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Water use and plant growth of selected container grown ornamental plants under capillary wick based irrigation system and conventional irrigation system in Kenya

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Abstract

The Ornamental Horticulture industry is a major industry in the world, comprising a complex group of enterprises which consume a lot of water. The current irrigation production system of potted ornamental plants in Kenya involves the use of hosepipes and watering cans, methods which are inefficient as water and nutrients are lost through drainage. A study was carried out from May 2015 to April 2016, in Jomo Kenyatta University of Agriculture and Technology (JKUAT) farm, Kenya, to evaluate a sub irrigation system, the Capillary Wick based Irrigation System, CWS, for selected potted ornamental plants (*Spathiphyllum clevelandii*, white anthurium; *Cordyline terminalis*, red dracaena; *Chlorophytum comosum*, spider plant; *Dracaena fragrans*, corn plant and *Epiprenum aureus*, money plant) production, as compared to the Conventional Irrigation System, CIS, overhead irrigation. The experiment was laid out in a split plot design replicated three times. The amount of water applied in the two systems was determined weekly throughout the growing period. Vegetative growth in both systems was assessed in terms of leaf expansion and plant height. The growth data was subjected to Analysis of Variance (ANOVA) and means separation done by Turkey at $p \leq 0.05$. CWS resulted in an average of 63.75% reduction in net water use compared with CIS. Thus, CWS offers promising potential for potted ornamental plants production when compared with CIS, given the added benefits of water conservation, reduced labour cost and nutrient runoff. Studies should be done with more ornamental plant species so as to determine their suitability for growing in the CWS.

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Introduction

The Ornamental Horticulture industry produces all kinds of plants – trees and shrubs, perennials and annuals, cut flowers and pot plants. It is a major industry in the world comprising a complex group of enterprises involved in the production and sales of plants in nurseries and florist crops, design of interior and exterior landscapes and the development of recreational areas for enjoyment, which consume a lot of water. Usually, generally, in Kenya, irrigation of potted ornamental plants is done using overhead irrigation systems such as watering cans and hose pipes, methods which can be very inefficient in water use, using large quantities of water and fertilizer. Irrigation systems that water directly into the containers apply less water than overhead application irrigation systems, thus conserving water. An example of such a type of irrigation system is the CWS (Bainbridge, 2002).

Effective management of water for ornamental potted plants production in water-scarce areas requires efficient approaches. Kenya is classified as a water scarce nation and Agriculture consumes 70% of the available water limiting access to water for domestic, industrial, environmental, recreational and energy production uses. Overhead irrigation is the most practical and the most commonly used irrigation system for potted ornamental plants. In practise, in the field, many nursery growers use drip or microjet irrigation for crops grown in containers >20 (twenty) litres (Beeson & Knox, 1991).

A number of approaches are being used by nursery growers to improve irrigation management, enhance efficient water use and to minimize the detrimental effect of water stress in plants. The CIS, overhead watering, results in lots of water loss and runoff (Klock-moore & Broschat, 2001). CWS, a subirrigation system, is a new innovative technique of irrigation that is simple to install, operate, and uses minimal amount of water and fertilizer (Bainbridge, 2002). It involves the use of a device that delivers water by capillary movement from a reservoir to the plant growing medium and has potential to enhance crop production and can therefore contribute to food security. This system is not currently commercially used in Kenya and is therefore necessary to evaluate its performance in order to determine its suitability for greenhouse ornamental potted plants production.
Generally, the current production system of potted ornamental potted plants in Kenya involves the use of overhead irrigation systems which often employs hose pipes and use of watering cans. This type of production is especially common for 15 litres container sizes or smaller. However, these methods are inefficient since the amount of water that actually reaches the plants is in the range of 12 to 50% (Beeson & Knox, 1991) More efficient systems are needed to be adopted for the production of potted ornamental plants especially with the increasing concern over environmental pollution by water arising from plants production systems. Greenhouse cultural production systems must pace up with environmental regulations aimed at protecting water resources. Sub irrigation systems can improve efficiency of water used throughout the production period, since water and nutrients are re-used.

Recently, there has been ongoing research to develop a CWS for use under Kenyan conditions which has identified a locally available wick material, that is, polyester cloth material, commonly used as shoulder shawl. It had the best performance in terms of water absorption pattern and maximum capillary height but had slightly lower water holding capacity, out of the five wick materials tested (Wesonga *et al.,* 2014). The use of this locally available material can ensure that the system is affordable to the majority resource poor growers in Kenya, who make a majority of the ornamental potted plant nurseries production units. So far, the study focus of CWS under the Kenyan conditions had been focusing on vegetable production (Wesonga *et al.,* 2014), but the system could be utilized in other areas such as potted ornamental plants whose management is challenging. This method has been used in mesquites, *Prosopis grandulosa* (Bainbridge, 2002), Palo verde, *Cercidium floridium* (Bainbridge, 2002), Kalanchoe, *Kalanchoe blossfeldiana* (Son *et al.,* 2006) and white anthurium, *Spathiphylum clevelandii* (Bryant and Yeager, 2002; Yeagar and Henley, 2004) among others in various countries.

Our objective was to evaluate efficient irrigation system for selected potted ornamental plants (*Epiprenum aureus,* money plant; *Spathiphyllum Clevelandii,* white anthurium; *Draceana fragrans*, corn plant; *Chlorophytum comosum,* spider plant; and *Cordyline terminalis,* red draceana) under CWS and CIS in Kenya.

Materials and methods

Experimental site

The experiment was conducted at JKUAT farm, Block A, Juja-Kenya (latitudes 3°35"S and Longitudes of 36°35"E, altitude 1525 meters above sea level) during the period from May, 2015 to April, 2016 (GoK, 1997). Juja is located 36km North-East of Nairobi along the Thika-Nairobi highway and is located in the Upper Midland Zone four which is semi-humid to semi-arid. It has a mean annual temperature of 20°C and mean maximum temperature of 30°C (Muchena *et al*. 1978; Wanjogu and Kamoni, 1986). The area receives an average rainfall of 856 mm with a bimodal distribution (Kaluli *et al.,* 2011).

Plant materials and Experimental Design

The plant materials consisted of *Cordyline terminalis,* red dracaena; *Epiprenum aureus,* money plant; *Dracaena fragrans,* corn plant; *Spathiphyllum clevelandii,* white anthurium and *Chlorophytum comosum,* spider plant. They were obtained from Farmline nursery, a commercial ornamental potted plant nursery, in Kasarani, Nairobi, for propagation purposes. The experiment was carried out as a split plot in complete randomized design with three replications. Three methods of fertilization application of top fertilization, side fertilization and fertigation formed the main plots while the two methods of irrigation were allocated to sub-plots.

Cuttings *of Cordyline terminalis,* red dracaena; *Epiprenum aureus,* money plant; and *Dracaena fragrans,* corn plant; and divisions of *Spathiphyllum clevelandii,* white anthurium and *Chlorophytum comosum,* spider plant; were propagated in the Department of Horticulture, JKUAT, nursery tunnels in sixty hole propagation trays, under coco-peat sand mixture while maintaining an EC of 1.2 (Digital EC Meter DEC-2, Atago Company Limited, Tokyo 105-0011, Japan) and pH of 5.5 (Digital pH Meter DPH-2, Atago Company Limited, Tokyo 105-0011, Japan). Before insertion, cutting bases were treated with rooting powder containing 0.6% indole-3-butyric acid (Hormoril Rooting Powder T-6, Amiran Kenya Ltd). After four weeks of growth, with plants at two leaf stage, plants were transplanted in Polyvinyl Chloride (PVC) pots of four (4) litres capacity which were used to establish the plants in soil: sand: manure (3:2:1) media mix (Wesonga *et al.,* 2014).

Source: Authors, 2015

Fig. 1. (a) Cuttings of *Cordyline terminalis,* red dracaena and (b) divisions of *Chlorophytum comosum,* spider plant, growing in JKUAT, Department of Horticulture tunnels.

The capillary wick irrigation system was laid out in a polythene covered greenhouse using six (6)-inch diameter reservoir plastic pipes, raised thirty (30)cm above the ground on a metal framework while the conventional irrigation system containers were placed directly opposite beside them on the same metal framework. The metal framework was used as a raised stand on which the potted plants were placed. The distance between the pipes was one (1) meter.

The CWS pots were first drilled with three drainage holes of five (5)mm circumference at the bottom of the pots, and then on each pipe, holes four (4)cm by five tenths (0.5)cm were drilled with a spacing of forty (40)cm through which capillary wicks were inserted into the piping system. Capillary wicks, four (4)cm in width and forty-five (45)cm in length were then dipped in water to saturate them and then inserted to the inside of the pot through the hole and aligned to the pot's inner wall perpendicularly to the media's surface. Media was then added into the pots as per the treatments.

The treatment pots were then transferred to the CWS in the greenhouse and the wicks inserted into the piping system. The part of wick material exposed to the outside was maintained at four (4)cm. Plants were fertilized at planting and thereafter at three weeks with ten (10) grams (g)/plant of Multicote (15:7:25) slow release fertilizer (Amiran Kenya Limited).

The troughs in the CWS were held at a one (1) percent slope. Irrigation water was contained in a four hundred sixty (460) litre (L) tank raised 1.8 metres above the ground. The flow of water from the tank into the piping system was automatically controlled using a float valve as shown in Fig. three (3) below (See Fig. 3).

Water was applied to the conventionally irrigated plants from the top using a watering can, which required the plants to be watered one by one, while for the plants in the capillary wick irrigation system, they were sub irrigated with wicks placed from the side of the pots. The excess water was collected into a saucer drain under each pot for CIS system.

Data Collection and Analysis

All ten plants in each replication were used for measurements on stem length and leaf length elongation from the petiole along the midrib. Leaf length was recorded daily over a period of three weeks. Stem length and leaf number were assessed weekly for a period of six weeks since the development of these parts was slower.

Source: Authors, 2015

Fig. 2. A Research Assistant waters plants in the greenhouse with the selected potted ornamental potted plants using a watering can.

The Greenhouse temperature values were recorded daily and the average computed for the period of study (May, 2015-April, 2016) (See Fig. 5).

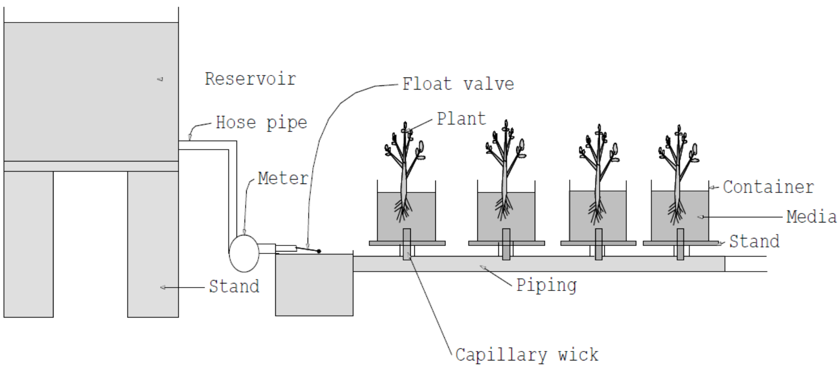

Fig. 3. Schematic diagram of capillary wick irrigation system. Water is conducted from the piping system via the capillary wick to the plant growth media in the container for plant uptake.

Fig. 4. Capillary wick irrigation system layout.

A total of ten cohorts were analyzed and averaged. Data was subjected to Analysis of Variance (ANOVA). Means separation was done by protected Fisher's least significant difference (Tukey's HSD) test at significance level of $p \leq 0.05$. Amounts of water applied by both irrigation methods were determined. Gross water use was defined as the amount of water applied. Net water use for the CIS was determined as the difference between the amounts applied and drained. Net water use for the CWS was determined as the amount of water applied, as drain water was not experienced. Daily values were cumulated over the twelve (12) month experimental period.

Results and discussion

In this study, we sought to evaluate efficient irrigation system for selected potted ornamental plants (*Epiprenum aureus,* money plant; *Spathiphyllum Clevelandii,* white anthurium; *Draceana fragrans,* corn plant; *Chlorophytum comosum*, spider plant; and *Cordyline terminalis,* red draceana) under CWS and CIS in Kenya. Specifically, we were to determine the amount of water used under CWS and CIS for the selected ornamental potted plants production, to determine the effect of CWS and CIS on growth of the selected ornamental potted plants and to evaluate the effect of fertilization method on growth of the selected ornamental potted plants under CWS.

Weather

The two treatments were placed in the same greenhouse, which led to selected potted ornamental plants in both treatments growing under the same air temperature conditions. There was variation in temperature in the greenhouse during a cool month as compared to a warmer month (Fig. 5), throughout during the growth period, with July, 2015 been the coolest month with an average temperature of 25°C while April was the hottest month with an average temperature of 36°C. This was due to the difference in seasons during the year. This can be summarized as in Fig. 5 below.

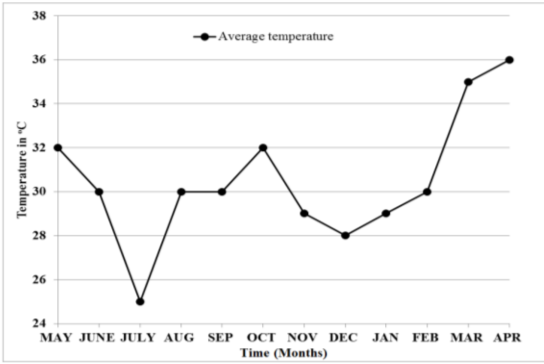

Fig. 5. Average temperatures in the greenhouse during the growth period.

Water use under CIS and CWS

Confirming our hypothesis regarding water use for the selected ornamental potted plants, our study revealed that CWS saved water averagely by 63.75% as compared to CIS. This is in line with other previous research that also reported that sub irrigation systems reduced total water use as compared to overhead irrigation systems and produced plants of similar or better quality to those grown using overhead irrigation systems (Klock-Moore & Broschat, 1999; Dole *et al.,* 1994; Holcomb *et al.,* 1992).

Where; W_{CWS} = water supplied by CWS
W_{CIS} = water supplied by CIS
W_{SV} = water saved

Plugging the values into the formula;

$$W_{SV} = \frac{W_{CIS} - W_{CWS}}{W_{CIS}} \times 100$$

Therefore, for our experiment, % water saving under the CWS can be summarized in the table below;

Table 1. Water use under CIS and CWS and the resultant percentage water saving.

MONTH	CIS	CWS	% WATER SAVING
MAY	840	307	63.5
JUNE	800	290	63.8
JULY	690	242	65
AUG	812	293	64
SEP	770	281	63.5
OCT	847	310	63.4
NOV	771	280	63.7
DEC	740	270	63.5
JAN	750	275	63.3
FEB	825	292	64.6
MAR	930	340	63.4
APR	950	349	63.3
TOTAL	9725	3529	

Our study revealed that gross water use of the CIS system was higher as compared to the gross water use by the CWS system. Over the 12 months growing period, gross water use for the CIS and CWS was 9725 and 3529 litres respectively (Fig. 6). For the CWS system, the net water use was equal to the gross water use as there was no drain.

The total gross water use for the CIS varied between 690 (July) and 950 (April) litres (Table 1) while for the CWS it varied between 242 (July) and 349 (April) litres (Table 1). These variations are due to the differences in weather (temperature) in the said months, with July been the coolest month with an average temperature of 25°C in the period of growth while April was the hottest month with an average temperature of 36 °C (Fig. 5). The annual difference of 6196 litres (Table 1) in gross water use between the CIS and the CWS implies 63.75% water savings by the CWS.

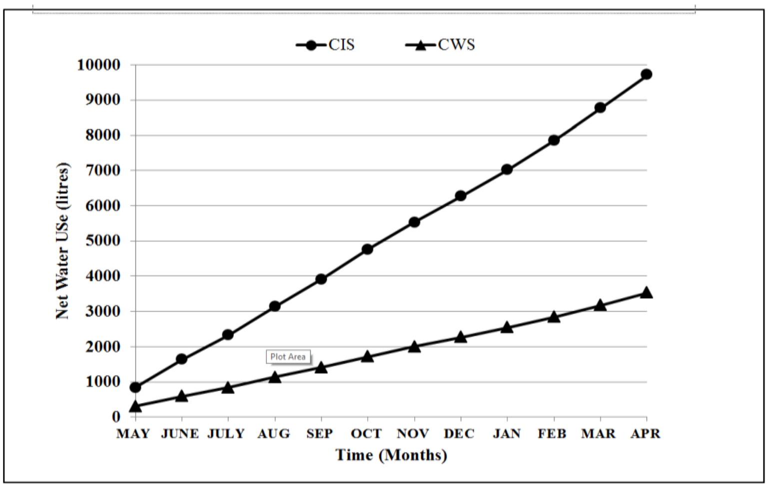

Fig. 6. Cumulative amount of water use under CIS and CWS between May, 2015 and April, 2016.

It is worth noting that CIS, overhead watering, was apt to splash soil and water from the selected potted ornamental plants pots during the process of watering. When this happened in the early stages of the experiment, we usually took thirty minutes to water all the plants in the experiment. So as to take care of this water loss, we adopted very specialized attention and care while watering using CIS so as to make sure such losses are completely avoided. This meant that we had to increase the watering hours to one and a half hours to water all the CIS potted ornamental plants. For potted plants grown under the CWS system, the only time we spent during the watering process was while refilling the reservoir tank that supplies water to the CWS pipes where we had inserted the capillary wicks that delivered water to the media in the pots. Thus, in our study, CWS helped reduce remarkably the working hours for watering to just ten (10) minutes. Lee *et al.,* reported that CWS helped reduce remarkably the working hours for watering from 4 hours in overhead irrigation system to just five (5) minutes for cyclamen grown in pots.

From our study, it was observed that application of CWS and the specialized attention while watering using CIS, overhead watering, we were able to effectively reduce incidences of pests and diseases throughout the growing period.

Throughout the period of growth, we never applied any pesticides or chemicals to control the pests and diseases. This is very good practice in production of ornamental plants as it ensures a high-quality plant and at the same time that which is free of pests and diseases, has the right foliage colour, quality leaves and stems and ultimately high aesthetic value for sale in the market. This ensured that the leaves were free from leaf chlorosis and necrosis. It is very clear from our study that our CWS system was highly beneficial to get uniform potted products with high quality. Capillarity action of the wick is a very important factor in wick culture systems since they are self-watering sub-irrigation systems using wick to absorb water. Capillarity and durability of the wick material were attributes for success of our capillary wick irrigation system. This, we believe, is due to the uniformity of watering, which is one of the greatest benefits of sub irrigation, because it creates uniform media moisture. In summary, sub irrigation through our CWS was an effective alternative to produce the selected potted ornamental plants. Compared with CIS, our study suggests that sub irrigation through CWS, is a viable irrigation system, yielding equal or better plant growth and nutrition with much less water (Fig. 6) and with zero leaching losses. Overall, it is significant to note that capillary wicks were able to support the selected potted ornamental plants growth effectively throughout the growing period (Fig. 7).

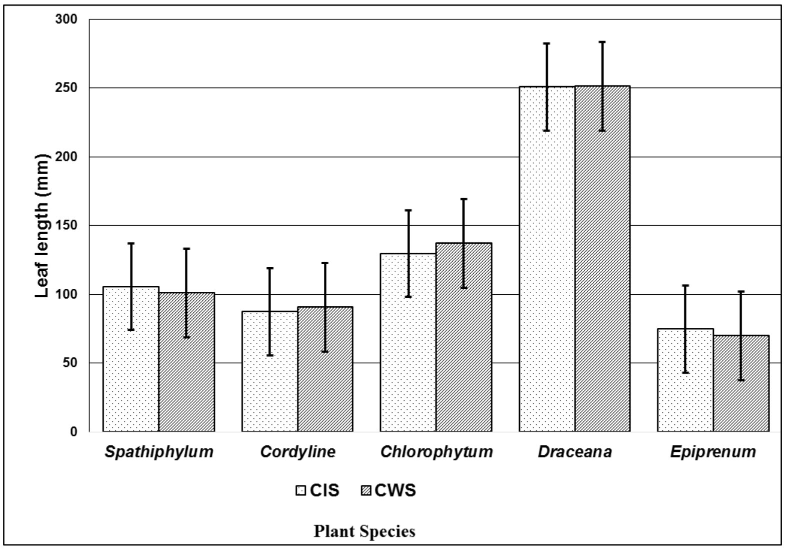

Fig. 7. Growth as influenced by irrigation system.

Ornamental potted plants that were grown in both irrigation systems were saleable and of high quality (based on colour and lack of blemishes) although our findings indicate that *Chlorophytum comosum,* spider plant; *Dracaena fragrans,* corn plant and *Cordyline terminalis,* red dracaena; had better growth under the CWS as compared to the other two species *Spathiphyllum clevelandii*, white anthurium; *Epiprenum aureus,* money plant; which performed better in CIS, although the differences were not significant. We suggest that the selected ornamental potted plants performance could be improved over time by fine tuning the nutrition and irrigation management of crops produced under these the CWS system with the added benefits of water conservation. Producing equal or better-quality ornamental potted plants under reduced water consumption is of great interest for ornamental potted plant growers. The similarity in the selected potted plant growth performance throughout the growing season was not surprising. For example, (Davis *et al.,* 2008) Observed no significant differences in growth of sub irrigated versus overhead irrigated northern red oak (*Quercus rubra* L.) seedlings. In koa (*Acacia koa* Gray), sub irrigated and overhead-irrigated plants had similar gas exchange, height, and root collar diameter (Dumroese *et al.,* 2011; Davis *et al.,* 2011).

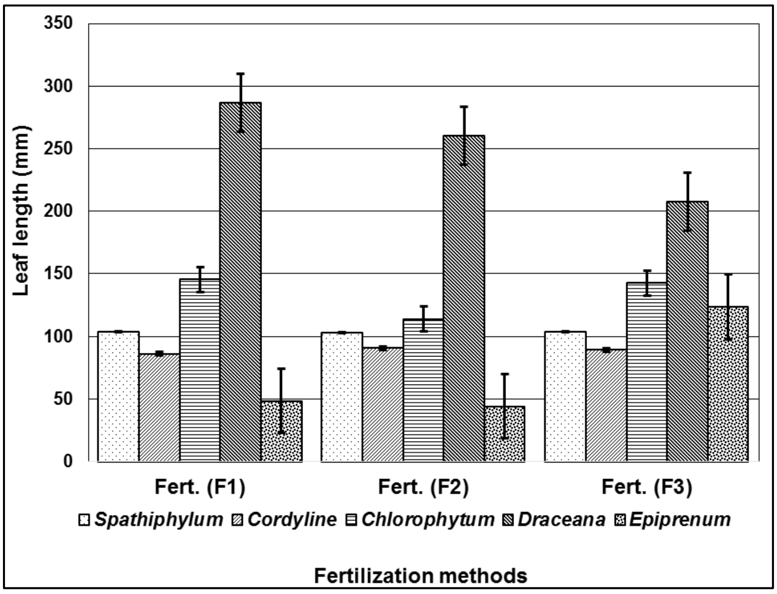

Fig. 8. Growth as influenced by fertilization method.

We applied fertilizer in our selected potted ornamental plants so as to maintain and achieve maximum growth. Inefficient fertilizer application methods do not supply the much-needed nutrients by the plants. Therefore, efficient fertilizer application methods must be adopted urgently in greenhouse for the selected ornamental potted plants production since minimizing fertilizer and water requirements for greenhouse production has become increasingly important to growers, because many are faced with higher water and fertilizer costs, decreasing availability of quality water, and government regulations provide for protecting surface and groundwater (Uva *et al*, 2001; Van Iersel, 1999).

Our findings indicate that the selected potted ornamental plants performed better under fertigation, followed by top fertilization and then side fertilization (Fig. 8). Fertigation, is the incorporation of soluble fertilizers into irrigation water. This we believe is due to the harmonization and integration between application of water and plants nutrients. The dissolved fertilizer often moves with applied water through the wick as the water is delivered to the plants. This enables the media to be supplied with uniform moisture and thus could explain why the plants performed better under fertigation (Fig. 8). Klock-moore *et al*, 2001 also found out that for overhead irrigated pots of areca palm (*Dypsis lutescens*), crossandra (*Crossandra infund ibuliformis*), pentas (*Pentas lanceolat*), and philodendron (*Philodendron*) 'Hope' plants, the water leached from the pots contained fertilizer salts. For top fertilization, even though nutrients are leached beyond the root zone, the excess water was collected through the underside saucers and re-used in the next watering cycle. This may explain why there is no significant difference between fertigation and top fertilization in our experiment. For side fertilization, the absorbability of the fertilizer on the wicks may have played a role in its uptake by the plant. Our results show that it is possible to optimize fertilization and keep environmental contamination under control, using our CWS for ornamental potted plants production. Thus, we propose that nursery growers producing potted ornamental plants adopt cultivation systems that collect and reuse the excess irrigation water.

Conclusion and recommendations

From the results of this study we conclude that production of the selected potted ornamental plants under CWS, an example of a sub irrigation system, is a water saving method by 63.75 % as compared to CIS. *Chlorophytum comosum*, spider plant; *Dracaena fragrans*, corn plant and *Epiprenum aureus*, money plant; had better growth under the CWS as compared to the other two species *Spathiphyllum clevelandii*, white anthurium;

Cordyline terminalis, red dracaena; which performed better in CIS, although the difference was not significant. Fertigation was the best fertilization method for the selected potted ornamental plants under CWS. CWS can be suited for effectively growing potted ornamental plants without lowering their quality. Our findings pave way for testing the system with a wider range of ornamental potted plants, other crops and ultimately commercialization of the system for the Kenyan conditions. CWS should be adopted for potted ornamental plants production since it conserves water, minimizes runoff, reduces need for irrigation equipment, is time efficient and economical. This will benefit our society and protect natural resources and the environment from pollution resulting from the application of excess fertilizer.

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