EFFECTS OF DIFFERENT IRRIGATION REGIMES ON THE GROWTH AND DEVELOPMENT OF CALATHEA (*CALATHEA MAKOYANE* L.)

Mbongeni L. Dlamini, Paul K. Wahome, Tajudeen O. Oseni, and Michael T. Masarirambi

Department of Horticulture, Faculty of Agriculture and Consumer Sciences, Luyengo Campus, University of Swaziland, Private Bag Luyengo, M205, Swaziland wahome@uniswa.sz

ABSTRACT

Irrigation is becoming increasingly important in areas where frequent drought incidence and seasonal rainfall is inadequate for crop production. On the other hand, water resources are becoming increasingly limited and can no longer satisfy the continuously increasing demand for irrigation water. The aim of this investigation was to determine the optimal moisture depletion level for the production of good quality calathea plants. Treatments used in the experiment included 75, 50, 40, and 30% allowable water depletion (AWD).The control was (50% AWD). A Randomized Complete Block Design (RCBD) was used in this experiment with four replications. Irrigation the plants at 50% AWD resulted in the highest plant height (28.5 cm), leaf area (57.2 cm^2) and number of leaves per plant (12.1) determined 12 weeks after potting (WAP). However, the highest root length (15.2 cm), shoot fresh mass (39.0 g), shoot dry mass (4.2 g), root fresh mass (19.4 g), and root dry mass (2.0 g), was obtained from plants irrigated at 75% AWD. The lowest plant height (24.7 cm), leaf area (49.0 cm^2), root length (12.3 cm), shoot fresh mass (16.9 g), shoot dry mass (1.8 g), root fresh mass (7.6 g), and number of leaves (5.1) were recorded in plants irrigated at 30% AWD. Irrigating the plants at 30% AWD resulted in an almost 60% reduction in the number of leaves per plants as compared to irrigating at 50% AWD. An almost similar 60% reduction in root length, shoot fresh mass, shoot dry mass, and root fresh mass of calathea plants occurred when irrigation was reduced from 75 to 30% AWD. It was, therefore, recommended that farmers who are interested in growing calathea should irrigate them at 75% AWD to promote more vegetative growth.

INTRODUCTION

Calatheas (*Calathea makoyana* L.) require regular watering especially during the growing season and the soil must be kept moist all times. On the other hand, water should be limited during the winter season making sure that the soil dries before the next watering. Leaf abscission and stem rot occur when plants are over-watered in winter while insufficient watering in summer may cause leaf curling and yellowing (Pollock, 2009). Greenhouse production is more advantageous than outdoor production since water for irrigation is used more effectively and can be controlled (Pollock, 2009).

Irrigated agriculture is very important in meeting the food and fibre needs of an increased global population (Hillel, 1982). According to Hoffman *et al*. (1992), irrigation management consists of determining when to irrigate (irrigation scheduling), the amount of water to apply at each irrigation and during each stage of plant growth, and the operation and maintenance of the irrigation system. Irrigation is the largest water user worldwide (Trout, 2000). As a large consumer of water, irrigation reduces the quantity of water available for other uses. However, irrigated agriculture is critical to the global food supply.

According to Trout (2000), rational water use can help increase yield and quality of crops. Economical water use can help in reducing production costs. This in turn can make agricultural products cheaper and more competitive in the local and international markets. Diminishing water supplies and increasing costs of pumping irrigation water necessitate increasing emphasis on water use efficiency studies on all crops, but especially on those that have high irrigation requirements. In arid regions, irrigation is essential for plant survival. Even in regions of high rainfall, there are periods of water shortage almost every year. If these occur during the critical periods of the growing season, and irrigation is not applied, crop growth and yield will be reduced. In order to make the best use of irrigation water, more information is required on the effects of various levels of water stress on the plant growth, period of production, yield and quality of important crops (Trout, 2000).

In most areas, water is a very limited resource. This necessitates effective use of available water for conventional irrigation practices supplementing the seasonal precipitation to ensure optimum crop production (Ali *et al*., 2009; Bot, 2010). Supplemental irrigation improves crop growth and productivity, especially in drier areas. Irrigation targets are most often set as a depletion percentage of the plant available water (Martin, 2009). More studies are still needed for deficit irrigation (Mannini and Gallina, 1996). Deficit irrigation aims at increasing the efficiency of irrigation water. It is designed to ensure that water stress will not be severe to cause yield losses.

Bot (2010) suggested that deficit irrigation is a strategy which could be applied to utilize water efficiently. On the other hand, Phocaides (2002) defined deficit irrigation as a practice whereby water supply is reduced below maximum levels and mild stress is allowed with minimal effects on yield. Deficit irrigation can be applied under conditions of scarce water supply and it can lead to greater economic gains. (Mohawesh and Karajeh, 2015) suggested that deficient irrigation should assure water stress that is not severe to cause negative effects in case of delayed watering. Armstrong *et al.* (2001) revealed that some farmers irrigate when a certain portion of the crop start wilting. It is important to know crop response to water stress during certain growth stages or else throughout the season. High yielding varieties are vulnerable to water stress than low yielding types. Crops suitable for deficit irrigation are usually short-seasoned crops and those that are drought tolerant (Phocaides, 2002).

According to Broner (2005), the need for irrigation is determined by soil moisture content and soil moisture tension. However, it is important to know a critical level to start irrigation to avoid soil becoming dry to an extent that it limits plant growth. Irrigation scheduling enables uniform water distribution preventing cases of under- and over-irrigation (Broner, 2005). It also saves water and energy needed for irrigation. Availability of adequate amount of moisture at critical stages of plant growth optimizes metabolic processes and effectiveness of mineral uptake (Seyfi and Rashidi, 2007). The authors observed that prudent use of irrigation water can help bring more area under irrigation. Similarly, Mohawesh and Karajeh (2015) indicated that, under low water availability, suitable irrigation management and scheduling are indispensable to increase water use efficiency in agriculture.

Water stress can be defined as reduced water availability which can either be due to water scarcity (drought), osmotic stress (high salt concentration) and water-logging as a result of too much water. Water stress may reduce photosynthesis, respiration, ion uptake; have an effect on metabolism and growth pattern in the plant (Jaleel *et al*., 2009; Naseri *et al*., 2010; Seyfi and Rashidi, 2007). Most plants have the ability to adapt to stress to enable growth and survival during water stress and subsequent survival. Managing water to reduce stress means knowing plant water requirement, early recognition of symptoms of water stress and planning ahead. Transpiration and stomatal functioning influence post-harvest quality of ornamental plants in the greenhouse. The rate of transpiration can shorten shelf-life and water stress causes loss of aesthetic value. Greenhouse production with controlled day length, temperature, relative humidity and water regimes aim at high quality ornamental plants with as little cost of production as possible (Arve *et al*., 2011).

Irrigation intensity depends on the soil and the amount of moisture it can hold for plant use called plant available water. The amount of water removed from the soil by the plant roots through absorption is known as the depletion volume (Arve *et al*., 2011). Irrigation should begin only when plants experience water stress severe enough to reduce yield and quality. Stress will cause reduction in yield and quality depending on the type of crop, and stage of development. Scheduling irrigation to determine when to irrigate should be done with respect to crop sensitivity to stress (Arve *et al*., 2011). Water stress on broadleaf plants is first evident on older leaves. Common symptoms include wilting, chlorosis, browning of leaf margins, and premature defoliation, and stunted growth (Arve *et al*., 2011).

Irrigation can be important for cut flower and ornamental plants because many are shallow rooted and, therefore, sensitive to water shortage. Cut flower and ornamental plant production is a high-cost enterprise with high value end-products and growers need to have irrigation available as an insurance against drought. There are several potential benefits from irrigating these plants, e.g. yield increase, improvement in plant establishment, continuity of supply to market, and quality (Bailey, 1990). The purpose of this investigation was to determine the influence of different irrigation regimes on the growth and development of calathea.

MATERIALS AND METHODS

The experiment was conducted in the greenhouse in the Horticulture Department, Faculty of Agriculture and Consumer Sciences, Luyengo Campus at the University of Swaziland. The area is located in the Middleveld of Swaziland, at latitude $21^0$34'S and longitude $31^0$12'E at an altitude of 730 m. The annual precipitation is about 980 mm, with most rainfall occurring between October and April. The average summer maximum temperature is 27^0C and 15^0C in winter (FAO, 2012).

Mature calathea plants were obtained from the lath house of the Horticulture Department. The plants were propagated by division and a single shoot was potted in each bag. Black 30 cm-polyethylene bags were used. The growing medium used consisted of a mixture of garden soil, sand and kraal manure at the ratio of 1:1:1 (v/v). Other management practices like weed pulling, fertilizer and pesticide application were uniformly performed across all treatments. Water was supplied by drip irrigation system. Sub-massive pumps were used to pump water from tanks to emitters which were used for irrigation.

Four irrigation treatments namely 75, 50, 40 and 30% of allowable water depletion (AWD) were used. The 50% AWD treatment was used as the control (Mahmood and Ahmad, 2005; Shaheen *et al*., 2011). The experiment was laid out in a Randomized Complete Block design (RCBD). There were 10 plants in each treatment. Treatments were replicated four times. Irrigation scheduling was performed by use of a tensiometer (Infield7c, handheld measuring device, UMS GmbH, Munich, Germany). Tension was determined by first making a 15 cm-deep hole with a stick and placing the tensiometer inside. Soil moisture depletion was used to schedule irrigation. It is assumed that as a plant grows, it utilizes the water around its root zone and the moisture eventually reaches a level where the plant experiences stress (Martin, 2001). Calathea plants were panted in three polyethylene bags filled with the growing medium. The plants were irrigated to field capacity (FC) and tension taken. The plants were maintained without additional irrigation. As the moisture was depleted, tension was occasionally measured until all plants wilted and died (Figure 1). At each point of tension determination, soil samples were collected and their fresh and dry mass determined, which was used for the determination of soil moisture content (Ahmed and Suliman, 2010; Mahmood and Ahmad, 2005; Shaheen *et al*. 2011). The tension at the point when the plants died was the permanent wilting point (PWP).

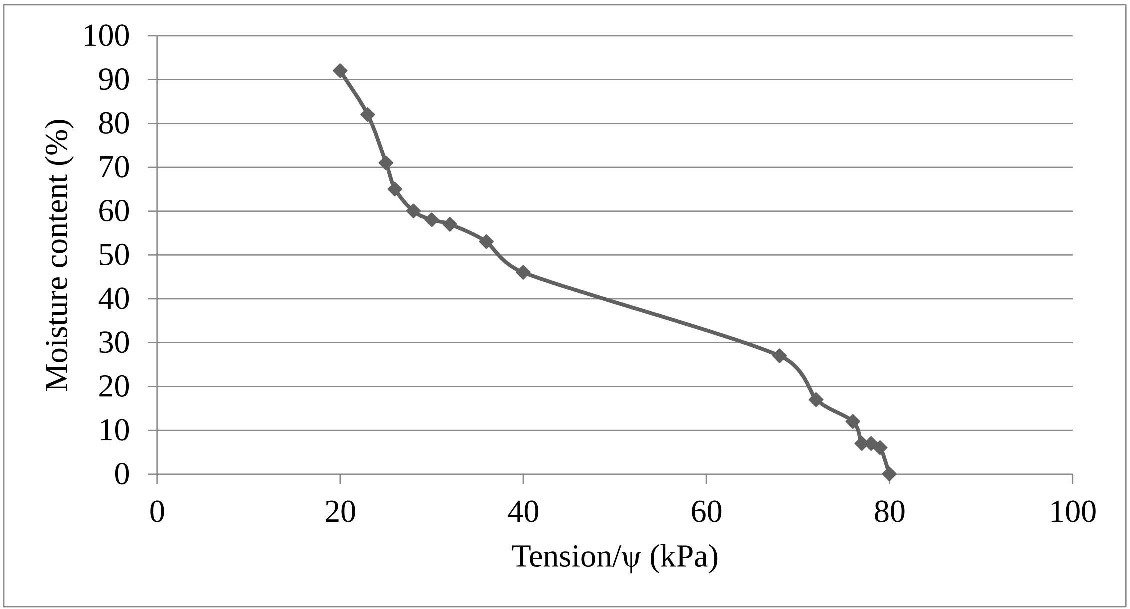

Figure 1: Irrigation scheduling based on tension and soil moisture content

Soil at FC had 20 kPa or 100% moisture content and the PWP had 70 kPa or 0% moisture content (Figure 1). The difference between FC and PWP is known as plant available water and it marks the safe range for management of irrigation (Martin, 2009).

Data collection started four weeks after potting (WAP) when the plants were well established. Data on the number of leaves, plant height, leaf length, and leaf width were collected at two-weeks intervals up until harvesting, whereby the plants were uprooted making sure the roots were not damaged. After harvesting shoot fresh mass, shoot oven dry mass, root fresh mass, root oven dry mass, and root length were determined. Leaf area was calculated by multiplying leaf length and leaf width using correction factor 0.75, which is the same as that of maize (Edje and Ossom, 2009). The data collected were subjected to the analysis of variance (ANOVA) using MSTAT-C statistical package (Nissen, 1989). For all means that were found to be significant, mean separation using the Duncan's New Multiple Range Test (DNMRT) at 5% level of significance was performed (Little and Hills, 1978).

RESULTS

Plant height

The highest plant height (28.5 cm) was obtained from calathea irrigated at 50% AWD (Figure 2). The next best result in terms of plant height was obtained from plants irrigated at 75% AWD. However, the lowest plant height (24.7 cm) was obtained from plants irrigated at 30% AWD determined 12 WAP. Reducing the irrigation water from 50 to 30% AWD resulted in an almost 15% reduction in plant height of the plants.

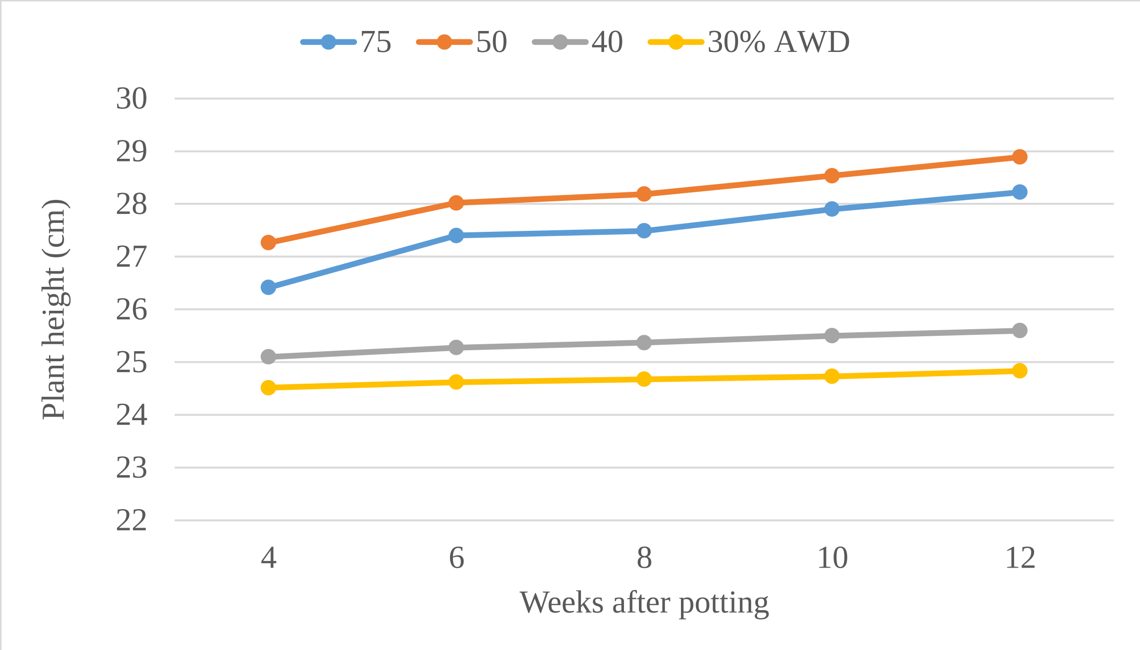

Figure 2: Effects of irrigating at different moisture depletion levels on plant height of calathea.

Leaf area

The highest leaf area (57.2 cm^2) was obtained from calathea plants irrigated at 50% AWD at 12 WAP (Figure 3). The next best result was obtained from plants irrigated at 75% AWD. However, plants irrigated at 30% exhibited the lowest leaf area (49.0 cm^2). Irrigating the plants at 30% AWD resulted in an almost 15% reduction in leaf area when compared to those irrigated at 50% AWD.

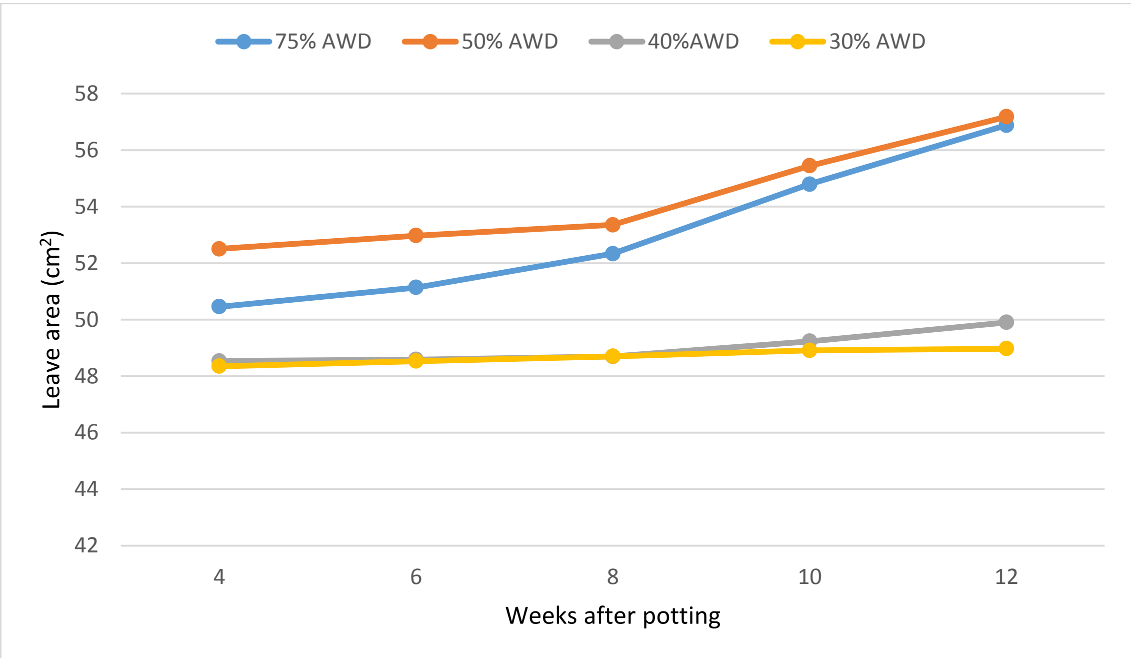

Figure 3: Effects of irrigating at different moisture depletion levels on leaf area of calathea.

Number of leaves

Irrigation scheduled at 75% AWD induced the highest number of leaves (12.1) in calathea at 12 WAP (Figure 4). The next best results were obtained from plants irrigated at 50% AWD. The lowest number of leaves (5.1) was observed in plant irrigated at 30% AWD. Irrigating the plants at 30% AWD resulted in an almost 60% reduction in number of leaves per plant as compared to those irrigated at 75% AWD.

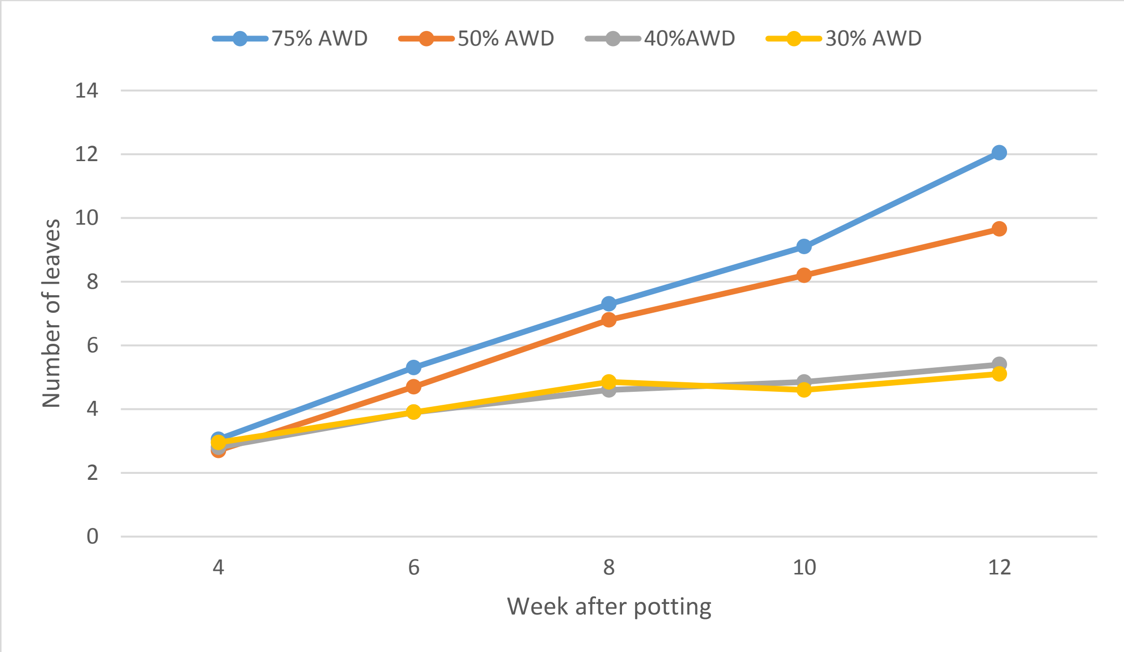

Figure 4: Effects of irrigating at different moisture depletion levels on number of leaves over of calathea.

Fresh and dry shoot masses

There was a significant ($P<0.05$) difference in fresh mass of calathea irrigated at different moisture depletion levels (Figure 5). Irrigation scheduled at 75% AWD produced plants with the highest shoot fresh mass (39.0 g) which was significantly ($P<0.05$) different from plants irrigated at 50, 40 and 30% AWD at 12 WAP. The next best result was obtained from plants irrigated at 50% AWD. The lowest shoot fresh mass (16.6 g) was obtained from plants irrigated at 40% AWD which was not significantly ($P>0.05$) different from those irrigated at 30% AWD. Irrigating the plants at 30% AWD resulted in an almost 60% reduction in shoot fresh mass when compared to those irrigated at 75% AWD. Each decrease in irrigation water application resulted in a corresponding reduction in shoot fresh mass (Figure 5).

Similarly, there was significant (P<0.05) difference in dry mass of calathea irrigated at different moisture depletion levels (Figure 5). Irrigation scheduled at 75% AWD produced plants with the highest shoot dry mass (4.2 g) which was significantly (P<0.05) different from plants irrigated at 50, 40 and 30% AWD at 12 WAP. The next best result was obtained from plants irrigated at 50% AWD. The lowest shoot dry mass (1.8 g) was obtained at from plants irrigated at 40% AWD. Similarly, irrigating the plants at 30% AWD resulted in an almost 60% reduction in shoot dry mass when compared to those irrigated at 75% AWD. Similarly, each decrease in irrigation water application resulted in a corresponding reduction in shoot fresh mass (Figure 5).

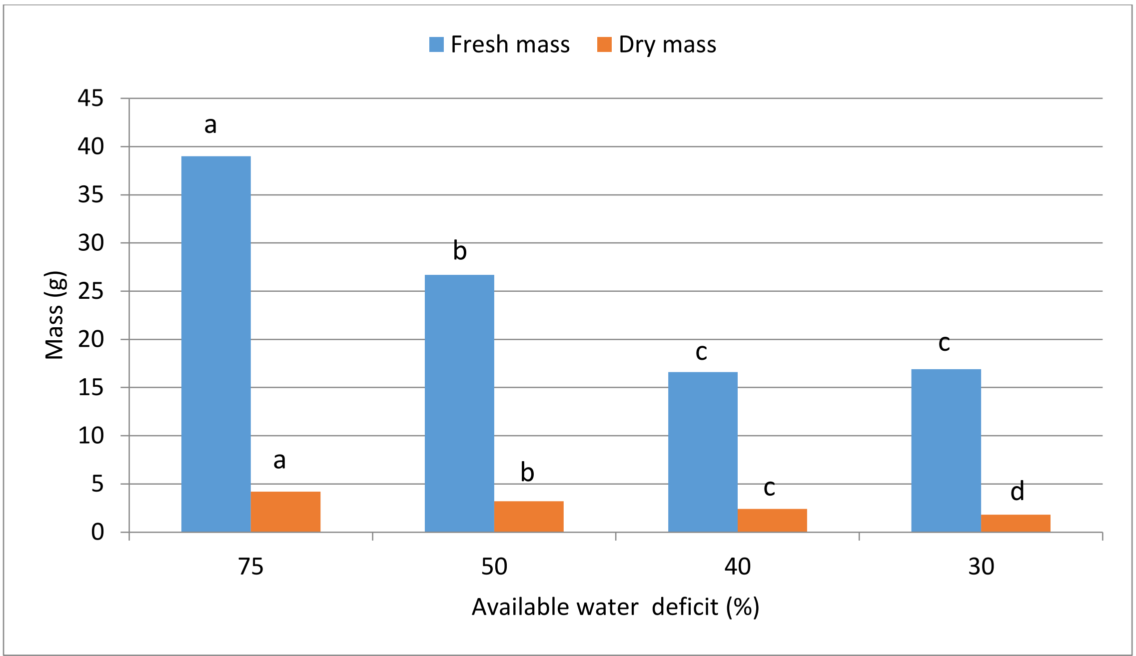

Figure 5: Effects of irrigating at different moisture depletion levels on shoot fresh and dry masses in calathea at 12 WAP.

Fresh and dry root masses

There was a significant (P<0.05) difference in fresh root mass of calathea in all the treatments (Figure 6). The highest root fresh mass (19.4 g) was obtained from plants irrigated at 75% AWD which was also significantly (P<0.05) different from those of plants irrigated at 50, 40 and 30% AWD (Figure 6). The lowest root fresh mass (7.6 g) was obtained from plants irrigated at 30% AWD and was not significantly (P>0.05) different from that of plants irrigated at 40% AWD. Irrigating the plants at 30% AWD resulted in an almost 60% reduction in root fresh mass when compared to those irrigated at 75% AWD.

There was a significant (P<0.05) difference in oven dry root mass of the plants irrigated at different water depletion levels (Figure 6). Irrigation scheduled at 75% AWD induced the highest oven dry root mass (2.0 g) which was significantly (P<0.05) different from that obtained from all other treatments at 12 WAP. The lowest oven dried root mass (1.0 g) was obtained from calathea plants irrigated at 40% AWD which was not significantly (P>0.05) different from that of plants irrigated at 30% AWD. Irrigating the plants at 40% AWD resulted in an almost 45% reduction in root dry mass when compared to those irrigated at 75% AWD.

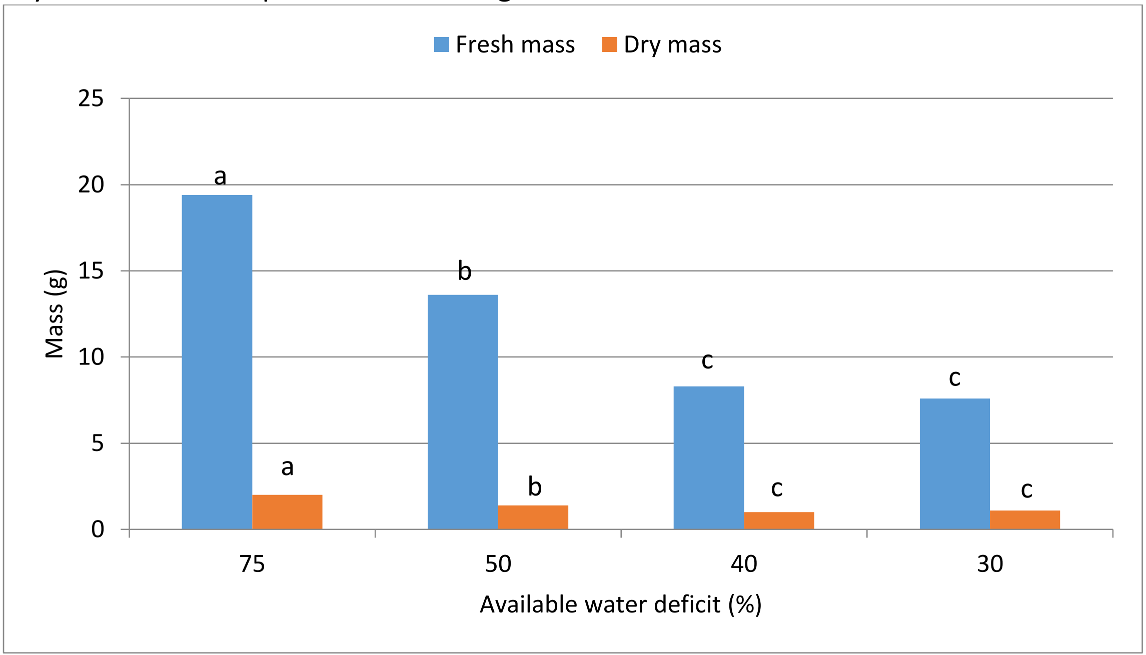

Figure 6: Effects of irrigating at different moisture depletion levels on fresh and oven dry root masses of calathea at12 WAP.

Root length

There was no significant (P>0.05) difference in root length of calathea plants irrigated at the different AWD (Figure 7). Plants irrigated at 75% AWD level had the highest root length (15.2 cm). The next best result was obtained from plants irrigated at 50% AWD. Plants irrigated at 30% AWD had the lowest root length (12.3 cm). Every decrease in water applied resulted in a corresponding decrease in root length of the plants.

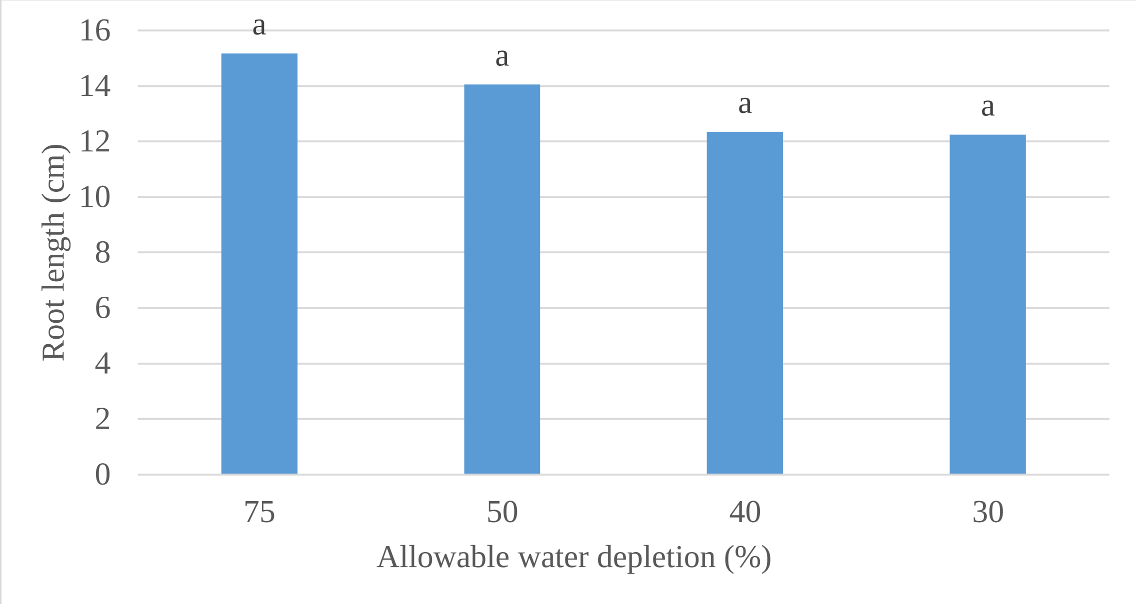

Figure 7: Effects of irrigating at different moisture depletion levels on root length of Calathea 12 AWD.

DISCUSSION

The highest plant height was obtained from calathea irrigated at 50% AWD followed by those irrigated at 75% AWD. Ngubeni and Wahome (2012) reported almost similar results where carnations irrigated at 75% and 50% had the highest plant height. Irrigating the plants at 30% AWD resulted in the lowest plant height throughout the growing period. Akinci and Losel (2009) reported that water stress caused major reductions in plant height as it reduces cell division and elongation. Hsiao (1973) stated that water stress directly and physically reduce growth by reducing cell turgor. The reduction in plant height of calathea in this investigation at low irrigation rates of 30 and 40% AWD could also have been attributed to water stress.

The highest leaf area was obtained from calathea plants irrigated at 50% AWD level while the lowest leaf area was obtained in plants irrigated at 30% AWD. The highest number of leaves was obtained at 75% AWD and the lowest was obtained at 30% AWD. Sharp and Davies (1979) reported that water stress drastically reduces leaf area expansion. Akinci and Losel (2009) also reported that water stress can cause great reductions in height, leaf number, and leaf area index, fresh and dry weight. However, Hsiao (1973) reported that mild stress can reduce the development of leaf surface area without affecting photosynthesis.

Calathea irrigated at 75% AWD had higher fresh and dry masses of both shoots and roots when compared to the other treatments. Plants irrigated at 30% AWD had the lowest fresh and dry masses of shoots and roots. Similar results were obtained by Kazaz *et al*. (2010) using carnations. Jaleel *et al.* (2009) stated that the most common effects of water stress are reduction in fresh and dry biomass production. Chapin (1991) reported that a decline in leaf growth leads to a decline in dry weight accumulation.

Akinci and Losel (2009) argued that growth rates are generally reduced by limited water supply and shoot growth being more inhibited than root growth. Efetha (2012) reported that depletion of soil water to less than 60% of available soil water can result in reduced root growth in beetroot. Similarly, Sharp and Davies (1979) reported that water stress drastically reduces root elongation. The maximum root length in this investigation was observed at 75% AWD while the lowest was obtained from plants irrigated at 30% AWD. To ensure that soil water is adequate throughout the entire root zone, soil water has to be depleted not more than 50% (Efetha, 2012). Enciso *et al*. (2007) also stated that soil conditions such as compact layer, shallow water table and dry soils can limit root growth. Hsiao (1973) stated that slow root growth in water stressed plants is caused by back pressure exerted by the soil as turgor to provide necessary cell pressure is reduced. However, in this investigation, no significant reduction in root length was observed in the different irrigation regimes.

CONCLUSION

Calathea irrigated at 75% AWD resulted in higher number of leaves, shoot fresh and dry masses, roots fresh and dry mass as well as leaf length. Plants irrigated at 50% depletion level had the highest plant height and leaf area. Irrigating the plants below 50% AWD resulted in a significant reduction in most of the parameters determined. From the study, it can be recommended that farmers who are interested in scheduling irrigation by the use of allowed soil water depletion should irrigate at 75% AWD level.

REFERENCES

Ahmed, F.E., and Suliman, A.S. (2010). Effect of water stress applied at different stages of growth on seed yield and water use efficiency of cowpea *Agriculture and Biology Journal of North America.* 1: 534-540.

Akinci, S. and Losel, D. M. (2012). *Plant water stress response mechanisms*. University of Sheffield, United Kingdom.

Ali, M.A., Abbas, A., Niaz, S., Zulkiffal, M. and Ali, S. (2009). Morpho-physiological criteria for drought tolerance in sorghum (*Sorghum bicolor*) at seedling and post-anthesis stages. *International Journal of Agriculture and Biology* 11: 674-680.

Armstrong, D., Thompson, C., O'Donnell, D. and Hinton, S. (2001). Irrigation Scheduling, Wise watering irrigation course, Tasmania.

Arve, L., Torre S., Olsen, J. and Tanino, K. (2011). *Stomatal response to drought stress and air humidity*, Norwegian University of Life Science, Norway, Canada.

Bailey, R. 1990. *Irrigated crops and their management*. Farming Press, Ipswich, UK.

Bot, P. (2010). *Effects of different irrigation levels on vegetative growth*, Uludag University, Turkey.

Broner, I. (2005). Irrigation Scheduling. http://www.ext.colostate.edu/pubs/crops/04708.pdf. 07/03/13.

Chapin, S. F. (1991). Integrated response of plants to stress. *American Institute of Biological Sciences* 41: 29-36.

Edje, O.T. and Ossom E.M. (2009). *Crop Science Handbook*. Blue Moon Publishers, Manzini, Swaziland.

Efetha, A. (2012). Irrigation Scheduling for Sugar Beet in Southern Alberta. http://www. agriculture.alberta.ca. 07/03/13.

Enciso, J. M., Porter, D. and Peries, X. (2007). *Irrigation monitoring with soil water sensors*. The Texas A &M University. United States of America.

FAO. (2012). Swaziland: Geography, population and water resources. http://www.fao.org /docrep/V8260B/V8260B11.htm. 23/04/12.

Hillel, D., 1982. *Advances in Irrigation*. Volume 1. Academic Press, New York, USA.

Hoffman, G. J., Howell, T. A. and Solomon, K. H. (1992). *Management of farm irrigation systems*. American Society of Agricultural Engineers, St. Joseph, Michigan.

Hsiao, T. C. (1973). Plant response to water stress. *Annual Review of Plant Physiology* 24: 519-570.

Jaleel, C. A., Manivannan, P., Wahid, A., Farooq, M., Somasundaram, R. and Panneerselvam, R. (2009). Drought stress in plants: a review on morphological characteristics and pigments composition. *International Journal of Agriculture and Biology* 11: 100-105.

Kazaz, S., Askin, M. A., Aydinsakir, K., Senyigit, U. and Kadayifci, A. (2010). Effects of different irrigation regimes on yield and some quality parameter of carnations. *Scientific Research and Essay* 5: 2921-2930.

Little, T. M. and Hills, F. J. (1978). Agricultural experimentation, design and analysis. John Wiley and Sons, Inc., New York.

Mahmood, N. and Ahmad, R.N. (2005). Determination of water requirements and response of wheat to irrigation at different soil moisture depletion levels. *International Journal of Agriculture and Biology* 7: 812-815.

Mannin, P. and Gallina, D. (1996). Effects of soil water on biochemical changes in some peach rootstock and cultivars. *Journal of Ataturk Central Horticultural Research Institute*, 25(1-2): 71-85.

Martin, E. (2001). Methods of measuring for irrigation scheduling. http://www.cals .arizona.edu/pubs/water/az1220.pdf. 07/03/13.

Mohawesh, O. and Karajeh, M. (2015). Greenhouse evaluation of deficit irrigation on the growth of tomato and eggplant and their interaction with *Meloidogyne javaca*. *South African Journal of Plant and Soil* 32: 55-60.

Naseri, R., Soleimanifard, A. and Soleimani, R. (2010). Yield and yield components of dry land wheat cultivars as influenced by supplementary irrigation at different growth stages. *American-Eurasian Journal of Agriculture and Environmental Science* 7: 684-688.

Nissen, O. (1989). *Mstat-C. A microcomputer programmed for the design and management and analysis of research experiments*. Michigan State University.U.S.A.

Ngubeni, P. and Wahome P.K. (2011). Effects of different irrigation regimes on growth, yield and quality of carnations (*Dianthus caryophyllus* L.). *UNISWA Research Journal of Agriculture, Science and Technology*. 14: 20-37.

Phocaides, A. (2002). *Micro irrigation in young fruit trees*, FAO, Rome, Italy.

Pollock, A. (2009). Houseplants: How to care for Calathea. http://www.helium.com. 07/03/13.

Seyfi, K. and Rashidi, M. (2007). Effect of drip irrigation and plastic mulch on crop yield and yield components of cantaloupe. *International Journal of Agriculture and Biology* 9: 247-249.

Shaheen, M.A., Hegazi, A.A. and Hmmam, S.S.A. (2011). Effect of water stress on vegetative characteristics and leaves chemical constituents of some transplants olive cultivars. *American-Eurasian Journal of agriculture and Environmental Science* 11: 663-670.

Sharp, R. E. and Davies, W. J. (1979). Osmotic adjustment and the inhibition of roots and shoots. www.pe.wzw.de/.../pdf/sds44.pdf. 23/04/12.

Trout, T.J., 2000. Environmental effects of irrigated agriculture. *Acta Horticulturae* 537: 605- 610.