EFFECTS OF NUTRIENT SOURCE AND LEAF HARVESTING INTENSITY ON PUMPKIN (*Cucurbita moschata* Duch.): 1. EDIBLE GROWTH AND QUALITY COMPONENTS

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ABSTRACT
Multi-purpose pumpkin is an important crop owing to its large fruits, tender leaves and seeds that are edible, nutritious and medicinal. In Kenya, many farmers do not know the right number of leaves to harvest as well as the fertilizer source to apply to this fruit-vegetable, resulting in low yields and poor quality produce. To address this problem, an experiment was conducted at two sites in Kakamega and Nyeri Counties. The goal was to enhance pumpkin yields and quality through integrated mineral nutrient and leaf harvesting management. The experimental design was a Randomized Complete Block Design, with four replications, in two sites, Kakamega and Nyeri that have great potential for pumpkin production. The factors tested at four levels each were nutrient source (0, 4 g 10N:10P:10K, 4 kg and 8 kg Farmyard Manure per plant), and leaf harvesting intensity (0, 1, 2 and 3 leaves per vine once per week). Plants were spaced at the standard 2 m x 4 m spacing, with one plant per experimental unit. Data on growth, yield and quality variables were recorded over a 12-month period and subjected to analysis of variance and Tukey's HSD test mean separation at P=0.05. The results showed that leaf harvesting intensity and nutrient source had significant (P<0.05) influence on leaf vegetable weight, fruit yield, sugar content and firmness in both sites. Harvesting two leaves had high yields and quality and the best nutrient source was 8 kg FYM. The optimal combined-treatment entailed harvesting two leaves per branch and applying 4 kg FYM. These optimal treatments are recommended for adoption to sustain enhanced pumpkin edible leaf vegetables and fruit yields and quality.
Keywords: Defoliation, Fruit quality, Fruit yield, Mineral Nutrition, Vegetable yield

INTRODUCTION
International trade of pumpkin leaves, fruits and seed is minor or non-existent, but at national level, leaves, fruits and seeds are important products on the local markets (FAO, 2010). The elongating pumpkin vines supply a good quantity of tender leaves, which are removed sequentially for use as vegetables. When grown as a leaf vegetable, usually the third and fourth leaves are harvested, while the tip and second leaves are left growing. Young, tender leaves and shoots are picked when needed for vegetables. Leaf harvesting may start 6 weeks after sowing and may be continued for at least 2 months with one harvest per week. Male flowers are sometimes harvested for consumption. Pumpkin fruits are picked when nearly or fully mature, 4–6 weeks after flowering, and are harvested in several rounds until the crop ends, 90–180 days after planting. Some farmers leave the fruits lying in the fields for weeks. Seeds are extracted as the fruits are consumed. Some seeds are stored for future planting and others are used as food (Grubben and Chigumira-Ngwerume, 2004).

It is important to note that leaves are very essential part of pumpkin plant, especially for physiological purposes such as photosynthesis. Although the leaves are consumed, farmers do not know the amount to harvest and at what stage of growth. Leaf defoliation compromises fruit as well as seed yield and quality of pumpkin that is considered precious to many small-scale farmers in Kenya. As result of this, farmers end up getting fruit yield as low as 5 t/ha and seed yield of 300 kg/ha (Guha and Sen, 1998). Achieving a good plant stand from planting to harvest stage is essential to obtaining excellent yields and quality. Supplying plants with available nutrients is one of the important ways that can help in achieving this good plant stand. Low soil fertility is recognized as an important constraint to food production and farm income in sub-Saharan Africa (Stoorvogel *et al.*, 1993; Sanchez *et al.*, 1996). Pumpkins grow well on organic matter and are often encountered on refuse heaps. The crop responds well to farmyard manure and to side-dressings of liquid manure. The rates recommended for application are 50–100 kg/ha N, 20–40 kg/ha P and 40–80 kg/ha K during the vegetative phase, depending on soil fertility. A part of the minerals can be top-dressed at the third and sixth week pot-germination at the rate of 50 kg/ha 10N:10P:10K (Place *et al.*, 2003). The objective of the present study was to enhance edible pumpkin leaf and fruit yields and quality through integrated nutrient source and leaf harvesting intensity application and management.

MATERIALS AND METHODS
The research was conducted in two different sites. One site was at the Kenya Agricultural and Livestock Research Organisation (KALRO) in Kakamega

County (Jaetzold and Schmidt, 2005). Kakamega field was located at 0º28'S and 34º75'E coordinates. The other site was located in Nyeri County at 0º41'S and 37º16'E coordinates (Jaetzold and Schmidt, 2005). The two sites were chosen because they are Regional Service Units targeted by the Kenyan government for enhancing pumpkin fruit-vegetable production and agribusiness to benefit small-scale, resource-poor farmers.

The research was conducted in a 4 x 4 factorial arrangement embedded in a randomized complete block design with four replications at each site. The two factors studied were: mineral nutrition source (nil, 4 g 10N:10P:10K, 4 and 8 kg farmyard manure per plant) and leaf harvesting intensity (0, 1, 2 and 3 leaves harvested once per branch per week). The 4 and 8 kg FYM/plant corresponded to 5 and 10 t/ha farmyard manure. One plant was used in each experimental unit, and the plants were spaced at 2 m x 4 m. Blocks were separated by 2-m paths.

The experimental field was prepared mechanically by ploughing and harrowing to pulverise the soil into a fine tilth. The NPK and FYM rates were applied to respective holes and incorporated into the soil before transplanting the seedlings. Seeds used were for the multi-purpose pumpkin (*Cucurbita moschata* Duchsene) local landrace, cultivated in almost all countries in the tropics and cherished for its edible leaves, fruits and seeds (Grubben and Chigumira-Ngwerume, 2004). Pumpkin seeds were germinated and grown in a nursery until they attained the 2-true leaf stage. The seedlings were transplanted to the main fields and planted into the holes. The plants were nurtured until they started developing vines, which were systematically coiled around each plant, leaving them to remain in contact with the soil. In addition, standard good agricultural practices such as weeding, irrigation and crop protection were applied when necessary. Fruit harvesting was then done after 5, 7, 9 and 11 months after planting. At every harvest, the number of fruits harvested were counted and recorded and their weights subsequently measured using a weighing balance in kilogrammes. Harvested fruits from each treatment were tested for total soluble solids/brix index (% sugar) using a hand-held refractometer (0-30º Brix) (RHW Refractometer, Optoelectronic Technology Company Limted, UK). The juice from sliced fruits was squeezed onto the lens of the refractometer and the index read. Mature pumpkin fruits were used to determine fruit firmness in kg force using a hand-held penetrometer (Model 62/DR, UK).

Data Analysis

Data values were analysed separately for the two sites since they had varied agro-ecological conditions. Data on growth, yield and quality variables were recorded over a 12-month period and subjected to analysis of variance and Tukey's HSD test mean separation at P = 0.05.

RESULTS AND DISCUSSION

Leaf Yields

Leaf harvesting intensity had a significant (P<0.05) influence on leaf weight of pumpkin plants in both sites (Table 1). Plants that had three leaves harvested had the highest leaf weight though not of high quality. The full trend was that three leaves harvesting intensity had the highest leaf weight, followed by two leaves harvesting intensity, then one leaf harvesting intensity, and lastly the control (no leaf harvesting).

Table 1: Effect of leaf harvesting intensity, nutrient source, and their interaction on total edible leaf weight (g/per plant) of multi-purpose pumpkin in Kakamega and Nyeri

Kakamega	Leaf harvest intensity (number harvested/branch/week)				
Nutrient source/plant	0	1	2	3	Mean
0 g	10h	353gh	809defg	530fgh	426*c*
4 g 10N:10P:10K	10h	543fgh	1133cdef	1351cd	759*b*
4 kg FYM	10h	624efgh	1354cd	1686bc	918*b*
8 kg FYM	10h	1206cde	2007b	2891a	1529*a*
Mean	10D	682C	1326B	1615A	
Nyeri	Leaf harvest intensity (number harvested/branch/week)				
Nutrient source/plant	0	1	2	3	Mean
0 g	10g	221fg	446ef	616e	323*d*
4 g 10N:10P:10K	10g	378ef	646de	924c	489*c*
4 kg FYM	10g	456ef	898cd	1526ab	723*b*
8 kg FYM	10g	604e	1281b	1746a	910*a*
Mean	10D	415C	818B	1203A	

* Values within each factor followed by the same letter are not significantly different at P = 0.05

Heavy leaf harvesting makes plants dwell on recovery of leaf growth, but the newly grown leaves are often too small and less suitable for marketing (Madakadze *et al.*, 2004; Isutsa and Mallowa, 2013). Nutrient source had a significant (P<0.05) influence on leaf weight in both sites (Table 1). In Kakamega, plants where FYM was applied at 8 kg had the highest leaf weight, followed by where 4 g NPK and 4 kg FYM were applied, which had no statistical difference from each other, and lastly the control that had lowest leaf weight. A similar trend was observed in Nyeri, where plants that received 8 kg FYM had the highest leaf weight, followed by plants that received 4 kg FYM, then 4 g NPK and lastly the control. Nitrogen and phosphorus play an important role in biochemical processes, including chlorophyll formation and root development, respectively (Bates *et al.*, 1990). This could be the reason behind high leaf weight for 8 kg FYM per plant.

Significant interaction effect (P<0.05) was observed between leaf harvesting intensity and nutrient source in both sites on total leaf weight (Table 1). Plants where three leaves were harvested and 8 kg FYM applied had the highest leaf weight. The lowest leaf weight was observed when no nutrient, 4 g NPK, 4 and 8 kg FYM were applied plus no leaf harvesting.

Fruit Yields

Leaf harvesting intensity had a significant (P<0.05) influence on fruit number in both sites (Table 2). Fruit number decreased with the increasing leaf harvesting intensity. Comparatively, the highest fruit number was obtained where no leaves were harvested (control). Harvesting one and two leaves from pumpkin plants had no significant difference from each other with respect to fruit number. The lowest number of fruits was obtained when three leaves were harvested from pumpkin plants. This trend was attributed to the effects of leaves and leaf surface area on photosynthetic capacity that promotes fruit development. Heavy defoliation negated the plants the photosynthetic machinery for photosynthates that contribute to fruit formation.

Table 2: Effect of leaf harvesting intensity, nutrient source and their interaction on total harvested fruit number per plant of multi-purpose pumpkin in Kakamega and Nyeri

Kakamega	Leaf harvest intensity (number harvested/ branch/week)				
Nutrient source/plant	0 leaf	1 leaf	2 leaves	3 leaves	Mean
0 g	4.8	3.3	3.5	1.0	3.1*c*
4 g 10N:10P:10K	6.3	5.0	4.8	3.5	4.9*b*
4 kg FYM	7.0	5.8	6.3	2.8	5.4*b*
8 kg FYM	7.3	5.8	5.8	3.0	5.4*b*
Mean	6.3A	4.9B	5.1B	2.6C	
Nyeri	Leaf harvest intensity (number harvested/ branch/week)				
Nutrient source/plant	0 leaf	1 leaf	2 leaves	3 leaves	Mean
0 g	6.5	6.5	6.8	4.3	6.0*b*
4 g 10N:10P:10K	7.5	6.8	6.5	5.8	6.6*ab*
4 kg FYM	8.8	6.5	7.3	5.5	7.0*a*
8 kg FYM	9.8	10.0	8.3	6.0	8.5*a*
Mean	8.1A	7.4B	7.2B	5.4C	

* Values within each factor followed by the same letter are not significantly different at P = 0.05

Nutrient source had a significant (P<0.05) influence on the number of pumpkin fruits (Table 2). However, this followed a reverse trend compared with effect of leaf harvesting intensity. The control had the lowest fruit number, while 8 kg FYM had the highest fruit number in Kakamega; plants where 4 g/plant NPK and 4 kg FYM were applied had no statistical difference. In Nyeri, 8 and 4 kg FYM and 4 g NPK had no significant difference in fruit number. This was attributed to the slow mineralization of nutrients from FYM to promote better growth and more fruits. These findings agreed with those of *Oloyede et al.*, 2013 and Mahmoud *et al*. (2009), who reported more cucumber fruits with organic and inorganic fertilizer compared to the control. There was no significant (P>0.05) interaction between leaf harvesting intensity and nutrient source on number of fruits of pumpkin plants in both sites (Table 2). However, the highest number of fruits was obtained from pumpkin plants receiving 8 kg FYM plus no leaf harvesting, and the lowest was obtained where no nutrients were applied and when three leaves were harvested.

Leaf harvesting intensity significantly (P<0.05) influenced fruit weight in both sites (Table 3). Th yield followed a similar trend like that of fruit number. The highest fruit weight was for the control, followed by when one or two leaves were harvested that had no statistically significant difference, and lastly when three leaves were harvested. Less or no leaves harvested could have led to better photosynthate accumulation in fruits and hence more weight (Ibrahim *et al*., 2010).

Nutrient source significantly (P<0.05) affected fruit weight of pumpkin plants in both sites (Table 3). In Kakamega, the lowest fruit weight was obtained when no nutrient was applied, while the highest fruit weight was obtained when 4 and 8 kg FYM, followed by 4 g/plant NPK were applied. A similar trend was observed in Nyeri where the lowest was obtained for the control, while the highest was obtained for 8 kg FYM, followed by 4 kg FYM and 4 g/plant NPK, which had no statistically significant difference. Manure and inorganic fertilizer have been reported to improve growth and yield of crops (Mathew, 1990; Oloyede *et al*., 2013). This effect may explain the reason behind heavier fruits on the pumpkin plants supplied with nutrients.

There was no significant (P>0.05) interaction between leaf harvesting intensity and nutrient source on fruit weight of pumpkin plants in both sites (Table 3). However, the highest fruit weight was obtained for pumpkin plants receiving 8 kg FYM plus no leaf harvesting, and the lowest was obtained when no nutrient was used (control) and when three leaves were harvested. This trend was as expected. High nutrients could not compensate for the loss of photosynthetic leaves that had been defoliated. Thus, leaf presence is more important in driving plant growth than does nutrients (Ibrahim *et al.*, 2010; Isutsa and Mallowa, 2013; Oloyede et al., 2013).

Table 3: Effect of leaf harvesting intensity, nutrient source and their interaction on total fruit weight (kg/per plant) of multi-purpose pumpkin in Kakamega and Nyeri

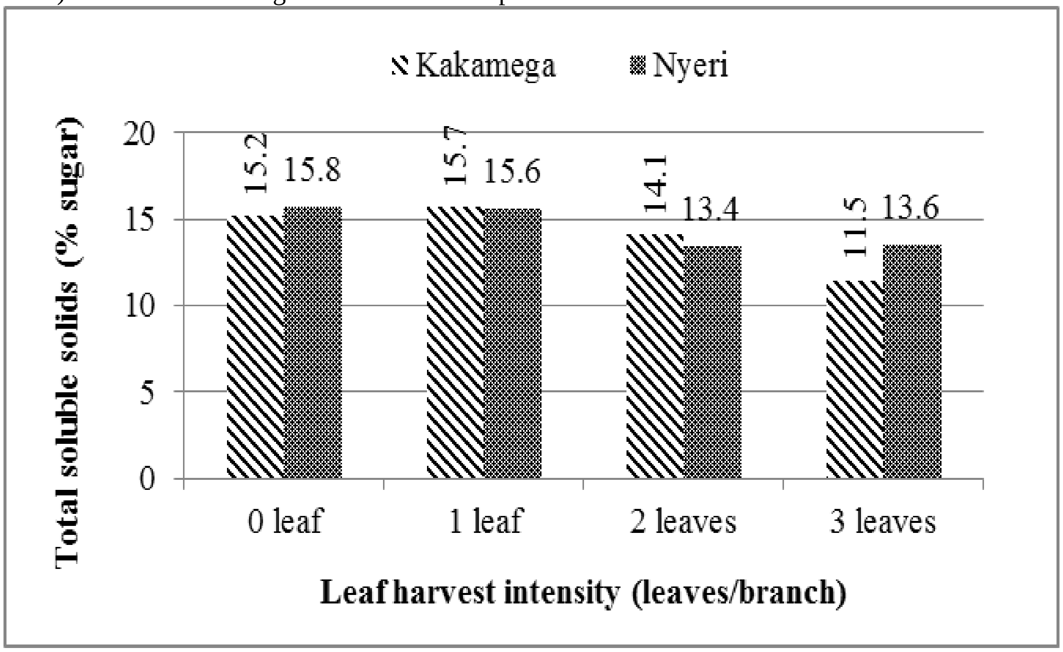
Kakamega	Leaf harvest intensity (number harvested/branch/week)				
Nutrient source/plant	0 leaf	1 leaf	2 leaves	3 leaves	Mean
0 g	14.5	8.5	8.8	1.8	8.4*b*
4 g 10N:10P:10K	22.1	15.1	13.9	7.6	14.7*ab*
4 kg FYM	23.9	17.5	16.9	6.0	16.1*a*
8 kg FYM	27.8	19.3	19.0	7.1	18.3*a*
Mean	22.1A	15.1AB	14.6AB	5.6B	
Nyeri	Leaf harvest intensity (number harvested/branch/week)				
Nutrient source/plant	0 leaf	1 leaf	2 leaves	3 leaves	Mean
0 g	17.0	13.4	15.6	6.3	13.1*c*
4 g 10N:10P:10K	24.1	18.5	17.5	9.8	17.5*b*
4 kg FYM	26.3	18.1	19.5	10.3	18.5*b*
8 kg FYM	34.4	29.4	25.0	12.1	25.2*a*
Mean	25.4A	19.8B	19.4B	9.6C	

* Values within each factor followed by the same letter are not significantly different at P = 0.05

Total Soluble Solids Fruit Quality

Leaf harvesting intensity had a significant (P<0.05) influence on total soluble solids of pumpkin fruits in both sites (Figure 1). Fruits with highest sugar content were obtained when no leaf was harvested, followed by one leaf, then two leaves, and lastly three leaves. Leaf harvesting influences fruit quality probably through the role leaves play in photosynthesis (Yeboah *et al.*, 2010). It is possible that those plants where less or no leaves were harvested had normal photosynthesis, leading to high accumulation of carbohydrates that increased total soluble solids in fruits. Significant effect was observed on total soluble solids of pumpkin fruits when nutrients were applied (Figure 1). The highest total soluble solids were obtained where no nutrients were applied, followed by 4 kg FYM, then 4 g NPK were applied, and lastly the 8 kg FYM. Potassium is among the nutrients reported to play a significant role in sugar accumulation (Selter *et al.*, 1980). This could be the reason why higher total soluble solids accumulated in plants where no FYM was applied. The 4 g NPK may not have supplied adequate potassium to significantly alter the total soluble solids, while 8 kg FYM may have supplied excessive nitrogen that diluted the effect of potassium on sugar accumulation (Oloyede *et al*., 2013). Moreover, high leaf harvesting and nutrients may have diluted photosynthates, leading to low soluble solids.

Significant interaction effect between leaf harvesting intensity and nutrient source was observed on total soluble solids of fruits in both sites (Figure 1). The lowest total soluble solids were observed when 8 kg FYM were applied plus up to three leaf harvest intensity, while the highest total soluble solids resulted when no nutrients were applied plus no leaf harvesting. When no leaves are harvested, plants grow slowly and accumulate sugar such that nutrient application does not dilute, but when nutrients are supplied, plants grow faster and bigger, leading to dilution of biochemical molecules (Oloyede *et al.*, 2013). No leaf harvesting is not able to compensate for the diluted sugars, while high leaf harvesting makes the dilution worse (Ibrahim *et al*., 2010). The results did not follow exactly the same trend in the two sites owing to differences in inherent soil fertility, as well as influence of other diverse agroecological factors.



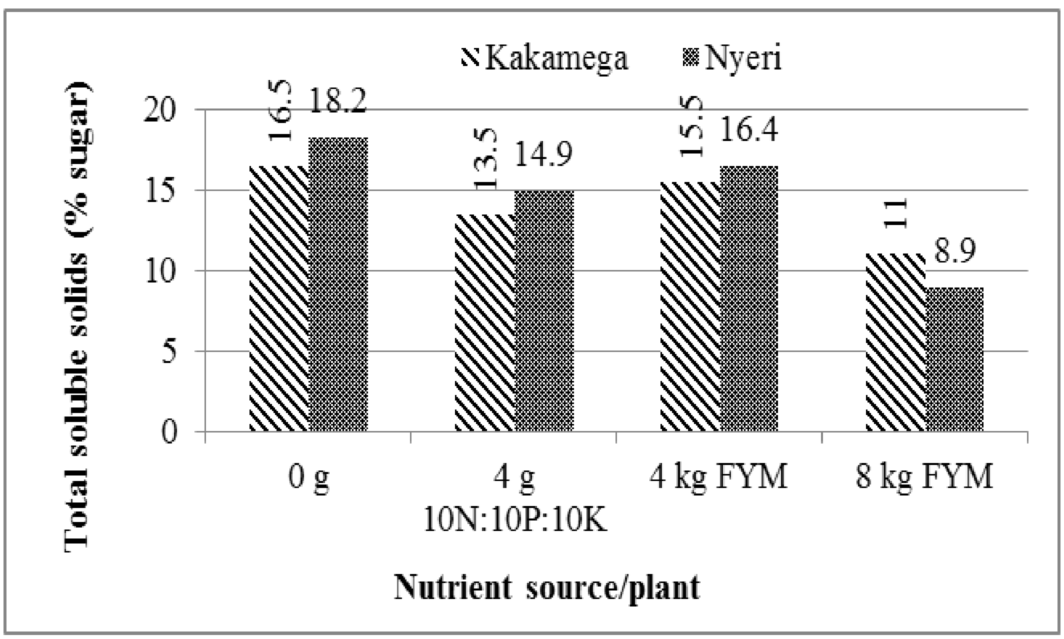
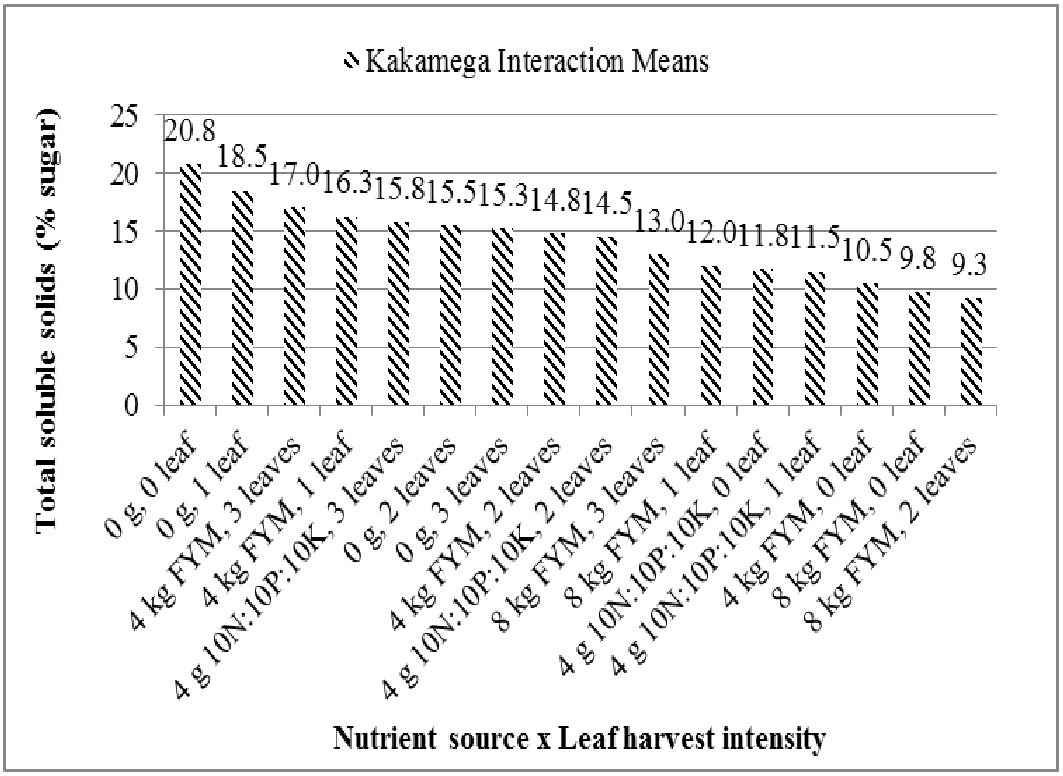


Figure 1 a: Effects of leaf harvest intensity, nutrient source and their interaction on total soluble solids (% sugar) of multi-purpose pumpkin fruits



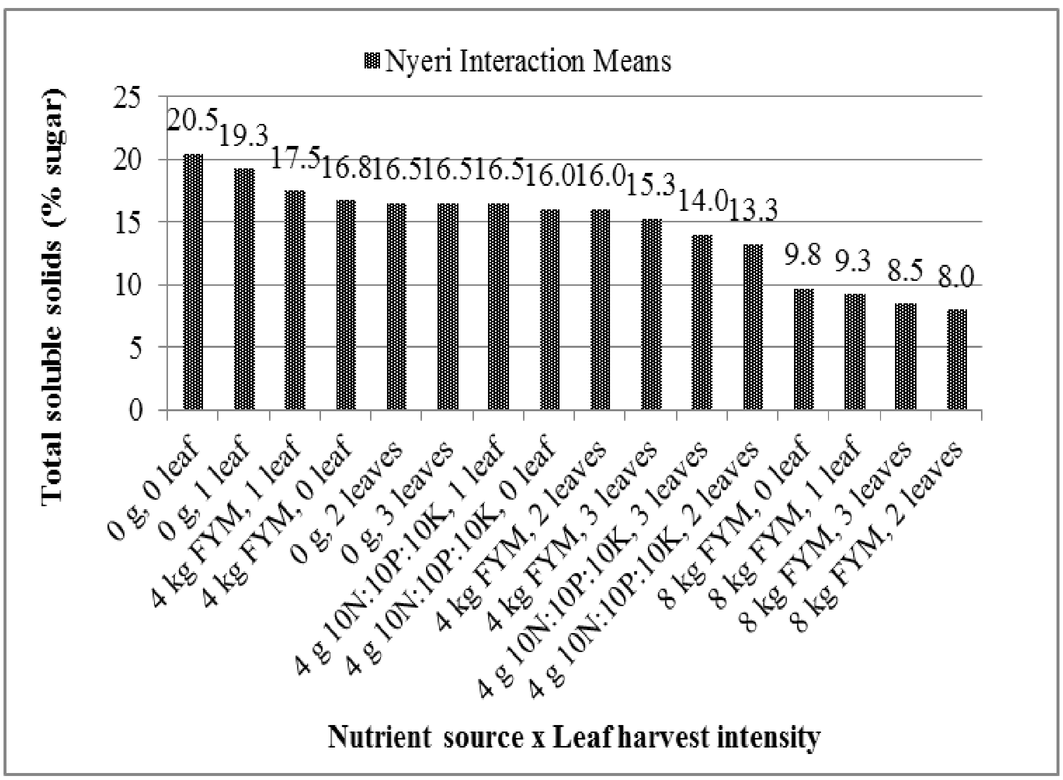


Figure 1 b: Effects of leaf harvest intensity, nutrient source and their interaction on total soluble solids (% sugar) of multi-purpose pumpkin fruits

Fruit Firmness Quality

Leaf harvesting intensity had a significant (*P*<0.05) influence on pumpkin fruit firmness (Figure 2). The most firm fruits were obtained when no leaves were harvested in both sites, followed by one leaf, two leaves, and lastly when three leaves were harvested. However, in Kakamega, no significant difference was observed for one, two and three leaf harvesting intensities. No leaf harvesting may improve photosynthetic activity that translates into improved growth, including root development (Fellman *et al*., 2013). Better root development leads to good water and nutrient absorption. Water and nutrients such as calcium have been reported to play a great role in membrane integrity and cell wall development (Yeboah *et al*., 2010).

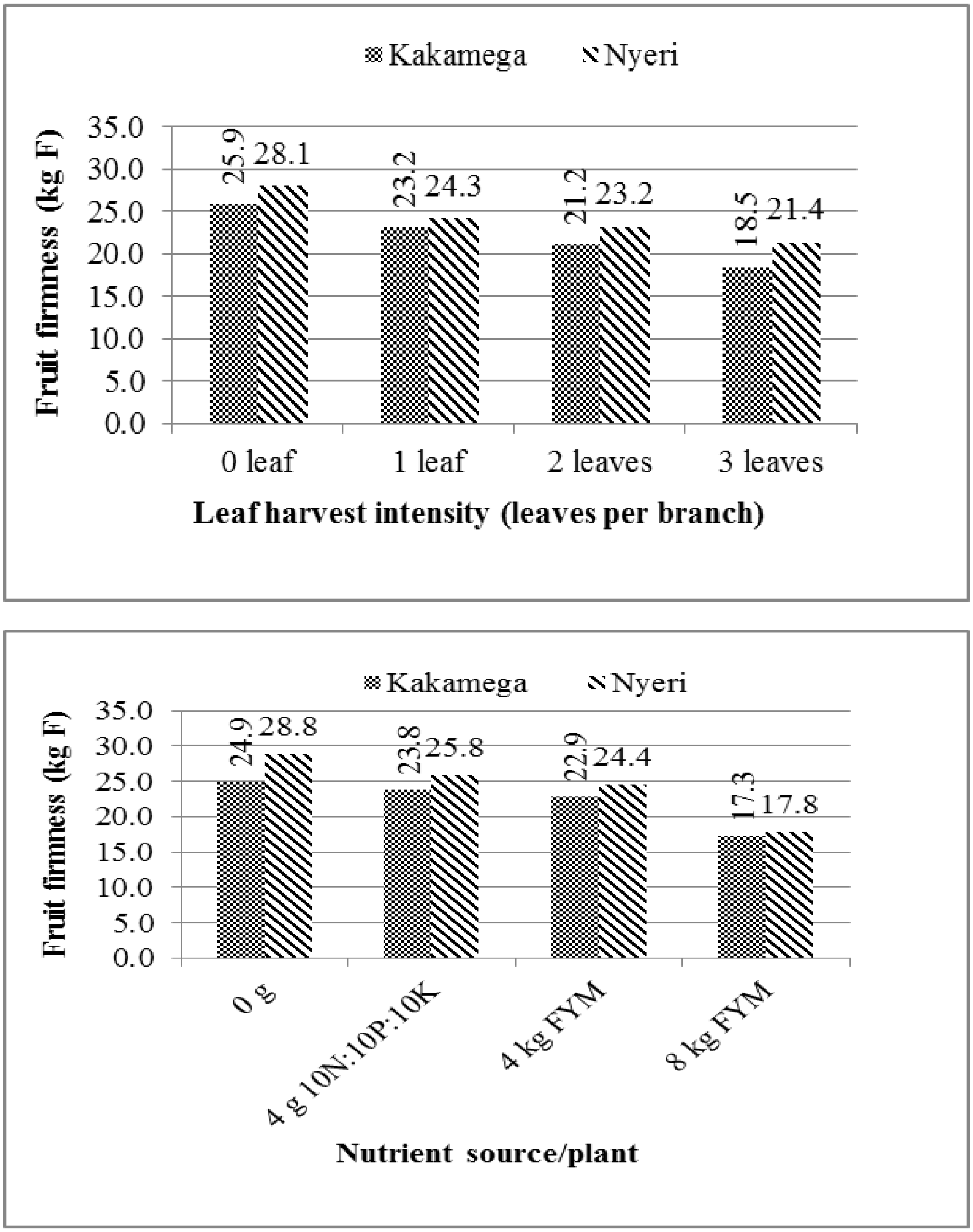
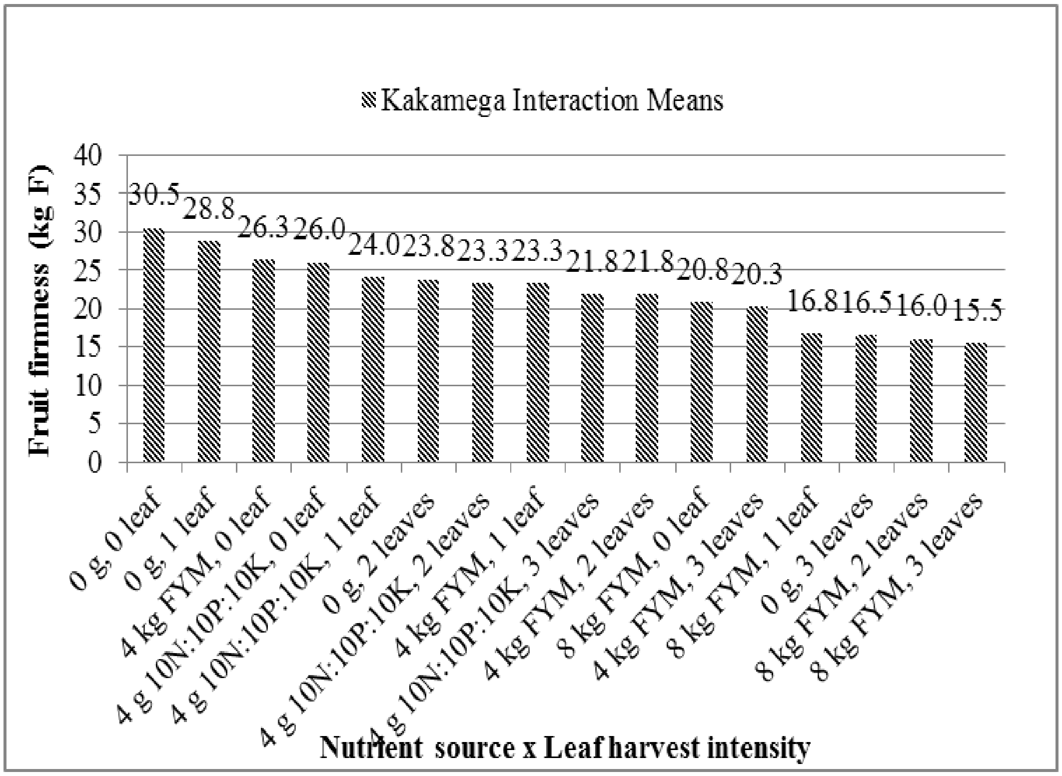


Figure 2 a: Effects of leaf harvest intensity, nutrient source and their interaction on firmness of multi-purpose pumpkin fruits



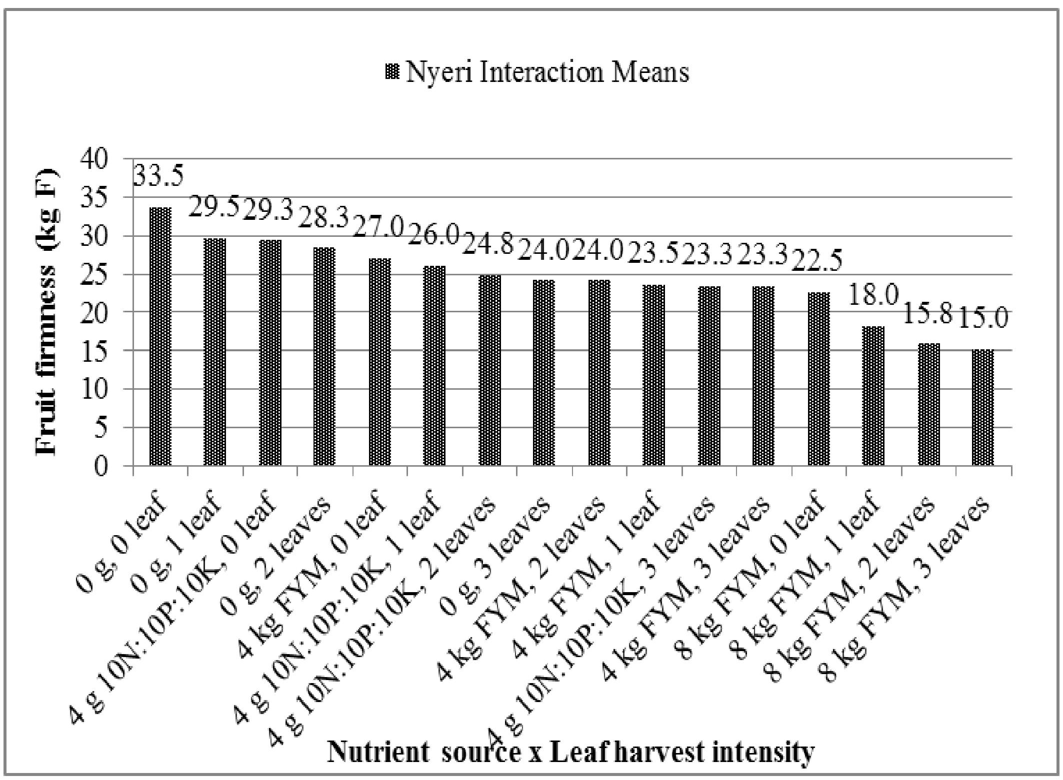


Figure 2 b: Effects of leaf harvest intensity, nutrient source and their interaction on firmness of multi-purpose pumpkin fruits

Nutrient source significantly ($P<0.05$) affected pumpkin fruit firmness (Figure 2). The trend was similar in both sites. The most firm fruits were obtained when no nutrients were applied, followed by 4 g/plant NPK, 4 kg FYM, and lastly 8 kg FYM, though there was no significant difference for 0, 4 kg FYM and 4 g NPK in Kakamega, and 4 kg FYM and 4 g NPK in Nyeri. Optimal nutrients are important in root development and cell wall development (Aiyelaagbe and Kintomo, 2002; Azeez *et al.*, 2010). It is possible that those fruits that received minimal nutrients had stronger cell walls, compared to those that did receive high nutrients. High nutrients could have led to high water uptake and cell expansion contributing to less firmness. A significant interaction effect was observed in fruit firmness (Figure 2). The highest fruit firmness was observed with no nutrients application plus no leaf harvesting, while the lowest was for 8 kg FYM plus three leaf harvesting. No leaf harvesting and no nutrients may lead to less softening through better accumulation of photosynthates. On the other hand, high leaf harvesting and nutrients may have diluted photosynthates, leading to soft fruits (Fellman *et al*., 2013).

CONCLUSION

Leaf harvesting intensity significantly influences growth, yield and quality of pumpkin fruits by decreasing these parameters as leaf harvesting intensity increases. Nutrient source significantly enhances growth and yield of pumpkin fruits whereby farmyard manure is superior to synthetic fertilizer, but dilutes nutrient accumulation leading to less sweet and firm fruits. Interaction between leaf harvesting intensity and nutrient source significantly influences edible pumpkin leaf growth and yield only in that high FYM application reverses processes negatively affected by heavy leaf harvesting. The negative effect of high leaf harvesting is not reversible or adequately compensated for by high FYM in the case of fruit yield, total soluble solids and firmness.

RECOMMENDATIONS

Harvesting one leaf per branch per week of multi-purpose pumpkin plants is recommended as it leads to better growth and subsequently high fruit yields and quality. The best treatment is 8 kg FYM per plant for high edible leaf and fruit yields. The best interaction treatment is of two leaf harvest intensity and 8 kg FYM per plant for edible leaf yield, and one leaf harvest intensity and 8 kg FYM per plant for fruit yield. These treatments should be adopted and applied to enhance pumpkin leaf vegetable and fruit production by small-scale growers.

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