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INCREASING LEAF HARVEST INTENSITY ENHANCES EDIBLE LEAF VEGETABLE YIELDS AND DECREASES MATURE FRUIT YIELDS IN MULTI-PURPOSE PUMPKIN

D. K. Isutsa and S. O. Mallowa
Chuka University, Chuka, Kenya
E-Mail: dorcaski@yahoo.com

ABSTRACT

The popular Pumpkin (*Cucurbita moschata* Duchsene) in Kenya is the multi-purpose type, grown for its edible tender leaves, mature fruits and seeds. It requires appropriate management to realize high yields. Pumpkin is an important crop because most plant parts are rich in nutrients and are edible. Leaves are preferred in African countries. In West Africa, seed consumption is common. In Asian countries, pumpkin seeds have several medicinal applications. Pumpkin is rich in carotenoids that keep the immune system strong and healthy. Its beta-carotene is a powerful antioxidant and anti-inflammatory agent that helps prevent build-up of cholesterol in arteries, thus reducing chances of strokes. Its alpha-carotene slows down aging, prevents cataract formation and reduces the risk of muscular degeneration that usually results in blindness. Its high fibre improves bowel health, potassium lowers hypertension risk, and zinc boosts immune system and bone density. The high demand for tender pumpkin leaves consumed as a vegetable accompanying the main meal brings about excessive defoliation that terminates the life of the plant prematurely. This research established optimum leaf harvest intensity (LHI) that maximizes either the tender leaf or mature fruit yields. Pumpkin seeds were grown for 3 weeks in a nursery bed followed by transplanting and growing each seedling singly at a spacing of 2 m x 4 m. The layout was completely randomized design with 4 LHI (0, 1, 2 and 3), replicated four times and repeated once. Data collection started when plants had 5-true leaves and it continued for 29 weeks (season 1) and 21 weeks (season 2). Data collection entailed defoliating up to 3 tip-most leaves, with the entire leaf stalk attached, from each vine once per week and then counting. Mature fruits were harvested as their colour started to turn yellowish-brown, counted and weighed. Data were subjected to analysis of variance and regression using Minitab version 15 program. Leaf yield significantly ($P<0.05$) increased with increase in LHI, but fruit yield significantly decreased. The highest yields were 580 edible leaves for 3-LHI and 20 kg fruits (25 t/ha) for 0-LHI. Fruit yield had a significant ($P<0.05$) negative relationship with LHI. Thus, the pumpkin leaf and fruit yields depend on leaf harvest intensity. If fruit production is desired, then LHI should be kept to a minimum. If edible leaves are desired then fruit yields should be forfeited. Maximum fruit productivity requires minimum leaf defoliation.

Keywords: Pumpkin (*Cucurbita moschata* Duchsene), leaf harvest intensity, defoliation, sink-source relationship, vegetables.

INTRODUCTION

Pumpkin (*Cucurbita moschata* Duchsene) is a leafy, fruit and seed vegetable in the family Cucurbitaceae and is known by various other vernacular names. It originated in Central to South America, from where it has spread to many other countries including Africa where it has become naturalized and is categorized among indigenous vegetable (Abukutsa-Onyango, 2007). Distribution of production depends on rainfall, irrigation water availability and local consumption habits (Grubben and Chigumira-Ngwerume, 2004). Cultivation of pumpkin has spread all over the world due to its hardiness, drought tolerance and ability to grow in a wide range of soil types and climates (Grubben and Chigumira-Ngwerume, 2004).

In 2000, worldwide production of pumpkins stood at 16 million tons from 1.3 million ha, while production in Africa was approximately 1.8 million tons on 140, 000 ha, yielding 12.8 t/ha on average. On a global scale, pumpkin is amenable to making many products using its tender leaves, mature fruits and seeds. However, preference varies from region to region. Leaves are the main edible product in African countries, leaving fruits under-utilized (Abukutsa-Onyango, 2003). In West Africa, seed consumption is common for medicinal value. In Asian countries, pumpkin seeds have several medicinal applications such as anti-helminthic and skin ailments reliever. Pumpkin is an important crop because most parts of the plant are edible and rich in nutrients (Holland *et al*., 1991). Pumpkin is rich in carotenoids that keep the immune system strong and healthy. Pumpkin beta-carotene is a powerful antioxidant and anti-inflammatory agent. It helps prevent build up of cholesterol in arteries, thus reducing chances of strokes. Being rich in alpha-carotene, pumpkin is believed to slow down aging and prevent cataract formation. Pumpkins reduce the risk of muscular degeneration that usually results in blindness. Pumpkin's high fibre improves bowel health, potassium lowers the risk of hypertension, and zinc boosts the immune system and bone density.

Pumpkins are grown worldwide for edible tender leaves, mature fruits and seeds that are a rich source of nutrients and income generation for growers. Pumpkin is an emerging vegetable gaining popularity currently due to its high nutritive and medicinal values (Mboyah, 2008). The nutrient and medicinal richness is leading to high demand of this crop in rural, peri-urban and urban sets ups. Edible leaves are harvested during the early

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vegetative growth stages of the plant, while mature fruits are harvested later in the season.

Elongating stems supply abundant tender leaves, removed in succession for consumption as vegetables. Usually the tender third and fourth leaves are harvested, while the much younger tip and second leaves are left to grow more for subsequent harvesting. Leaf harvesting may start 6 weeks after sowing, or when each vine has at least five fully formed leaves. Leaf harvesting is continued for at least 2 months with mostly one harvest per week. An average yield of edible leaves is 2 t/ha per picking, or about 20 t/ha during a harvest period of two months.

It has been noted that there is no standardized leaf harvest intensity that growers should follow to maximize yields. Leaf harvest intensity is left at the discretion of the grower to the detriment of the pumpkin plant and difficulty in comparing yields and planning pumpkin supply across regions. Under this scenario, it becomes difficult to conduct pumpkin business and meet consumer demands. Besides, leaves are photosynthetic machinery of plants and the number of leaves on a plant determines plant growth rate and yield. Severe and haphazard defoliation leads to reduced photosynthate manufacture and supply for plant growth. There is, therefore, a need of proper leaf defoliation management to achieve high yields.

Pumpkin fruits are picked when fully mature, at 4-6 weeks after flowering, in several rounds until the crop ends, 90-180 days after planting. Some farmers leave fruits lying in fields for weeks. Seeds are extracted from fruits for future planting or use as food snack after roasting. The number of mature fruits harvested per plant is low, and the weight of individual fruits varies widely from 1 kg to 10 kg, depending mainly on cultivar and inputs management regime. Under low input conditions, fruit yield is around 5 t/ha. With good care, fruit yield of 15 t/ha is possible. With improved cultivars fruit yield of 30 t/ha is attainable.

The high demand for edible pumpkin leafy vegetables has brought about excessive defoliation during harvesting (Abukutsa, 2008; Mboyah, 2008). Leaf harvesting can affect plant growth and biomass production in many ways. The leaves form the photosynthetic machinery of the plant; removal of leaves therefore constitutes a reduction in photosynthetic tissue and hence reduction in production of photo-assimilates needed for crop growth (Barrett, 1987). Excess leaf harvesting also leads to deficiency of essential nutrients in the soil because nutrients absorbed by the plant are removed through the harvested plant leaves.

Despite the importance of multi-purpose pumpkin as a leaf, fruit and seed crop, few studies have been conducted to evaluate how leaf harvest intensity affects plant growth and overall leaf and fruit yields, unlike in other crops, such as cowpea, cassava and sweet potato (Dahniya *et al*., 1981; An *et al*., 2003; Ariyo *et al*., 2003; Ibrahim, *et al*., 2010), where studies have revealed significant effects on yields. In cowpea, early stage and high leaf harvest intensity decrease leafy vegetable and grain yields (Ibrahim *et al*., 2010). Excess cassava leaf harvesting had a negative effect on tuber yields (Dahniya *et al*., 1981; Ariyo *et al*., 2003).

The objective of this study was to establish the leaf harvest intensity that maximizes leaf and fruit yields by subjecting the data to analysis of variance. In addition, this study sought to establish the relationship between the edible fruits and harvested tender leaves by regressing fruit yield in terms of number and weight versus harvested tender edible leaves.

MATERIALS AND METHODS

The research was conducted on an agricultural farm located at Egerton University, Njoro, in the Kenyan Rift Valley region. The farm lies at elevation of 2238 m above sea level, latitude of 0° 23’ South and longitude of 35° 35’ East. The average rainfall received normally ranges from 840-1100 mm per year, while maximum and minimum temperatures range from 19^{o}C to 22^{o}C and 5^{o}C to 8^{o}C, respectively (Jaetzold and Schmidt, 1983). The farm has dark-reddish clay with greyish brown to dark grey top soils of good drainage.

Pumpkin seeds used were for a local landrace preferred mainly for edible leaves and fruits. Seeds were extracted from fresh fruits, air-dried for two days, sown and watered as necessary until seeds germinated and grew adequately. Hardening of seedlings was done by exposing them to high light intensity and reducing watering. A field was ploughed and harrowed to a medium tilth.

Seedlings were transplanted singly to a spacing of 2 m x 4 m in the field. Seedlings were immediately watered and mulched to conserve moisture. Watering was continued depending on weather conditions until the plants established well and then watering was reduced gradually. The experiment was laid out in a completely randomized design with four replications and four leaf harvest intensities (0, 1, 2, and 3 leaves harvested once per week per branch). The experiment was repeated once.

Hand-weeding was done to ensure a weed-free field, reduction of competition for food and control of alternate hosts for disease and insect pests. Spraying against insect pests and diseases was done as necessary. Vine coiling around the main planting hole was done to prevent intertwining of adjacent plants.

Harvesting of leaves started after 6 weeks post-transplanting and was continued for 21 (season 2) to 29 (season 1) weeks. Harvesting was done by breaking entire leaf stalk up to the point of origin on the vine. Fruits were harvested starting with primary, king fruits as they matured and turned yellowish-brown. The fresh leaves and fruits were counted and weighed immediately after harvesting. Data were subjected to analysis of variance using the Minitab version 15 computer program.

RESULTS

Effect of leaf harvest intensity on edible leaf and fruit yields

There was a significant effect (P=0.000) of LHI on the number of edible leaves harvested. The number of

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edible leaves harvested significantly increased with increase in LHI in both seasons 1 and 2 (Figure-1). The 3-LHI provided the highest number of edible leaf vegetables. With 0-LHI, no edible leaf vegetables were realized. These two trends were as expected.

Plants regenerated more leaves that became available for harvesting during successive weeks. Growth vigour of the plants, however, depended on the intensity of leaf defoliation. High leaf intensity caused decline in plant growth vigour, while low leaf harvest intensity did not reduce the growth vigour.

Contrary to the trend in number of edible leaves harvested, the number of edible fruits harvested significantly (P=0.016) decreased with increase in LHI in both seasons 1 and 2 (Figure-2). The same trend (P=0.001) was observed in the weight of harvested fruits (Figure-3).

The highest number and weight of edible fruits harvested was realized for the 0-LHI, while the lowest number and weight of fruits resulted for the 3-LHI. This result implied that edible leaf harvesting was imparting a major negative effect on fruit production by pumpkin plants both in terms of number and weight.

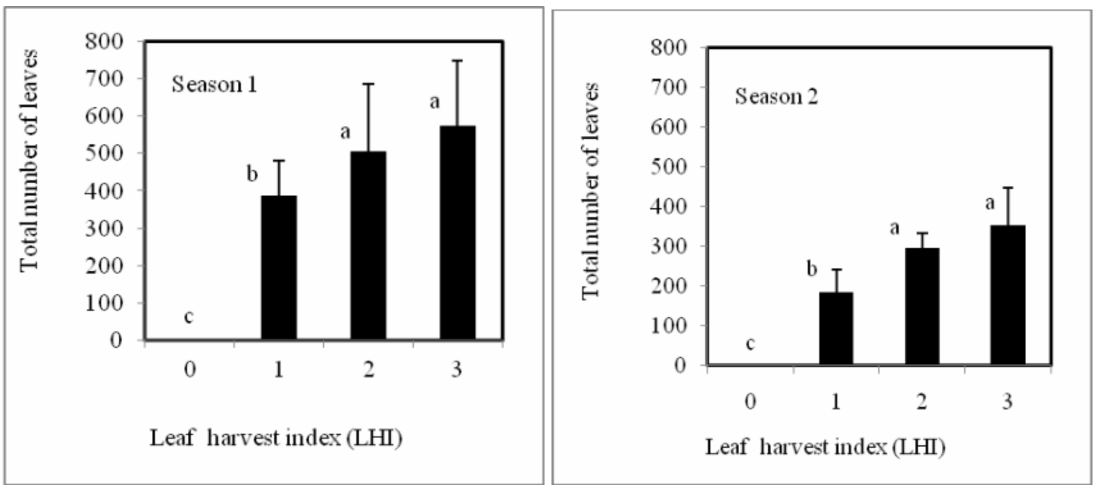

Figure-1. Response of total number of leaves per plant to LHI. LHI followed by the same letter are not significantly different at *P* = 0.05. Season 1 = 29 weeks. Season 2 = 21 weeks.

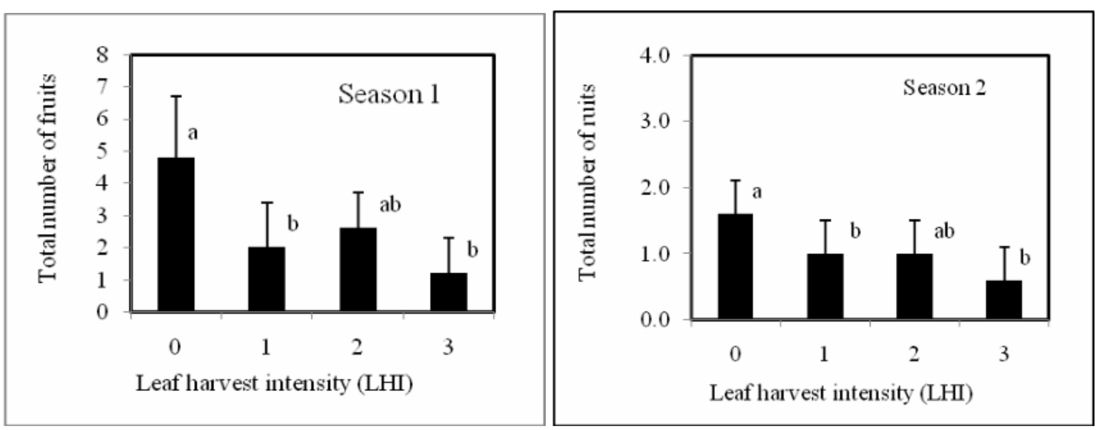

Figure-2. Response of total number of fruits per plant to LHI. LHI followed by the same letter are not significantly different at *P* = 0.05. Season 1 = 29 weeks. Season 2 = 21 weeks.

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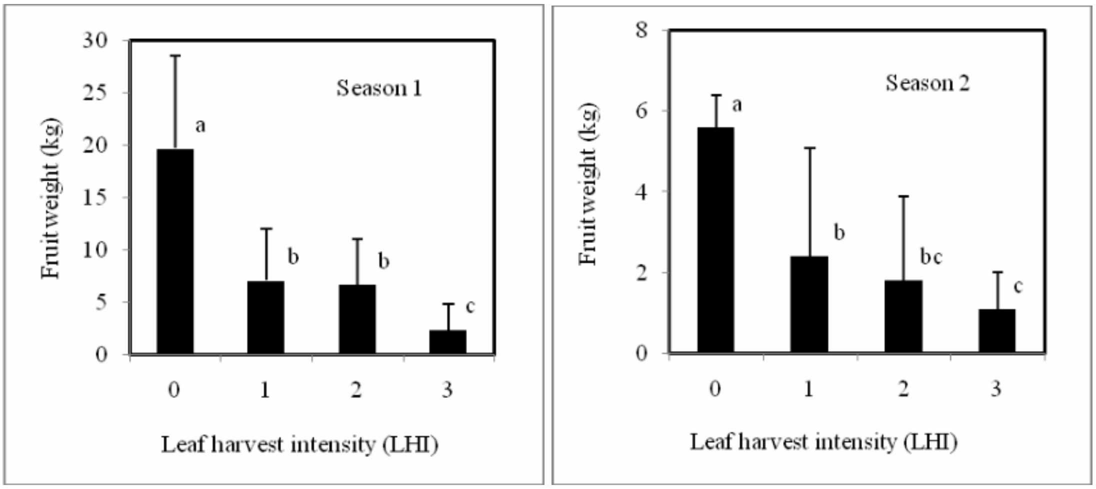

Figure-3. Response of total fruit weight per plant to LHI. LHI followed by the same letter are not significantly different at *P* = 0.05. Season 1 = 29 weeks. Season 2 = 21 weeks.

Relationship between fruits and edible leaves

The negative impact of pumpkin leaf harvest on pumpkin fruit yields was revealed by the significant (P<0.05) negative relationship between LHI and fruit yields in both seasons 1 and 2 (Figures 4 and 5). The relationship was the same in terms of pumpkin fruit number (Figure-4) and fruit weight (Figure-5).

For total fruits per plant, the slope was -1.02 and R^2 was 70% in season 1. In season 2, the slope was -0.30 and R^2 was 88.2%. For total pumpkin fruit weight per plant, the slope was -5.23 and R^2 was 81.9% in season 1. In season 2 the slope was -1.4.1 and R^2 was 83.7%. Thus removal of photosynthates' source-leaves negatively affected thriving of sink fruits.

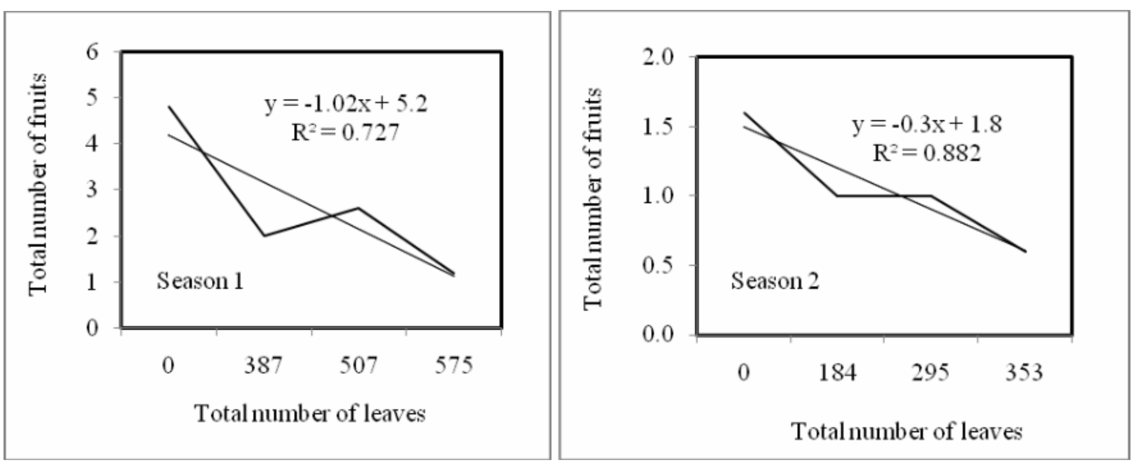

Figure-4. Total fruit number against total number of leaves harvested per plant. Season 1 = 29 weeks. Season 2 = 21 weeks.

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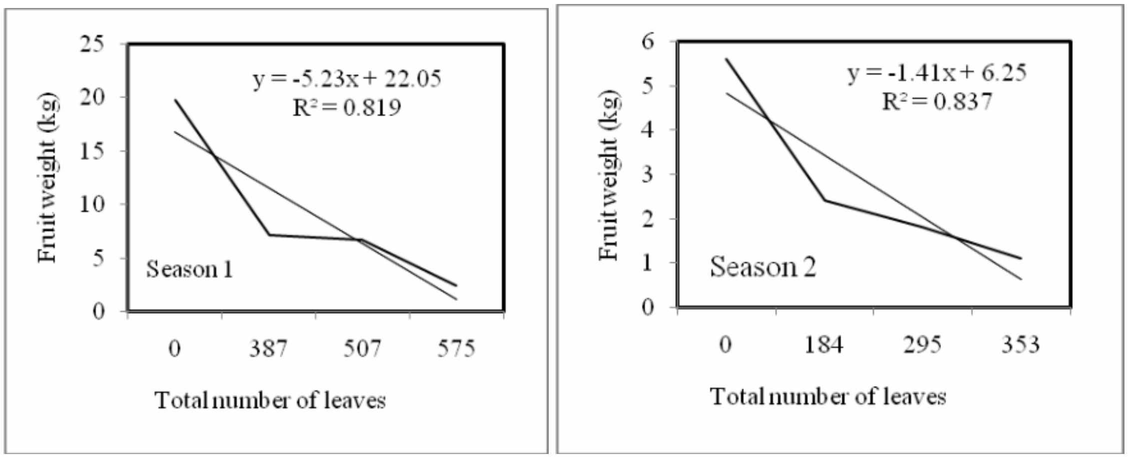

Figure-5. Total fruit weight against total number of leaves harvested per plant. Season 1 = 29 weeks. Season 2 = 21 weeks.

DISCUSSIONS

The green portions of plants, including leaves, form the photosynthetic machinery of plants. Removal of leaves, therefore, constitutes a reduction in photo-assimilates needed for crop growth. The rate of reduction of photo-assimilates is even more pronounced if tender leaves are removed. Leaves are the photosynthetic sites of plants, hence sources of photosynthates. The rate of CO_2 assimilation per unit area of leaf is an important feature of higher plants as it integrates all the biochemical and biophysical processes. The leaf area determines the percentage of incident radiation intercepted for energy supply in photosynthesis (Dahniyaa *et al*., 1981; Woodrow *et al*., 1990).

The observation for pumpkin was similar to that in sweet potato, cassava, cowpea and clover (Boatman and Haggar, 1984; An *et al*., 2003; Ariyo *et al*., 2003; Ibrahim *et al*., 2010). Young leaves and shoots of cassava are also harvested and eaten as vegetables and may be as important as roots in generating income. Excessive harvesting of leaves has been shown to negatively affect roots in the DRC where cassava leaves are extensively commercialized (Dahniya *et al*., 1981).

Leaf removal reduces area of subsequent emerging white clover leaves when measured as they become fully opened, although some compensatory expansion occurs after this. Petiole length also reduces considerably (Boatman and Haggar, 1984). Removal of older lamina has a similar effect to removing all the lamina but the effect increases by removing petioles in addition to the lamina. The youngest plants show the greatest reduction in leaf size following leaf removal. Defoliation has little effect on the rate of development of subsequent leaves. It was concluded that white clover seedlings have a considerable ability to recover from leaf removal, particularly if only the lamina of old leaves is removed, but the growth reduction following removal of petioles and lamina appears to be severe.

Defoliation can alter sink-source relationship. Removing leaves can increase the sink strength of the remaining developing leaves. Plants respond to a shortage of carbohydrates brought about by defoliation by showing general increase in allocation of resources to shoot growth and decreased allocation to fruit and root growth (De Roover *et al*., 1999). According to Hoogesteger and Karlson (1992), defoliation can alter photosynthesis directly through sink-source relationships. Following leaf harvesting, photosynthates are directed towards development of new leaves at the expense of being stored for grain or fruit production or being translocated to the root system for root and nodule growth (Mihaliak and Lincoln, 1989).

CONCLUSIONS

The present study has revealed that management of pumpkin plants should be chosen depending on the desired produce. If fruit production is desired, then leaf harvesting should be kept to a minimum. Harvesting up to 3 tender leaves per branch maximizes edible leaf vegetable yields. The pumpkin plants tend to renew themselves and continue yielding more leaves for subsequent harvests.

Multi-purpose pumpkin plants can be maintained in a vegetative phase for a long time to provide tender leaves for consumption as vegetables through leaf harvesting. This would be ideal particularly in places where consumption of leaves is higher and relished more than consumption of fruits, due to limited number of recipes that utilize pumpkin fruits.

Failure to harvest leaves turns older leaves into sinks and initiates flowering for fruit production. Fruits are very powerful sinks that deplete photosynthates in pumpkin plants, making them deteriorate once the fruits mature on the vines. Thus, non-defoliated pumpkin plants are likely to have a shorter lifespan than defoliated pumpkin plants.

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