EFFECTS OF DIFFERENT IRRIGATION REGIMES ON GROWTH, YIELD AND QUALITY OF CARNATION (*DIANTHUS CARYOPHYLLUS* L.) CUT FLOWERS

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ABSTRACT

Carnations need only low amounts of water but it is important to avoid water stress during the vegetative stage of growth. The objective of the experiment was to determine the effects of different irrigation regimes on growth, yield and quality of carnations. A greenhouse experiment was carried out to determine the optimal water management scheme for growing of carnations in order to contribute to increased water use efficiency and reduce cost of production. The different irrigation levels used were 25, 50, 75 and 100% of field capacity (FC). Tensiometers were used to schedule irrigation. Two tensiometers were installed in each treatment. The treatments were laid out in a Randomized Complete Block Design (RCBD). The results showed that carnations irrigated at 75% FC had the highest plant height (53.0 cm) followed by plants irrigated at 50% FC measured 8 weeks after transplanting (WAT). However, highest leaf area (7.6 cm^2) was obtained from plants irrigated at 50% FC. The highest yield in terms of number of cut flower stems/plant (9.3) was obtained from carnations irrigated at 100% FC. Plants irrigated at 75% FC had the highest diameter of flowers (6.1 cm) and length of cut flowers (45.0 cm). It is recommended that farmers who are interested in growing

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Additional index words: Carnation, cut flower quality, cut flower yield, drought stress, irrigation
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carnation using same media should irrigate their plants at 75% FC for optimal vegetative growth and quality of cut flowers.

INTRODUCTION

Floriculture is a fast-growing major sector of the agricultural industry in Swaziland. Its contribution both towards small-scale and large-scale farm incomes, employment opportunities, foreign exchange earnings, and food production has experienced unprecedented growth in recent years (Anon., 2006). Floriculture industry is still in its infant stage in Swaziland though. However, there is big market for cut flowers in the Republic of South Africa (RSA) as well as in the European Union (EU). Hence, floricultural production is expected to increase tremendously in the near and long-term future (Anon., 2005).

Satisfying customer needs of an exciting flower is a major challenge facing cut flower business worldwide (Mayoli and Isutsa, 2010). Carnation (*Dianthus caryophyllus* L.) is essentially a florist crop, that is widely cultivated on a commercial scale in different parts of the world (Bhattacharjee, 2003). According to Dole and Harold (2005), carnations are used as bedding plants as well as for cut flower production. They have low water requirements during the early stages of growth but it is important to avoid water stress during the vegetative stage of growth. Water requirement increases as vegetative growth progresses. However, water requirement should be reduced as the plants approach the flowering stage (Larson, 1992).

Carnations require 2.5 cm of water a week, either from rainfall or irrigation (Anon., 2011). When a carnation plant is in full growth and healthy, it absorbs 6-7 litres of water/ m^2/day (KF Bioplants, 2011). When irrigating plants, enough water should be applied to moisten the top 15 cm of the soil. Bhattacharjee (2003) recommended that carnation soils should be thoroughly wetted when water is applied. However, the soil should be allowed to dry between watering, especially in the early stages of growth. Provided other factors are favourable, maximum flower production would occur when soil moisture stress is zero and internal plant stress is close to zero (The Flower Expert, 2008). Care must be taken not to make the soil too wet which can cause yellowing of foliage as a result of waterlogging (The Flower Expert, 2011).

Water, one of the indispensable elements of life, is the leading technological factor used to increase agricultural productivity (Kazaz *et al*., 2010). The maximization of yield per unit area particularly in arid, semi-arid and greenhouse production is possible through supplying plants with water they require at the suitable time (Kazaz *et al*., 2010). The scarcity of water resources is one of the main challenges in the world and it's considered as a limiting factor for the economic development especially in agriculture. Also, the demand on water resources is increasing with time for both agriculture and non-agricultural purposes (Mamkagh, 2009). As production of cut flowers increases in developing countries, concerns are being raised about environmental impact, with particular regard to water utilization, the effects of extraction and pollution of waterways by chemical run-off and leaching (Taylor *et al*., 2011).

No plants can survive without water. However, some plants are more resilient than others. In general, shallow-rooted plants, such as azaleas, primulas, chrysanthemums, rhododendrons, hybrid roses, and dahlias require more water than deep-rooted ones (Perry, 2008). Water requirements of plants are quite different. Therefore, the effects of irrigation water amount and frequency on growth, development and yield of plants should be determined for each plant species (Kazaz *et al*., 2010). The irrigation water amount and frequency in carnation plants vary with soil texture, photoperiod, air temperature and humidity, air movement, and water loss through transpiration (Kazaz *et al*., 2010).

In nature, water is essentially the most limiting factor for plant growth especially in arid and semi-arid regions. This is also the case in home or commercial landscapes. If plants do not receive adequate rainfall or irrigation, the resulting drought stress can reduce growth more than all other environmental stresses combined (Perry, 2008). According to Perry (2008), drought can be defined as the absence of rainfall or irrigation for a period of time sufficient to deplete soil moisture and injure plants. Drought stress results when water loss from the plant exceeds the ability of the plant's roots to absorb water and when plant's water content is reduced enough to interfere with normal plant processes. The time required for drought injury to occur depends on the water-holding capacity of the soil, environmental conditions, stage of plant growth and plant species. Drought stress is characterized by reduction of water content, diminished leaf water potential, turgor pressure, closure of stomata, decrease in cell enlargement and growth (Jaleel *et al*., 2009). Drought reduces plant growth by affecting various physiological and biochemical processes, such as photosynthesis, respiration, translocation, ion uptake, and hormone synthesis (Perry, 2008).

According to Jaleel *et al*. (2009), many plants do not tolerate submersion of their roots in water for long periods of time. Excessive moisture in the soil causes oxygen levels in the soil to decrease, impeding proper root respiration. As a result, carbon dioxide, methane, hydrogen and nitrogen gas levels around the roots increase sharply, thus, roots can suffocate and die. Toxic compounds, such as ethanol and hydrogen sulfide, as well as numerous other harmful compounds, can build up in saturated soils. Photosynthesis is inhibited and growth slows or even stops. Drought stress tolerance is seen in almost all plants but its extent varies from species to species and even within species (Jaleel *et al*., 2009).

Current knowledge and understanding of water use and demand questions the effectiveness and sustainability of the conventional sectorial systems and methods of water supply for either domestic or irrigation purposes (Peter, 2009). Water stress is a major limitation to crop productivity worldwide and global climate change suggests a future increase in the risk of drought. For the efficient use of the limited water resources in agricultural production, the yield and quality parameters of plants under different irrigation schedules should be determined. The aim of this study was, therefore, to determine the effects of different irrigation regimes on growth, yield and quality of carnation cut flowers.

MATERIALS AND METHODS

Experimental design

The experiment was conducted during the summer season (between November 2009 and February 2010) in the greenhouse of the Horticulture Department, Faculty of Agriculture, Luyengo Campus, at the University of Swaziland. The site is located at an altitude of 750 m above sea level, latitude 25^0 34' S and longitude 31^0 12' E. The mean annual precipitation is 980 mm with most of the rain falling between October and March (FAO, 2006a; FAO, 2006b). Five-weeks-old carnation seedlings were used in this experiment. The seedlings were obtained from Vickery Seedlings Ltd., Malkerns, Swaziland. The growing medium used consisted of a mixture of garden soil, compost and sand. They were mixed at the ratio of 1:1:1 (v/v). Five-litres black plastic bags were used to grow the plants.

There were four treatments, namely irrigating when growing medium water content reached 25, 50, 75 and 100% of field capacity (FC). A Randomized Complete Block Design (RCBD) was used in this trial. Each treatment was replicated four times. Each block consisted of 32 plants. The 30-cm-long tensiometers were used to determine soil moisture content. Two tensiometers were placed in two different pots for each treatment/plot at random in the first block.

Determination of soil moisture content

The soil water content was pre-determined using the gravimetric method in order to formulate the irrigation schedules. The pots were filled with the above mentioned growing medium mixtures. A tensiometer was placed in each pot. The growing medium was then irrigated to FC. As water dried out in the pots, soil samples were taken to the laboratory for moisture determination at the same time taking the suction on the tensiometers, which is related to the amount of water in the soil. Water moves out freely in and out of tensiometers and as the water dries out in the medium, the suction increases and the reading goes up. However, when irrigation is done the reading drops down to zero. After finding out the moisture content, means of the four samples collected each day were determined and used to draw an irrigation schedule (Figure 1). Soil moisture determination was continued until the medium was completely dry. By extrapolation from the graph (Figure 1), the irrigation schedule was determined as follows: 25% FC: 75kPa; 50% FC: 45kPa; 75% FC: 23kPa; and 100% FC: 9kPa.

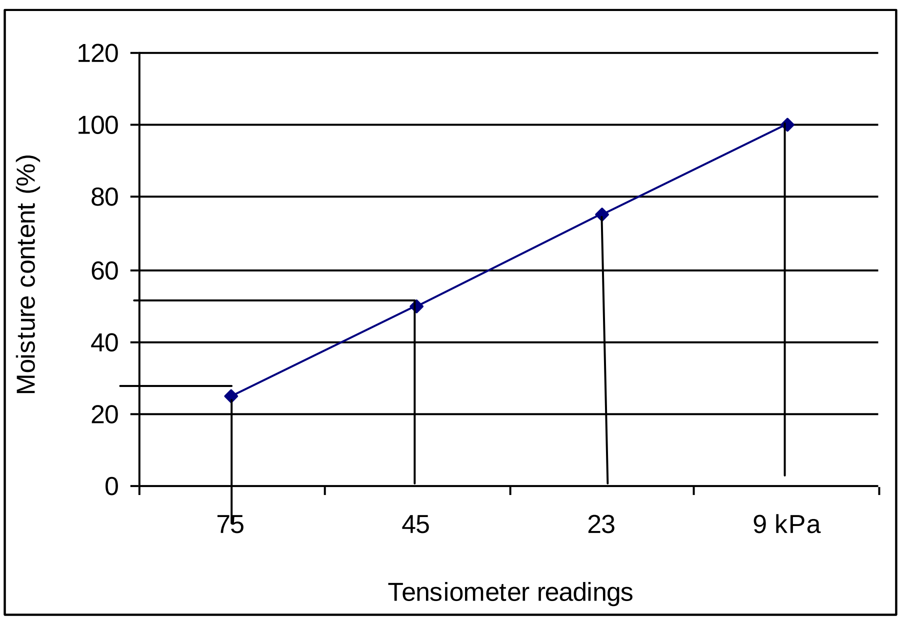

Figure 1: Determination of irrigation schedule for the experiment

Data collection and analysis

Four randomly selected plants were used in each plot for data collection from the second to eight weeks after transplanting (WAT). Data collected included: plant height, leaf width and leaf length (which were used in determination of leaf area). Fresh and dry mass of the shoots and roots were determined after harvesting. The yield, in terms of number of cut flowers stem/plant, length of cut flower stems and flower diameter were determined at the end of the experiment. The shoot: root ratio was calculated from the shoot and root dry masses.

The data collected were subjected to analysis of variance (ANOVA) using MSTAT-C statistical package. For all means that were found to be significant at 5% level, mean separation was done using the Duncan's New Multiple Range Test (DNMRT).

RESULTS AND DISCUSSION

Plant height

The height of carnations irrigated at 75% FC was significantly ($P < 0.05$) greater than that of plants irrigated at 25, 50 and 100% FC at all sampling dates (Table 1). There was no significant ($P < 0.05$) difference in plant height between plants irrigated at 25 and 50% FC. Plants irrigated at 100% FC had the lowest plant height at all sampling dates and for all treatments (Table 1). El-Boraie *et al*. (2009) observedsimilar lowest plant height in *Hibiscus* plants provided with the highest irrigation water. Increasing application of irrigation water from 25 to 75% FC tended to increase plant height in carnations. Mesbah (2009) argued that the positive effect of irrigation on plant height may be attributed to effect of irrigation on the encouragement of cell division, cell elongation and consequently increase in meristematic growth. According to Kazaz *et al.* (2010), the saturation of all soil pores with water under high irrigation intervals leads to a reduction in oxygen availability in the root zone, which causes reduction in growth. The low plant height observed in this study, when carnations were irrigated at 100% FC could also be attributed to poor soil water relations, i.e., flooding and exclusion of oxygen from the root zone.

Table 1. Effect of different irrigation regimes on plant height of carnations.

Soil moisture content (% FC)	No. of weeks after transplanting/plant height (cm)			
	2	4	6	8
25	29.0b*	34.3b	41.8b	49.7b
50	29.3b	33.7b	42.6b	49.8b
75	31.9a	35.8a	45.7a	53.0a
100	25.5c	31.4c	37.0c	47.6c

*Means followed by same letter along columns not significantly different. Mean separation by DNMRT at P = 0.05.

Leaf area

The biggest leaf area (7.6 cm^2) was obtained from carnation plants irrigated at 50% FC while the smallest (6.2 cm^2) was obtained in plants irrigated at 25% FC at 8 WAT. At 8 WAT, there was no significant ($P < 0.05$) difference in leaf area of plants irrigated at 75 and 100% FC (Table 2). Increasing irrigation water application from 25 to 50% FC resulted in a significant ($P < 0.05$) increase in leaf area in the carnations from 4 to 8 WAT. The smallest leaf area was obtained from plants irrigated at 25% FC. Small leaf area in carnation (Alvarez *et al.*, 2011) and sunflower (Dar *et al.*, 2009) has also been recorded under low irrigation rates. According to Wessellius and Brouwer (1976), small leaf area at low water application rate can be attributed to inhibition of leaf enlargement by dehydration. Leaf area is correlated to yield in crop plants. However, bigger leaf area results in increased water loss through transpiration (Ali *et al.*, 2009).

Table 2. Effect of different irrigation regimes on leaf area of carnations.

Soil moisture content (% FC)	No. of weeks after transplanting/ leaf area (cm^2)			
	2	4	6	8
25	3.6ab*	4.5b	4.9c	6.2c
50	4.0a	4.8a	6.2a	7.6a
75	3.2c	3.4c	4.7c	6.6b
100	3.4bc	4.9a	5.6b	6.5b

*Means followed by same letter along columns not significantly different. Mean separation by DNMRT at P = 0.05.

Fresh and dry mass of shoots

Fresh mass of shoots of carnations irrigated at 75% FC was significantly ($P < 0.05$) higher than that of plants irrigated at 25, 50 and 100% FC (Table 3). Plants irrigated at 50% FC had the second highest fresh mass of shoots. The lowest fresh mass of shoots (128.0 g) was obtained from plants irrigated at 25% FC.

Carnations irrigated at 75% FC had a significantly ($P < 0.05$) higher dry mass of shoots (25.0 g) than those irrigated at 25, 50 and 100% FC (Table 3). Plants irrigated at 25% FC had the lowest dry mass of shoots (21.5 g). Increasing irrigation water application from 25 to 75% FC resulted in a significant ($P < 0.05$) increase in carnation shoot dry mass. Similar observation were reported also in carnations by Kazaz *et al*. (2010). According to Jaleel *et al*. (2009) and Naseri *et al*. (2010), the most common adverse effect of water stress is reduction in fresh and dry biomass production. An increase in stem fresh mass with increasing irrigation water application is often associated with longer, thicker and bigger flowers (Kazaz *et al*., 2010).

Carnations irrigated at 25% FC had the lowest fresh mass of shoots. The lower fresh mass may be attributed to loss of leaves by plants during the growth period. The plants were wilted at the time of collecting fresh mass samples and that greatly affected their masses. Increasing irrigation water applied resulted in increased yield of wheat while water deficit resulted in reduction in vegetative growth (Naseri *et al*., 2010).

Table 3. Effect of different irrigation regimes on the vegetative growth, cut flower yield and quality in carnations.

Soil moisture content (% FC)	Shoot fresh mass (g)	Shoot dry mass (g)	Root fresh mass (g)	Root dry mass (g)	Root: shoot ratio	No. of flowers/ plant	Flower stem length (cm)	Flower diameter (cm)
25	128.0d	21.5d	13.3c	3.5c	5.8c	5.5c	41.5b	5.0c
50	135.0b	22.8c	14.3a	4.0a	7.5b	8.8b	41.0c	5.0c
75	138.3a	25.0a	13.5b	4.0a	7.3a	8.5b	45.0a	6.1a
100	131.3c	24.5b	13.0c	3.8b	5.3c	9.3a	38.5d	5.4b

*Means followed by same letter along columns not significantly different. Mean separation by DNMRT at P = 0.05.

Fresh and dry mass of roots

Carnations irrigated at 50% FC had a higher fresh mass of roots (14.3 g) compared to those irrigated at 25, 75 and 100% FC (Table 3). There was no significant ($P < 0.05$) difference in fresh mass of roots in carnations irrigated at 25 and 100% FC. Plants irrigated at 25 and 100% had the lowest fresh mass of roots and this could be attributed to lack of moisture and oxygen deficit in the root zone, respectively (Perry and Harrison, 1974). Increasing irrigation water application from 25 to 50% FC resulted in a significant ($P < 0.05$) increase in root fresh mass. However, increasing irrigation water application from 75 to 100% FC resulted in a significant ($P < 0.05$) reduction in root fresh mass.

There was no significant ($P < 0.05$) difference in dry mass of roots between carnations irrigated at 50 and 75% FC (Table 3). The lowest dry mass (3.5 g) was obtained from carnations irrigated at 25% FC. Increasing irrigation water application from 25 to 50% resulted in a significant ($P < 0.05$) increase in root dry mass but further increase above 75% FC resulted in its reduction (Table 3). Wignarajah *et al.* (1976) reported that flooding usually reduces both shoot and root growth of plants. Excessive moisture in the soil causes oxygen levels in the soil to decrease, impeding proper root respiration. As a result, carbon dioxide, methane, hydrogen and nitrogen gas levels around the roots increase sharply, thus, roots can suffocate and die.

Crop yield and dry matter are greatly affected by irrigation regimes. The dry mass of roots showed no significant ($P < 0.05$) difference between carnations irrigated at 50 and 75% FC. These plants had the highest dry mass of roots. The lowest dry mass of roots was obtained from plants irrigated at 25% FC in this investigation and could be attributed to inadequate water availability.

Shoot: root ratio

The highest shoot to root ratio (1:7.5) was obtained from carnations irrigated at 75% FC, followed by those irrigated at 50% FC (Table 3). There was no significant ($P < 0.05$)

difference in shoot: root ratio between carnations irrigated at 25 and 100% FC (Table 3). According to Ali *et al*. (2009), water stress significantly increases root: shoot ratio. Long roots have been proved to be a helpful tool for increasing crop yield under drought conditions (Ali *et al.,* 2009). According to Khan *et al*. (2010), root length is affected less by water stress when compared to shoot growth. While the effect of root growth by water stress is minimal, root: shoot ratio normally increases during water stress (Khan *et al*., 2010). This may be due to more suppression of shoot than root growth under water stress environment. Reason for increased root: shoot ratio under water stress may be due to limited supply of water and nutrients to the shoot and some hormonal changes. The continued growth of roots in water stressed soil is particularly important to cope with the effects of water stress (Khan *et al*., 2010).

Number of cut flower stems

The highest number of cut flowers stems per plant (9.3) was obtained from carnations irrigated at 100% FC while the lowest (5.5) was obtained from those irrigated at 25% FC (Table 3). There was no significant ($P < 0.05$) difference in number of cut flower stems between carnations irrigated at 50 and 75% FC (Table 3). Increasing irrigation water application from 25 to 50% FC resulted in 37.5% increase in number of cut flower stems per plant. Although the highest number of cut flower stems was obtained from carnations irrigated at 100% FC, the plants exhibited yellowing and death of foliage. This could be attributed to availability of excess water in the medium (The Flower Expert, 2008; 2011). When soil is too wet, carnations produce yellow foliage and lower yields. Increasing irrigation water application above 25% FC resulted in increased yield of cut flowers. A similar observation was also reported in carnations by Kazaz *et al.* (2010).

Length of cut flower stems

The highest length of cut flower stems (45.0 cm) was obtained from carnations irrigated at 75% FC while the lowest (38.5 cm) was obtained from those irrigated at 100% FC (Table 3). Increasing irrigation water application from 75 to 100% FC resulted in a14.4% reduction in cut flower stem length. Similarly, Kazaz *et al*. (2010) reported a low carnation cut flower stem length at high soil moisture content. One of the most important quality criteria in carnations is the cut flower stem length. Aydinsakir *et al*. (2011) and Kazaz *et al*. (2010) observed an increase in carnation cut flower stem length with increased irrigation water amounts and frequency.

Diameter of flowers

The highest diameter of carnation flowers was obtained in plants irrigated at 75% FC and the lowest was obtained from plants irrigated at 25% FC. The diameter of cut flowers of carnations irrigated at 75% FC was significantly ($P < 0.05$) higher when compared to that of plants irrigated at 25, 50 and 100% FC (Table 3). There was no significant ($P < 0.05$) difference in flower diameter between plants irrigated at 25 and 100% FC. Alvarez *et* al. (2011) also observed low carnation flower diameter under severe water stress. Kazaz *et al*. (2010) attributed low flower diameter under limited water application levels to reduction in vegetative growth and biomass production.

CONCLUSION

Irrigating carnations at 75% FC resulted in higher plant height, shoot fresh and dry masses, root dry mass, root: shoot ratio, cut flower stem length, and flower diameter. The next best results were obtained from plants irrigated at 50% FC. The lowest vegetative growth, yield and quality of carnation were observed from plants irrigated at 25 and 100% FC.

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