INTERNATIONAL JOURNAL OF SCIENCE AND NATURE

www.scienceandnature.org

INTERACTIVE EFFECTS OF IRRIGATION RATE AND LEAF HARVEST INTENSITY ON EDIBLE LEAF AND FRUIT YIELDS OF MULTIPURPOSE PUMPKIN (*Cucurbita moschata* Duchesne)

[1]Mwaura, M. M., [1,2*]Isutsa, D. K., [1]Ogweno, J. O. & [3]Kasina, M.
[1]Egerton University, P. O. Box 536-20115, Egerton
[2]Chuka University, P. O. Box 109-60400, Chuka
[3]Kenya Agricultural Research Institute, P. O. Box 14733-00800, Nairobi
[*]Correspondence author's e-mail: dorcaski@yahoo.com

ABSTRACT
Pumpkin (*Cucurbita moschata* Duchesne) leaves, flowers, fruits and seeds are highly delectable and nutritious. However, their yields are lowered by deficit rainfall and intensive leaf harvesting. This study determined effects of irrigation rate and leaf harvest intensity (LHI) on their yields. A split-plot experiment with four replications in a rainshelter to block rainfall was used in Embu and Kabete sites. Irrigation was applied to main plots and leaf harvest intensity to split-plots. Irrigation rates were 1, 2, 3 and 4 litres once weekly per plant through drip tubes. Leaf harvest intensities were 0, 1, 2 and 3 leaves once fortnightly per branch. Data were analysed using JMPIN 5.1 program and means were separated using the Tukey's Studentized Range Test at P=0.05. Irrigation had no significant (P>0.05) effect on leaf and fruit yields. Leaf harvest intensity had a significant (P<0.05) effect on edible leaf and fruit number and weight. The 3 LHI had significantly highest edible leaf number (115.4 in Embu and 121.8 in Kabete) and fresh weight (1687.7 g in Embu and 1598.7 g in Kabete). The 2 litres plus 3 LHI had significantly highest edible leaf number and weight (129.3 and 1885.8 g in Embu; 129.8 and 1803.75 g in Kabete). Increasing LHI significantly decreased fruit number and weight. The 1 LHI had significantly highest total fruit number (12.2) and weight (17.7 kg), while the 3 LHI had the lowest (10.8 and 5.2 kg). Interaction between irrigation rate and LHI had no significant effect on total fruit number and weight. It is recommended to harvest two leaves per branch for quality marketable leaves and one leaf per branch for more and heavier fruits. Generally, applying 3 litres of water once weekly per plant is recommended to supplement deficit rains and ensure highest and quality yields.

KEY WORDS: Climate change mitigation, Fruit-vegetable, Rainshelter, Water deficit.

INTRODUCTION

Pumpkin (*Cucurbita moschata* Duchesne) is an African Indigenous Vegetable that is rapidly gaining popularity in urban, peri-urban and rural areas in Africa. Pumpkin serves as a reliable source of produce and provides families growing them with a variety of diets that help ensure stability in household food security. Leaves, flowers and fruits are used as vegetables, while seeds are consumed after roasting to make snack foods. Pumpkins grow in almost any part of East Africa and store for over 8 months after harvesting as long as the fruit retains its stalk (Grubben and Chigumira-Ngwerume, 2004). Due to these features, pumpkin is a suitable food security crop (Horticultural Crops Development Authority, 2012).

Currently there is an increase in production and consumption orchestrated by reported medicinal properties (Horticultural Crops Development Authority, 2012). Pumpkins are known to possess antioxidant beta-carotene, which has been shown to help improve immune function and reduce the risk of cancer and heart disease. In addition, pumpkin also contains many vitamins and nutrients, including calcium, iron, magnesium, potassium, zinc, selenium, niacin, foliate, and vitamins A, C, and E (Ghanbari *et al.,* 2007; Ondigi *et al*., 2008). Multi-purpose pumpkin production in Kenya is constrained by water deficit and unregulated leaf harvest intensity that lead to low leaf vegetable and fruit yields. Although potential of increasing pumpkin production through supplementary irrigation and regulated leaf harvest intensity exists, there is limited knowledge on the effects of integrating supplementary irrigation with leaf harvest intensity on the leaf vegetable and fruit yields. Water deficit management in pumpkin production among smallholder farmers is achieved by intercropping plants or restricting production to rainy periods. Water acts as a mode of transport for both organic and inorganic solutes in the soil and plant (Suat, 2006). The main consequence of moisture deficit is decreased growth and development caused by reduced photosynthesis. Low water availability causes physical limitations in plants. During moisture deficit, stomata close to conserve water and this also closes the pathway for the exchange of water, carbon dioxide and oxygen, resulting in decreased photosynthesis and consequently reduced yields (Katul *et al*., 2010). Plant leaves play a very important role in plant growth, development and production. They function as a centre of photosynthesis, which is a source of assimilates required for plant growth, development and production processes, among others (Ibrahim *et al.,* 2010). Knowledge of the effect of integrated water and leaf harvest intensity management on multi-purpose pumpkin yields could empower smallholder farmers to enhance production of the fruit-vegetable. The objective of the present study was to determine the interactive effects of irrigation water rate

and leaf harvest intensity on edible leaf and fruit yields of multi-purpose pumpkin.

MATERIALS AND METHODS

Multi-purpose pumpkin growth in the field

Multi-purpose pumpkin was planted in a rain shelter in two different sites at the Kenya Agricultural Research Institute (KARI) Centers at Kabete and Embu. KARI-Kabete station is located 8 km northwest of Nairobi at 36°41' E, 01°15' S and 1737 m above sea level (Jaetzold *et al*., 2005). The area is sub-humid with average annual maximum and minimum temperatures of 23.8^{o}C and 12.6^{o}C, respectively. It has a bimodal annual rainfall pattern, averaging 980 mm and ranging from 600 to 1800 mm, in two distinct rainy seasons (Jaetzold *et al*., 2005). The site has well drained, very deep dark-reddish brown to dark-red, friable clay soil classified as a Humic-Nitisols, according to the Soil Map of the World, and known locally as the Kikuyu red clay loam (Jaetzold *et al*., 2005). The KARI-Embu is located in Embu County and lies between latitudes 0°08' and 0°35' S and Longitudes 37°19' and 37°40' E, at 1000-1500 m above sea level (Jaetzold *et al*., 2005). The site has deep Nitisols of moderate to high fertility. It has a bimodal rainfall pattern and an average annual rainfall of 1250 mm per year, which is divided into two distinct rainy seasons. The study was conducted from June 2012 to April 2013 to determine the interactive effects of irrigation water rate and leaf harvest intensity on edible fruit and leaf yields of multi-purpose pumpkin. A split-plot experiment embedded in a Randomized Complete Block Design with four replications was used. Irrigation was applied to main plots and leaf harvest intensity to split-plots. Individual plots measured 2 m x 2 m separated from each other by 1 m buffer. The four irrigation rates and the four leaf harvest intensities formed 16 treatment combinations, which were randomly allocated to each of the four replicates. Specially designed drippers (Amiran Kenya Limited, Nairobi) were used to uniformly discharge two litres of irrigation water per hour. To achieve the different irrigation rates of 1, 2, 3 and 4 litres, drippers were opened for ½, 1, 1 ½, and 2 hours per plant once a week. The experimental area was kept weed-free by two hand-weeding sessions and three weed-rogueing sessions. Disease and pests were controlled using manufacturer recommended pesticides. The leaf harvest exercise entailed manual picking of mature, well developed edible leaves with the stalk intact from every branch in accordance with the particular treatment, whereby 0 LHI meant none, 1 LHI meant one leaf per branch, 2 LHI meant two leaves per branch, and 3 LHI meant three leaves per branch, once every fortnight for 10 weeks, starting from the 8 weeks after emergence. Mature leaves on all branches on a plant were harvested in accordance with the particular treatment and put together to give the total for each plant. Leaves were counted and weighed, and the weight expressed in grams per plant. Fruit harvesting was done on piece meal basis, as they attained maturity. Physiological maturity was determined by fruits having a dry leaf stalk, hard skin and dull sound when knocked with a thumb. Harvesting was done by cutting with a sharp knife to leave a stalk of 3 cm on each fruit. Fruits were counted and weighed, and the weight expressed in kilogrammes.

Data Analysis

Data collected for leaf and fruit yields in terms of number and fresh weight were subjected to analysis of variance (ANOVA) using JMPIN 5.1 (Sall *et al*., 2003) statistical software. Mean separation for all significant treatments was carried out using Tukey's Studentized Range Test at P=0.05.

RESULTS & DISCUSSION

Effect of irrigation and LHI on edible leaves

Irrigation had no significant effect (P>0.05) on the number of leaves harvested in both sites (Table 1).

TABLE 1: Effect of irrigation rate and leaf harvest intensity on number of edible leaves at different weeks after emergence

Irrigation (L): Embu	8 WAE	10 WAE	12 WAE	14 WAE	16 WAE	Total
1	17.5	25.6	26.3	26.3	21.8	77.4
2	17.3	24.7	29.4	28.9	21.9	82.3
3	15.2	25.1	28.3	25.7	21.4	74.8
4	16.2	23.7	27.6	26.9	20.3	73.6
P-value	*0.17*	*0.95*	*0.4*	*0.4*	*0.47*	*0.53*
Irrigation (L): Kabete						
1	14.9	24.9	26.2	28.0	24.7	77.9
2	14.4	22.0	28.4	27.9	23.1	74.6
3	14.4	22.9	26.0	29.2	22.4	73.4
4	15.1	21.9	26.3	25.8	20.5	68.4
P-value	*0.91*	*0.78*	*0.47*	*0.50*	*0.06*	*0.47*
LHI: Embu						
0	10.0	10.0^{c}	10.0^{d}	10.0^{c}	10.0^{d}	10.0^{d}
1	15.8	20.9^{b}	25.6^{c}	26.9^{b}	22.4^{c}	70.3^{c}
2	16.1	26.1^{b}	31.9^{b}	32.7^{b}	26.7^{b}	92.1^{b}
3	17.1	34.7^{a}	39.4^{a}	41.3^{a}	31.6^{a}	121.8^{a}
P-value	*<0.0001**	*<0.0001**	*<0.000**	*<0.0001**	*<0.0001**	*<0.0001**
LHI: Kabete						
0	10.0^{b}	10.0^{c}	10.0^{c}	10.0^{c}	10.0^{c}	10.0^{c}
1	17.6^{a}	24.7^{b}	29.5^{b}	27.5^{b}	20.5^{b}	81.3^{b}
2	19.4^{a}	29.2^{ab}	36.3^{a}	32.6^{ab}	27.1^{a}	101.4^{a}
3	19.1^{a}	35.1^{a}	35.6^{a}	37.8^{a}	27.8^{a}	115.4^{a}
P-value	*<0.0001**	*<0.0001**	*<0.0001**	*<0.0001**	*<0.0001**	*<0.000**

*Means followed by the same letters or no letters within a column are not significantly different, according to the Tukey's Studentized Range Test at P = 0.05

The amount of water applied did not significantly influence the number of edible leaves. Nevertheless, application of 2 litres in Embu had the highest total edible leaves (82.3), while 1 litre had the highest total edible leaves in Kabete (77.9). Four litres had the lowest edible leaves in both sites (73.6 in Embu and 68.4 in Kabete). Leaf harvest intensity had a significant effect (P<0.05) on bi-weekly and total number of edible leaves (Table 1). Harvesting 3 leaves significantly had the highest number of edible leaves in both sites (115.4 in Embu and 121.8 in Kabete). The number of edible leaves increased with the increase in leaf harvest intensity.

TABLE 2: Effect of irrigation rate and leaf harvest intensity on weight of edible leaves at different weeks after emergence

Irrigation (L): Embu	8 WAE	10 WAE	12 WAE	14 WAE	16 WAE	Total
1	159.3	242.6	265.7	217.4	159.6	1004.6
2	155.6	267	325.9	242.1	147.8	1098.4
3	120	306.4	300.7	255.9	170.9	1113.9
4	158	302.9	341.4	258.1	148.1	1168. 6
P-value	*0.468*	*0.2259*	*0.1785*	*0.6744*	*0.5591*	*0.3648*
Irrigation (L): Kabete						
1	56.5	124.9	151.7	242.5	288.1	823.7
2	62.3	139.7	194.1	233.5	281.9	871.4
3	69.8	148	176.3	268.8	303.8	926.6
4	68.4	167.9	202.5	234.4	254.4	887.5
P-value	*0.7721*	*0.5412*	*0.3414*	*0.8365*	*0.8938*	*0.878*
LHI: Embu						
0	10.0^{c}	10.0^{c}	10.0^{c}	10.0^{c}	10.0^{c}	10.00^{c}
1	145.9^{b}	309.4^{b}	344.6^{b}	244.8^{b}	135.8^{b}	1140.6^{b}
2	197.8^{ab}	405.5^{a}	448.1^{ab}	311.4^{ab}	224.4^{a}	1547.2^{a}
3	239.1^{a}	394.0^{ab}	431.0^{a}	407.3^{a}	256.3^{a}	1687.7^{a}
P-value	*<0.000**	*<0.0001**	*<0.0001**	*<0.0001**	*<0.0001**	*<0.0001**
LHI: Kabete						
0	10.0^{b}	10.0^{c}	10.0^{c}	10.0^{c}	10.0^{c}	10.0^{c}
1	68.6^{a}	109.5^{b}	164.3^{b}	216.0^{b}	320.0^{b}	838.4^{b}
2	77.9^{a}	198.6^{a}	229.4^{b}	295.6^{b}	300.6^{b}	1062.1^{b}
3	100.6^{a}	262.3^{a}	320.8^{a}	457.5^{a}	497.5^{a}	1598.7^{a}
P-value	*<0.0001**	*<0.0001**	*<0.0001**	*<0.0001**	*<0.0001**	*<0.0001**

*Means followed by the same letters or no letters within a column are not significantly different, according to the Tukey's Studentized Range Test at P = 0.05

Irrigation rate had no significant effect (P>0.05) on the fresh weight of edible leaves (Table 2), but the trend was that increasing irrigation water generally increased the fresh weight of edible leaves. This result indicated that increasing amount of water increased the total fresh weight of edible leaves, even if not significantly. Leaf harvest intensity had a significant effect (P<0.05) on bi-weekly and total weight of edible leaves (Table 2). Harvesting of three leaves significantly had the highest total fresh weight of edible leaves, which were 1687.7 g in Embu and 1598.7 g in Kabete. The interaction between irrigation rate and leaf harvest intensity had a significant effect (P<0.05) on the number of edible leaves (Table 3). The interaction of two and three leaves with any rate of irrigation water produced significantly higher number and weight of edible leaves. The interaction of 2 litres of irrigation with 3 LHI produced significantly the highest number and weight of edible leaves, which were 129.3 and 1885.8 g in Embu site, and 129.8 and 1803.75 g in Kabete site.The lack of a significant effect of irrigation rate on the number and weight of edible leaves was attributed to the fact that pumpkin is classified as a drought tolerant crop and can continue to grow on low amounts of soil moisture (Radovich *et al*., 2011). The one, two and three litres of irrigation water applied once per week were enough to facilitate production, while the four litres of irrigation water may have been too much, leading to anaerobic soil conditions that are known to impede root functions such as respiration, nutrient uptake and translocation (Faust, 1989). The impediment condition is in some crops manifested as stunted plant growth. Increasing leaf harvest intensity significantly increased the number of edible leaves. The impact of leaf harvest intensity on the number of edible leaves was similar to that reported by Olasantan (2007) that apical shoot harvest promotes apical shoot growth, which in turn enhances leaf growth and fruit yield in pumpkin. The declining trend observed in the weight of edible leaves as the irrigation water increased probably indicated that higher soil moisture rates favoured partitioning of assimilates to leaf initiation rather than leaf growth. These findings were in agreement with those of Asoegwu (1988) that showed that higher soil water content enhanced vegetative growth in an experiment conducted to determine the effect of irrigation on leaf and pod production in fluted pumpkin.The increase in weight of edible leaves with increase in leaf harvest intensity was similar to that reported by Madakadze *et al*., (2004) that plants with a leaf harvesting frequency of 7 days had significantly higher leaf yields than leaf harvesting frequencies of 14 and 21 days. The leaf harvest intensity of three leaves per branch in this erxperiment can be equated to the 7 days harvesting frequency in the experiment of Madakadze *et al*., (2004). Saidi *et al*., (2009) also concluded that cowpea leaf vegetable yield was significantly affected by leaf harvest interval after emergence. The significant increase of leaf number and leaf weight by moderate irrigation rate and highest leaf harvest intensity implied that provision of moderate amounts of irrigation water enabled pumpkin to regenerate more and heavier new leaves following defoliation.

Effect of irrigation rate and leaf harvest intensity on total number and weight of fruits

Irrigation rate had no significant effect (P>0.05) on the fruit number (Table 4), but the trend was that application of 1 litre had the highest fruit number (11.9) in Embu, while 3 litres had the highest fruit number in Kabete (12.6). Application of 2 litres had the lowest fruit number (11.3 and 11.6 in Embu and Kabete, respectively). Leaf harvest intensity had a significant effect (P<0.5) on the fruits in Embu (Table 4). Harvesting of one leaf significantly increased the number of fruits produced (12.2), compared with the other treatments, although not significantly different from 0 LHI (11.9) and 2 LHI (11.1).

TABLE 4: Effect of irrigation rate and leaf harvest intensity on the number and weight of pumpkin fruits

	Total number of fruits		Total weight of fruits (kg)	
Irrigation (L)	Embu	Kabete	Embu	Kabete
1	11.9	12.3	13.9	15.9
2	11.3	11.6	12.9	13.8
3	11.4	12.6	13.2	17.2
4	11.4	11.7	14.2	14.1
P-value	*0.4313*	*0.4385*	*0.6455*	*0.2314*
LHI				
0	11.9^{ab}	12.8	14.3^{ab}	16.2^{ab}
1	12.2^{a}	12.5	15.4^{a}	17.7^{a}
2	11.1^{ab}	12.0	12.5^{ab}	11.9^{ab}
3	10.9^{b}	10.8	11.9^{b}	5.2^{b}
P-value	*0.0119**	*0.0539*	*0.0107**	*0.0255**

*Means followed by the same letters or no letters within a column are not significantly different, according to the Tukey's Studentized Range Test at P = 0.05

Leaf harvest intensity had no significant effect (P>0.05) on the number of fruits in Kabete. However, the trend showed a decrease in the number of fruits as the leaf harvest intensity increased. Harvesting of three leaves had the least number of fruits (10.9 and 10.8) in Embu and Kabete, respectively. Irrigation rate had no significant effect (P>0.05) on the total weight of pumpkin fruits (Table 4). However, application of 4 litres had the heaviest fruits (14.2 kg) in Embu, while application of 3 litres had the heaviest fruits (17.2 kg) in Kabete. Application of 2 litres had the lowest weight of pumpkin fruits (12.9 and 13.8 kg in Embu and Kabete, respectively). Leaf harvest intensity had a significant effect (P<0.05) on the weight of fruits in both sites (Table 4). The 1 LHI had significantly heavier fruits (15.4 and 17.7 kg in Embu and Kabete, respectively) than the 3 LHI (11.9 and 5.2 kg in Embu and Kabete, respectively). However, these results were not significantly different from those of 0 LHI and 2 LHI. Interaction between irrigation rate and LHI had no significant effect (P>0.05) on the total number of fruits (Fig. 1). However, interaction of 1 litre and 1 LHI had highest total number of fruits (13.0 in Embu and 14.3 in Kabete), compared to the other treatment combinations. Interaction between any irrigation rate and 3 LHI had lowest total number of fruits, compared to the other treatment combinations. Interaction had no significant effect (P>0.05) on the total weight of fruits (Fig. 2). However, 1 litre and 1 LHI had the highest total weight of fruits (16.9 kg) in Embu, while 3 litres and 1 LHI had the highest total fruit weight (22.79 kg) in Kabete. The trend in both sites showed that total fruit weight was high for any irrigation rate in combination with low leaf harvest intensity. But as the number of leaves harvested increased, the total weight of fruits decreased.

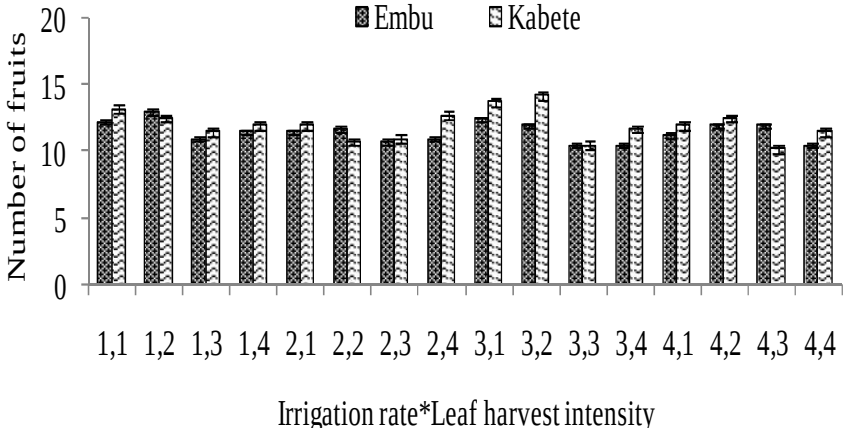

FIGURE 1: Effect of the interaction between irrigation rate and leaf harvest intensity on number of pumpkin fruits at the Embu and Kabete sites. Irrigation rates refer to 1, 2, 3 and 4 litres applied once weekly per plant through drip tubes throughout the growth period, while four levels of leaf harvest intensity refer to 0, 1, 2 and 3 leaves harvested once per two weeks per branch.

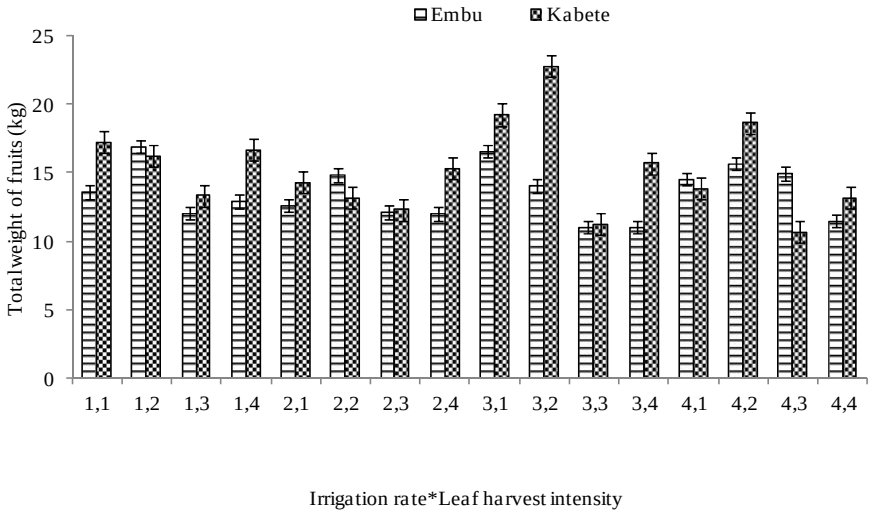

FIGURE 2: Effect of the interaction between irrigation rate and leaf harvest intensity on weight of pumpkin fruits at the Embu and Kabete sites. Irrigation rates refer to 1, 2, 3 and 4 litres applied once weekly per plant through drip tubes throughout the growth period, while four levels of leaf harvest intensity refer to 0, 1, 2 and 3 leaves harvested once per two weeks per branch.

The lack of a significant effect of irrigation rate on the total number of fruits was similar to that reported by Ghanbari *et al.,* (2007) that irrigation interval had no significant effect on the number of pumpkin fruits produced per unit area. The results were also similar to those of Yi-jie Li *et al*., (2011), who studied growth and photosynthesis of *Lycoris haywardii* Traub in response to watering frequencies and observed no significant difference in bulb number among the treatments. Lack of a significant effect of irrigation rate on the total weight of fruits was also similar to the findings of Maynard (2006) on drip irrigation effects on yield and fruit size of jack-o-lantern pumpkins that showed that irrigation had no significant effect on average weight per pumpkin, but the weight depended on cultivar. Leaf harvest intensity negatively affected the total weight of fruits. The total yield of fruits was lowest in treatments where more leaves were harvested. Harvesting of few or no leaves at all left the plant with adequate foliage to support photosynthesis that sustained recovery, sufficient growth and fruit production. The present results agreed with the findings of Saidi *et al.* (2010) in cowpeas. The result also agreed with those of Olasantan (2007) in pumpkin that showed that apical shoot harvest effects growth, apical shoot and fruit yield; harvesting 30-cm-long apical shoots at 1-week interval reduced the numbers of fruits by 20% to 50%, compared to harvesting 60-cm and 90-cm-long apical shoots. The present results agreed with those of Valverde *et al*., (2006) that showed lowest growth rate in the high intensity defoliation plot of tropical Palm **(***Chamaedorea elegans*). Furthermore, Saidi *et al*. (2009) reported that fruit development and seed formation inside the fruit are processes that are high energy sinks, whose demand for photoassimilates is not met when photosynthetic area is reduced or depleted through intensive leaf harvesting. The results implied that the higher the number of leaves on the plant, the higher the photosynthetic area that probably result in more assimilates being manufactured to support fruit development. On the other hand, the 0 LHI did not emerge as the leading in production of fruit number and weight probably because the excess number of leaves on the plants competed and diverted some of the photoassimilates from the fruit sinks.

CONCLUSIONS & RECOMMENDATIONS

Leaf harvesting should be avoided or if harvesting is to be done, only one leaf should be harvested in a system where the objective is to produce fruits. Harvesting of two leaves per branch is recommended for the production of high quality marketable leaves. Since application of 3 litres of irrigation water once per week produced the highest number of edible leaves and fruits and had the longest harvesting period, it is advisable to use 3 litres of irrigation water once per week per plant during the dry season for highest pumpkin leaf and fruit yields. Since the irrigation rate and leaf harvest intensity that maximizes edible leaf and fruit yields of the multipurpose pumpkin varies with production site, it is recommended to test given management practices in each production site before determining the suitable rates to adopt.

ACKNOWLEDGEMENTS

The authors acknowledge the financial support given by Kenya Agricultural Productivity and Agribusiness Project, Egerton University for logistical support and KARI for technical support and financial facilitation to attend and present findings in a conference.

REFERENCES

Asoegwu, S. N. (1988) Effects of irrigation on the leaf and pod production of fluted pumpkin (*Telfairia occidentalis* Hook. f.) in Southern Nigeria. *Scientia Horticulturae* **34**(3), 161-168.

Ertek, A., Sensoy, S., Kueçuekyumuk, C. and Gedik, I. (2004) Irrigation frequency and amount affect yield components of summer squash (*Cucurbita pepo* L.). *Agricultural Water Management* **67**(1), 63-76.

Ghanbari, A., Nadjali, F., Shabahang, J. (2007) Effects of irrigation regimes and row arrangement on yield, yield

components and seed quality of pumpkin. *Asian Journal of Plant Sciences* **6**(7), 1072-1079

Grubben, G.J.H., and Chigumira-Ngwerume, F. (2004) *Cucurbita moschata* Duch. *In*: Grubben, G.J.H. and Denton, O.A. (Eds.). PROTA 2: Vegetables/Legumes. [CD-Rom]. PROTA, Wageningen, Netherlands.

Horticulture Validated Report (2012) HCDA, Nairobi
Ibrahim, U., Auwalu, B.M., and Udom, G.N. (2010) Effect of stage and intensity of defoliation on the performance of vegetable cowpea (*Vigna unguiculata* (L.) Walp). *World Journal of Agricultural Science* **6**(4), 460-465.

Katul, G., Manzoni, S., Palmroth, S. and Oren, R. (2010) A stomatal optimization theory to describe the effects of atmospheric CO_2 on leaf photosynthesis and transpiration. *Annals of Botany* **105**, 431-442.

Madakadze, R., Kodzanaji, T. and Mugumwa, R. (2007) Effect of plant spacing and harvesting frequency on *Corchorus olitorious* leaf and seed yields. *Africa Crop Science Journal* **8**, 279-282.

Maynard, T. (2006) Drip irrigation effect on yield and fruit size of jack-o-lantern pumpkins. http://www. hort.purdue. edu/hort/ext/veg.

Olasantan, F.O. (2007) Apical shoot harvest affects growth and apical shoot and fruit yields of pumpkin. *Journal of Vegetable Science* **12**(3), 73-87.
Ondigi, A.N., Toili, W.W., Ijani. S.M.A. and Omuterema, O.S. (2008).Comparative analysis of production practices and utilization of pumpkins (*Cucurbita pepo* and *Cucurbita maxima*) by smallholder farmers in the Lake Victoria Basin, East Africa. *African Journal of Environmental Science and Technology* **2**(9), 296-304.

Radovich, T. (2011) Pumpkin and squash: Farm and forestry production profile for pumpkin and squash specialty crops for Pacific Island. http://www. agroforestry.net/Scp5.

Saidi, M., Itulya, F. M., Aguyoh, J. and Ngouajio, M. (2009) Leaf harvesting time and frequency affect vegetative and grain yield of cowpea. *Agronomy Journal* **102**, 827-833.

Saidi, M., Itulya, F.M., Aguyoh, J. and Ngouajio, M. (2010) Effects of cowpea leaf harvesting initiation time and frequency on tissue nitrogen content and productivity of a dual-purpose cowpea-maize intercrop. *HortScience* **45**(3), 369-375

Suat, S., Ertek, E., Gedik, I., Cenk, K. (2006) Irrigation frequency and amount affect yield and quality of field-grown melon (*Cucumis melo* L.). *Agricultural Water Management* **88**(1-3), 269-274. http:/www. sciencedirect. com. Accessed on 25/1/13.

Valverde, T., Mariana-Apolinar, T. and Mendoza-Amarom, S. (2006) Effect of leaf harvesting on the demography of the tropical palm (*Chamaedorea elegans*) in South-Eastern Mexico. *Journal of Sustainable Forestry* **23**, 85-105

Yi-jie Li, Bao-Zhong, Y. and Zhi-Long Bie. (2011) Response of muskmelon to drip irrigation water inside a plastic greenhouse. International Conference, 27-29th May 2011, pp. 333-337.