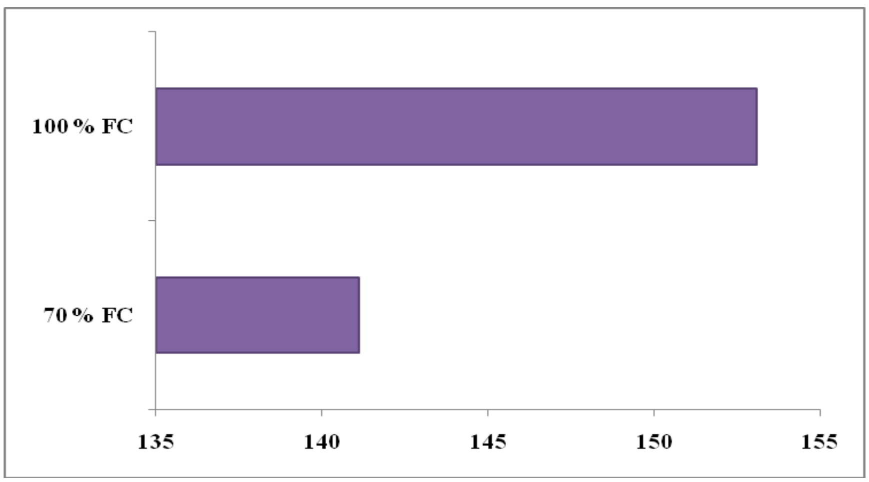

Fig.2 Effect of moisture regimes on WUE (g/litre of water) of chrysanthemum var. Marigold

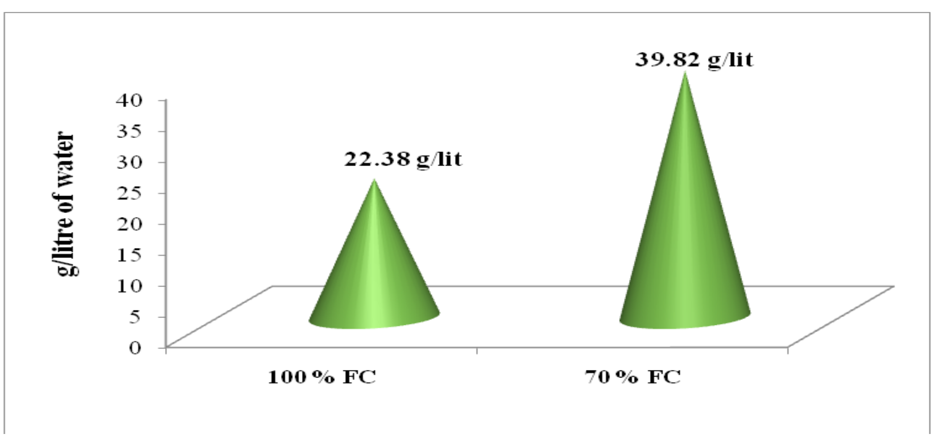

Plate.1 Effect of different moisture regimes on morphology of chrysanthemum var. Marigold under controlled condition

Plate.2 Effect of different moisture regimes on root growth of chrysanthemum var. Marigold under controlled condition

Table.1a Performance of chrysanthemum var. Marigold under different moisture regimes on growth and flowering parameters

Treatments / Parameters	Plant height (cm)	Average plant spread (cm)	Primary branches / plant	Secondary branches/ plant	Number of leaves	Diameter of the flower head (cm)	Number of flowers/plant
70 % FC	19.81	28.38	3.00	2.42	36.67	4.18	87.92
100 % FC	30.33	38.21	5.67	5.67	71.67	5.93	136.75
SE d	**0.70**	**2.32**	**0.63**	**0.59**	**5.01**	**0.26**	**6.02**
CD @ 5%	**1.46**	**4.81**	**1.31**	**1.22**	**10.39**	**0.55**	**12.49**

Table.1b Performance of chrysanthemum var. Marigold under different moisture regimes on yield and physiological attributes

Treatments / Parameters	Average weight of individual flowers (g)	Yield of flowers per plant (g)	Shelf life (Days)	Root: shoot ratio	Length of root (cm)	RWC (%)	Total Fresh Biomass (g)
70 % FC	5.38	550.00	4.92	0.42	34.50	84.64	141.10
100 % FC	7.21	881.67	7.58	0.28	16.37	94.29	153.09
SE d	**0.37**	**35.95**	**0.39**	**0.29**	**0.43**	**1.30**	**1.34**
CD @ 5%	**0.76**	**74.55**	**0.80**	**0.45**	**0.89**	**2.71**	**2.78**

Table.2 Effect of different moisture regimes on gas exchange characteristics of chrysanthemum var. Marigold under controlled condition

Treatments / Parameters	Photosynthetic rate (A) micro mol (Co2) ($m^{-2} s^{-1}$)	Transpiration rate (E) milli mol (H_2O) ($m^{-2} s^{-1}$)	Stomatal conductance (GS) Mol H_2O ($m^{-2} s^{-1}$)
70 % FC	5.16	2.22	0.15
100 % FC	7.56	3.26	0.16
SE d	**1.14**	**0.40**	**0.04**
CD @ 5%	**2.37**	**0.83**	**0.08**

Table.3 Effect of different moisture regimes on biomass, cumulative water transpired and water use efficiency of chrysanthemum var. Marigold

Treatments	Cumulative water Transpired/plant (ml)	Root biomass (g)	Shoot biomass (g)	Total fresh biomass produced during treatment period (g/plant)	WUE (g/litter of water)
100 % FC					
T1R1	6380	17.50	13.50	147.80	20.80
T1R2	5370	14.50	10.50	148.30	26.57
T1R3	5470	14.50	12.00	152.30	27.00
T1R4	5020	18.00	13.00	155.30	31.61
T1R5	6910	15.50	14.50	157.80	21.95
T1R6	5650	17.00	14.50	157.30	28.80
T1R7	5900	17.00	15.00	152.80	22.49
70% FC					
T2R1	5710	18.50	15.50	143.80	39.00
T2R2	5500	17.50	16.00	135.80	42.31
T2R3	5220	19.50	17.50	139.80	46.49
T2R4	4850	20.00	18.50	141.90	49.01
T2R5	5770	21.00	19.00	142.80	35.13
T2R6	5980	22.00	18.50	142.80	33.90
T2R7	6250	21.00	17.00	140.80	31.95
SE (d)	0.09	2.21	1.44	1.68	1.28
CD @ 5%	1.06	4.01	2.87	3.22	2.47

Yield and quality parameters

When comparing the yield and quality parameters of chrysanthemum var. Marigold under two moisture regimes (Table 1a), it was observed that the total number of flowers/plant was significantly higher in treatment with 100 % field capacity (136.75) compared to plants under 70 % of field capacity (87.92). This result was supported with the findings of Taweesak *et al.,* (2014) in chrysanthemum. The weight of individual flowers and hundred flower weight was increased with enhanced moisture level in the soil and was directly proportional to the plant biomass. The increased vegetative growth directly influenced the weight of individual flowers. The plants maintained under 100 % FC recorded maximum individual flower weight (7.21g) when compared to weight of individual flowers in 70 % FC (5.38 g) (Table 1b). The best quality flowers were obtained in the plants under field capacity of 100 %, according to Farias *et al.,* (2005). Superior quality of flowers with extended shelf life (7.58 days) was observed in plants at 100 FC % compared to plants under 70 % FC (4.92 days) (Table 1b). The yield of flowers under 100% FC was recorded significantly (881.67 g/plant) than the yield of plants under 70 % FC (550.0 g/plant) (Table 1b and Fig. 2). These results were supported with the findings of Spadeto *et al.,* (2018) in chrysanthemum. Effective utilization of irrigation water, soil nutrients, higher photosynthetic rate as well as enhanced translocation of photosynthates under higher moisture environment were responsible for achieving the highest yield (Ngouajio *et al.*, 2010). The diameter of the flower head was lower (4.18 cm) with low moisture regimes (70 % FC) whereas higher flower head diameter (5.93 cm) was observed in 100 % FC (Table 1a). The higher moisture regime enhanced the flower and flower quality characteristics, than the low moisture regime treatment. This was in accordance with the findings of Nazarideljou *et al.*, (2015) in zinnia.

Water use efficiency (WUE)

The water use efficiency is an index to quantify the use efficiency of water resources towards crop production. Under limited water supply condition, WUE plays crucial role to screen suitable irrigation regimes. Water use efficiency was higher in plants maintained at 70% FC. These results were also confirming the statement of Arquero *et al.*, (2006), which shows that plants grown at100 % FC had lower water use efficiency than plants under 70 % FC. The WUE were recorded in plants under 70 % FC treatment was 39.82 g/litter of water, when the plants under high moisture condition *i.e.*100 % FC was 22.38 g/litter of water (Table 3 and Fig. 2). Enhanced water uptake through investments in the root system can result in reduced plant size and water expenditure for growth maintenance can observed in plants grown under low moisture situation (Lopes *et al.*, 2011). The highest WUE was found in the lowest level of moisture at 70 % FC, indicating comparatively more efficient use of irrigation water than higher moisture level. This is in conformity with the report that water use efficiency (WUE) is reduced with increasing soil moisture availability by Waraich *et al.*, (2011) and Jawaharlal *et al.*, (2017). In conclusion, performance of chrysanthemum var. Marigold was highly influenced by moisture regimes treatment in terms of growth, physiological, yield and quality parameters under controlled condition. Soil at 100% FC was significantly increased the plant height, average plant spread, number of branches/plant, number of flowers/plant, average weight of individual flowers, RWC, root and shoot biomass, total fresh biomass, gas exchange characteristics *i.e*. photosynthetic rate, stomatal conductance and transpiration rate compared to 70 % field capacity treatment. However, water use efficiency (WUE) of chrysanthemum increased under low moisture condition (70 % FC) compared to 100 % FC. The improvement in physiological parameters had significantly influenced the growth, yield, quality and shelf life of flowers under moisture regimes. It is concluded that the higher moisture regime *i.e.* 100 % FC enhanced the plant growth, yield and quality aspects as compared to low moisture regime.

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