I.J.S.N., VOL.7 (4) 2016: 756-764 ISSN 2229 – 6441

INTERNATIONAL JOURNAL OF SCIENCE AND NATURE

www.scienceandnature.org

PARTICIPATORY GERMPLASM CONSERVATION AND SEED PRODUCTION OF NATURALIZED PUMPKIN LANDRACES IN KENYA

[1]Kirimi, J.K, [1,2]Isutsa, D.K. & [3]Nyende, A.B.
[1]Chuka University, P. O. Box 109-60400, Chuka, Kenya
[1,2]Egerton University, P. O. Box 536-20115, Egerton, Kenya
[3]Jomo Kenyatta University of Agriculture and Technology, P. O. Box 62000-00200, Nairobi, Kenya
[*]Corresponding author email: dorcaski@yahoo.com

ABSTRACT
Although seeds come first in the food chain, local and international companies find it unprofitable to invest in provision of African indigenous vegetable seeds to growers. The present study trained farmers in on-farm multiplication of seeds for preferred local pumpkin landraces previously collected from Kakamega and Nyeri counties in Kenya. Nine naturalized accessions of *Cucurbita moschata* (Lam.) Poir were selected for use based on their earlier superior performance in evaluation trials. They were planted at 2 m x 2m in a completely randomized design, replicated three times in Butere-Mumias, and managed by farmers in Shinyalu and Othaya. Qualitative and quantitative data were collected and subjected to Chi-square and variance analyses, respectively. The three sites significantly (P<0.05) affected quantitative characters, except germination percentage. Butere-Mumias had highest yields, except average fruit and 100-seed weight. Germination was 99% in Shinyalu and rotten fruits were 88 in Othaya. Accessions significantly (P<0.05) differed quantitatively, except in rotten fruits and germination percentage. Highest performance was for KK-30 and included 17 total fruits/accession, 7 average fruits/plant, 48.7 kg fruit weight/accession, 5.8 kg average fruit weight/accession, 5,981 total seeds/accession, 2,786 average seeds/plant, 554 total seeds/fruit, and 18 g of 100-seed weight/accession. Accessions NY-142 and NY-154 performed poorly in most characters. Germination was 100% in KK-40 and 91% in NY-142 and NY-154. Accession KK-35 and KK-45 had no rotten fruits. Germination percentage was 99% in Shinyalu and 97.7% in Othaya. The male and female farmers trained were 100 and 114, and not significantly (P>0.05) different. The farmers trained in three years were 132 in Kakamega and 82 in Nyeri. The present study has found sufficient seed yield variation in naturalized pumpkin accessions in Kenya that could be exploited. Consequently, KK-30, KK-35, KK-40 and KK-45 are recommended for adoption and development into commercial pumpkin seed and fruit production cultivars. Regional farmers should be mobilized and empowered to commercially produce and conserve the preferred, but endangered pumpkin produce and germplasm.

KEYWORDS: Accession; Seed multiplication; Selection; Farmer training, African indigenous vegetables.

INTRODUCTION
Seeds are the first link in the food chain (Majuju, 2010). They determine whether an output will be realized or not (Ayieko and Tschirley, 2006), and have the greatest potential to increase productivity and enhance food security (Muyanga *et al*., 2005). Seeds are a vital input and a basic form of conserving genetic resources (Ajayi, 2007). They facilitate food resource diversification and prevent genetic erosion (Majuju, 2010). The challenge in pumpkin production is to develop seed production and delivery systems that encourage wider use of quality seeds (Ayieko and Tschirley, 2006). Quality of pumpkin seeds varies due to many factors such as fruit size, weight and maturity (Roopa, 2006). Inability of the formal seed system to produce high quality indigenous pumpkin seeds to meet demand is a bottleneck to production of pumpkin on a commercial scale (Nyoro and Ariga, 2004). This inability compels small-scale farmers to save seeds from one harvest to plant in subsequent seasons (Lewis and Mulvany, 1997). Only when there is a binding need do the farmers obtain seeds from off-farm sources (Longley *et al*., 2001). This own-farm seed saving practice leads to recycling of seeds that have been exhausted through generations of cultivation (Ayieko and Tschirley, 2006). Recycled seeds generally produce low yields (Majuju, 2010).

Local landraces tend to be productive under marginal conditions through withstanding of both abiotic and biotic stresses, and adaption to environment-friendly farming systems like intercropping (Onyango and Onyango, 2005). However, their potential to meet the growing demand has been limited by lack of good quality seeds (Kimenye, 2013). Local and international seed companies find it unprofitable to make the investment required to provide the quantity, quality and variety of demanded African Indigenous Vegetables (AIV) seeds (Onyango, 2007). Community based seed systems are coming under pressure due to drought, crop failure, unconducive storage conditions, and poverty (Berg, 1996). These factors are eroding the diversity of seeds available to farmers (Lewis and Mulvany, 1997). Sources of off-farm seeds include relatives, local markets and relief distributors (Longley *et al*., 2001). These supply systems hinge on the cultural heritage where farmers save, sell and exchange germplasm

(Majuju, 2010). They provide low cost, easy to access seeds, often with little or no need for cash, all of which are important where no seed companies operate (Ellis-jones *et al*., 2008). With increasing demand for pumpkin fruits in urban and peri-urban regions, there is need for increased production (Onyango, 2007). This calls for good quality seeds to catalyze increased productivity (Ellis-jones *et al.*, 2008). Community-based approaches for seed multiplication ensure availability of seeds to farmers. Seed bulking can be implemented through farmer groups supplied with starter seeds to multiply and distribute at harvest to other farmers (Ayieko and Tschirley, 2006). Participatory seed bulking provides economic incentives for farmers to continue cultivating genetically desirable crops and supports the maintenance of more diverse, locally adapted plant populations (Louette and Smale, 1998). This has enabled farmers to acquire and use improved seeds (Cromwell, 1996). Community seed banks are outlets for accessing local seeds and associated knowledge through mobilizing social and human capital for sensitization and conservation of agro-biodiversity. They strengthen farmers' capacities on conservation, distribution and sustainable use of local crop genetic resources (Maharjan *et al*., 2011). Community seed banks refer to individuals and informal groups, who store seeds for sharing among themselves. Seeds are retained from participants' own production with no formal quality control, except individual selection efforts and handling skills (Lewis and Mulvany, 1997). This strategy prevents disuse of local landraces (Onyango and Onyango, 2005). Despite the contribution of pumpkin to food and nutrition security in rural regions, its seed availability continues to be a challenge. Consequently, the present study selected multi-purpose pumpkin (*Cucurbita moschata* (Lam.) Poir.) cultivars preferred from Kakamega and Nyeri regions in Kenya, evaluated and bulked their seeds on-farm with farmers, and set up a community support system to conserve the seeds *ex situ* for use as need arises.

MATERIALS AND METHODS

Research Sites

Seed bulking was conducted in Kakamega and Nyeri Counties. Kakamega in Western Kenya lies at 00° 16' N, 34° 45' E and 1585 m above sea level. The mean annual temperature is 20°C, mean bimodal rainfall is 2012 mm annually, and soils are classified as dystro-mollic Nitisols (Jaetzold and Schmidt, 1983a). Nyeri in Central Kenya lies at 37º E, 0º 38´ S, and 1810 m above sea level. Annual mean temperature is 19^{o}C. It has a bi-modal rainfall pattern, averaging 1500 mm per annum (Kassam *et al.*, 1991). The soils are well drained, extremely deep, dark reddish brown to dark brown, friable and slightly smeary clays with acid humic top soils (andohumic Nitosols with umbric Andosols) (Jaetzold and Schmidt, 1983b).

Selection of Accessions for Seed Bulking

The accessions used in seed bulking were selected based on preliminary information given by key informant pumpkin farmers about the original landraces through informal and directed interviews. Accessions not originally cultivated in the communities of Kakamega and Nyeri were eliminated. Morphological characterization of qualitative and quantitative characteristics and evaluation results for mother trials were used to confirm and select high yielding accessions from those recommended by key informants.

Fruit weight was used as the main selection criteria because it showed maximum genotypic direct effect on yield (Naik *et al*., 2015). The preferred accessions were selected based on farmers' ranking of organoleptic qualities of fruits and leaves, tolerance to biotic factors, and fruit total number and weight in baby trials. Quality and yield stability were judged principal criteria for selection of accessions. In addition, molecular characterization results were used to select distinct and genetically diverse accessions based on their dissimilarity.

Site Selection and Seed Bulking

Shinyalu and Othaya sites were selected based on farmer groups' willingness to allocate land and participate in on-farm seed bulking and training. Butere-Mumias site was selected due to availability of a large piece of land able to achieve recommended accession separation distance. Farmer groups were supplied with starter seed in Shinyalu and Othaya. The seeds were planted on 5th and 7th June, 2014 in Butere-Mumias and Shinyalu, respectively, and on 13th June, 2014 in Othaya. They were planted at a spacing of 2 m x 2 m in isolation in a Completely Randomized Design. Butere-Mumias site was managed by the researcher. Shinyalu and Othaya sites were managed by farmers. All the sites were replicated.

The land for seed bulking was prepared mechanically through ploughing and harrowing to pulverize the soil into a fine tilth. Diammonium phosphate fertilizer and farm yard manure were applied to the respective planting holes and mixed with the soil before sowing seeds. This ensured vigorous germination. Two weeks after germination, thinning was done to leave one vigorous seedling per hole to facilitate better growth and development by reducing competition for nutrients. Genetic purity was maintained by preventing cross-pollination with other undesirable varieties maintaining a distance of 450 m between pumpkin farms (Rashid and Singh, 2000). Standard cultural management practices for pumpkin production such as weeding and irrigation when there were no rains were strictly adhered to. No vegetable leaves were harvested from pumpkin plants earmarked for seed production to prevent plant starvation.

Variables Measured

The fruits at every harvest for each accession were counted and weighed. Fruit harvesting was conducted between the 5th and 7th months after planting. Twenty mature fruits were randomly selected from fruits harvested in Butere-Mumias, while 24 fruits, three for each accession, were selected for Shinyalu and Othaya sites. Fruits that weighed less than 1 kg, and those with abnormal shape, deformity, or pest and disease attacks, among other factors, were discarded.

Seeds were extracted from fruits conforming to the required genetic characteristics. The fruits were cut cross-sectionally and seeds extracted by scraping them manually using a table spoon. The seed pulp with potential germination inhibitors was washed off using clean water. The extracted seeds were air-dried under partial shade for

8 hours on a tarpaulin. This was followed by sun-drying for half a day starting from morning to mid-day to prevent damage by high temperature and UV radiation in sunlight. After drying, broken, fungal-infected, seed coat-damaged poorly-filled, small-sized, low quality seeds, fruit pulp pieces and debris were removed manually. Seed moisture affects seed storage life. The lower the seed moisture content, the longer the storage life. Long-term storage of pumpkin seeds can be achieved at 6% moisture content. Therefore, seed moisture content was tested using salt-in-a-glass method, where seeds from each accession were randomly picked and put into a glass with salt, shaken and left to stand for 10 minutes. Wet seeds were further dried to attain the correct storage moisture content.

Dry seeds were treated with 4 g/kg actellic super fungicide and stored in moisture-impervious 700 gauge polybags to prevent moisture entry that causes vigour loss during storage. Seeds from each fruit and accession were counted and weighed on an electronic weighing machine to determine total and 100-seed weights.

Germination test was done on 200 seeds for each accession to assess the effect of bulking site and accession on seed viability. Hot water, heat-sterilized, 3-day room-cooled, dry sand substrate with no soil pathogens was used for seed germination. Sand was chosen for germination because it was easy to wash, sterilize and accessible. Newly sterilized sand was used for each accession. The seeds were planted, well-watered and observed for 10 days. The total germinated seeds were counted and divided by two to get percentage germination for each accession.

On-Farm Training of Farmers in Seed Banking

Farmers were trained in seed bulking, on-farm seed saving, establishment and submission to the created community seed bank. Trainings were also conducted during evaluation of mother and baby trials from 2012 to 2014 in Kakamega and Nyeri counties. The group approach was employed in trainings to facilitate experience-sharing, participation, ownership, coordination and mutual-benefiting from the seed bulking processes by farmers. Farmer leaders mobilized group members and entirely supervised implementation of the project. A community seed bank supported by KAPAP was set up at Butere-Mumias Ekero market for farmer-training and demonstration of AIVs seed storage and banking activities.

Data Collection and Analysis

The measured and recorded quantitative data were subjected to analysis of variance, while farmer-training data were subjected to Chi-square analysis using the SAS software. All significant differences were separated using the LSD test at P=0.05.

RESULTS AND DISCUSSION

Morphological characterization and evaluation was used to select the nine *Cucurbita moschata* (Lam.) Poir accessions for seed bulking. The selected accessions were code named: KK-30, KK-35, KK-40, KK-45, KK-65, NY-72, NY-80, NY-142 and NY-154. Ethno-botanical information from key informant farmers on qualities of the selected accessions included: fruit hardness and sweetness, cooked leaf softness and sweetness, roasted seed tastiness, vegetative period longevity, drought tolerance, and pest and disease freedom. The belief by some farmers that the accessions possessed medicinal values was also used as a selection criterion. The farmers believed that the seeds helped prevent helminthes, cured stomachaches and were natural aphrodisiacs when eaten raw. The selected accessions were high yielding and grouped in different clusters and subclusters by the various characterization techniques. The selected and bulked accessions were genetically distinct and variable.

Fruit and Seed Characteristics for Three Sites

The seed bulking sites were significantly different in all quantitative characters, except germination percentage (Table 1). The mean number and weight of fruits, and total number of seeds were all high in Butere-Mumias. Average fruit weight, average number of seeds per fruit, 100-seed weight and germination were all high in Shinyalu site (Table 1). Seed viability and germination were highest in Shinyalu and lowest in Othaya (Table 1). The mean number of rotten fruits was high in Othaya site. Accessions in Othaya bulking site produced low yields for all the characteristics. Butere-Mumias produced high yields, except for average fruit weight. Shinyalu had highest 100-seed weight and germination percentage (Table 2).

Fruit and Seed Characteristics of Bulked Accessions

The accessions were significantly (P<0.05) different in all quantitative characters (Table 3). The average number and weight of fruits were highest in accessions KK-30 and KK-65, and lowest in accessions NY-142 and NY-154, while the 100-seed weight were highest in accession KK-40 and lowest in accession NY-142 (Figure 1). The total and average number of seeds per plant and fruit were highest in accessions KK-30 and KK-40, and were lowest in accession NY-142 (Figure 2).

TABLE 1: Effect of accession and site on average fruit and seed characteristics

Character	n	Min.	Max.	Butere-Mumias	Shinyalu	Othaya	Mean (n = 3)	P-value
Number of fruits/acc/site	64	1	17	7.4	4.9	3.3	5.2	0.000
Total fruit weight (kg/acc/site	64	2.3	48.7	22.6	18.9	10.7	17.4	0.000
Average fruit weight (kg)/acc/site	64	1.3	5.8	3.1	3.9	3.0	3.3	0.000
Number of rotten fruits/acc/site	64	0	4	0.5	0.4	1.4	0.8	0.000
Total number of seeds/acc/site	64	387	5,981	2,786.4	2,170.3	1,077.5	2,011.4	0.000
Average number of seeds/acc/site	64	219	554	379.6	448.6	319.6	382.5	0.000
100-seed weight (g)/acc/site	64	7.4	18.0	13.2	14.8	11.1	13.0	0.000
Germination test (%)/acc/site	64	84	100	98.2	99.0	97.7	98.3	0.620

TABLE 2: Effect of site on total fruit and seed yields

Character	Butere-Mumias	Shinyalu	Othaya	Total	Mean (n=3)
Total number of fruits/site	475	312	212	999	333
Total fruit weight (kg)/site	1,448.7	1,212	684	3,344.7	1,114.9
Average fruit weights (kg)/site	200.3	250	195.3	645.6	215.2
Total number of rotten fruits/site	29	28	88	145	48.3
Total number of seeds/site	178,330	138,896	68,960	386,186	128,728.7
Average number of seeds/site	24,279	28,708	20,460	73,447	24,482.3
Total seed weight (kg)/site	23.5	20.6	7.7	51.8	17.3
Average seed weight (g)/site	367.2	321.8	120.3	809.3	269.8
Average 100-seed weight (g)/site	13.2	14.8	11.1	39.1	13.0
Average germination test (%)/site	98.2	99	97.7	294.9	98.3

TABLE 3: Effect of accession on fruit and seed characteristics

Character	Minimum	Maximum	Accession mean (n = 144)	*P*-value
Number of fruits/accession	1	17	6.9	0.000
Total fruit weight (kg)/accession	2.3	48.7	23.2	0.000
Average fruit weight (kg)/accession	1.3	5.8	4.5	0.000
Number of rotten fruits/accession	0	4	1.0	0.000
Total number of seeds/accession	387	5981	2681.8	0.000
Average no. of seeds/accession	219	554	510.1	0.000
100-seed weight (g)/accession	7.4	18.0	17.4	0.000
Germination test (%)/accession	84	100	98.3	0.013

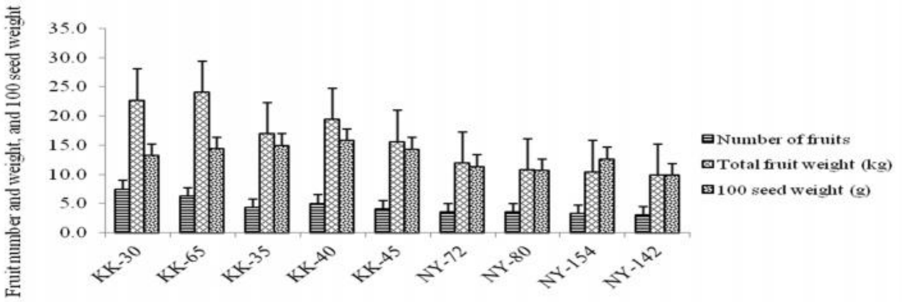

FIGURE 1: Effect of accession on fruit number, total weight, and 100-seed weight. Bars represent standard deviation

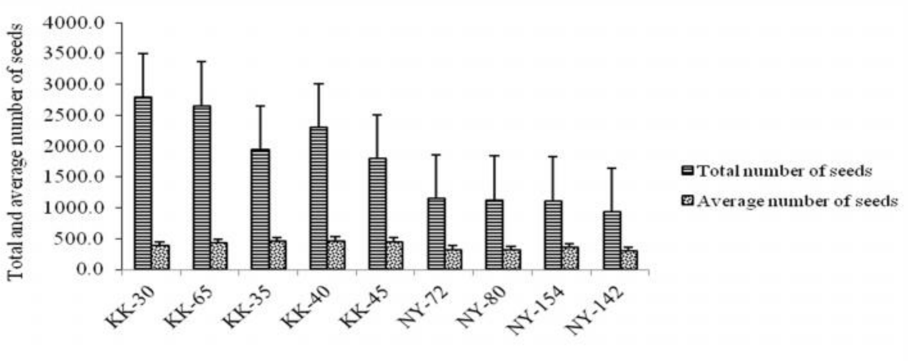

FIGURE 2: Effect of accession on total number of seeds per plant and average number of seeds per fruit. Error bars represent standard deviation

Seed Number, Viability and Quality of Accessions

Total and average fruits, total weight, fruit weight per accession, rotten fruits, total seeds and average seeds per accession, 100-seed weight were high in KK-30, while average 100-seed weight and germination percentage were highest for KK-40. Total number of fruits, fruit weight per accession, total number of seeds and germination test were lowest for NY-154, while average number of fruits, fruit weight, number of seeds and fruits per accession, 100-seed weight were lowest for accession NY-142. Total fruit weight and average fruit weight per accession were lowest for NY-80, while total and average rotten fruits were lowest for KK-40. Accession KK-35 and KK-45 had no rotten fruits. Germination percentage was 100% in accession KK-40 and 91% in NY-154 (Table 4).

TABLE 4: Accessions giving highest and lowest performance for each highlighted total and average characteristics

Accession code	Character	NFA	TFW	AFW	NRF	TNS	ANSF	100SW	GT%
KK-30	Total no. of fruits/accession	17.0	48.7	5.8	4.0	5981.0	554.0	18.0	98.2
NY-154		1.0	2.3	2.3	0.0	387.0	260.0	10.3	91.0
KK-30	Avg no. of fruits/plant	7.4	22.6	3.1	0.5	2786.4	379.4	13.2	98.2
NY-142		3.0	9.8	3.1	1.5	926.8	294.5	9.8	99.5
KK-30	Total fruit weight (kg)/accession	17.0	48.7	5.8	4.0	5981.0	554.0	18.0	98.2
NY-80		2.0	2.6	1.3	0.0	597.0	255.0	8.6	97.5
KK-65	Total fruit weight (kg)/plant	6.3	24.0	3.8	1.3	2652.8	426.0	14.4	99.0
NY-142		3.0	9.8	3.1	1.5	926.8	294.5	9.8	99.5
KK-30	Avg fruit weight (kg)/accession	17.0	48.7	5.8	4.0	5981.0	554.0	18.0	98.2
NY-154		1.0	2.3	2.3	0.0	387.0	260.0	10.3	91.0
KK-35	Avg fruit weight (kg)/plant	4.3	16.9	4.0	0.0	1934.5	458.0	14.9	97.5
NY-80		3.5	10.7	2.8	1.5	1124.3	312.0	10.6	97.5
KK-30	No. of rotten fruits/accession	17.0	48.7	5.8	4.0	5981.0	554.0	18.0	98.2
KK-40		6.0	20.7	4.3	1.0	2525.0	483.0	16.3	100.0
KK-35	Zero rotten fruits/accession	4.3	16.9	4.0	0.0	1934.5	458.0	14.9	97.5
KK-45		4.0	15.5	3.9	0.0	1794.5	448.3	14.2	99.5
KK-72	Avg no. of rotten fruits/plant	7.4	22.6	3.1	1.8	2786.4	379.4	13.2	98.2
KK-30		5.0	19.4	3.9	0.5	2299.3	462.0	15.8	100.0
KK-30	Total no. of seeds/accession	17.0	48.7	5.8	4.0	5981.0	554.0	18.0	98.2
NY-154		1.0	2.3	2.3	0.0	387.0	260.0	10.3	91.0
KK-30	Avg no. seeds/plant	7.4	22.6	3.1	0.5	2786.4	379.4	13.2	98.2
NY-142		3.0	9.8	3.1	1.5	926.8	294.5	9.8	99.5
KK-30	Total no. seeds/fruit	17.0	48.7	5.8	4.0	5981.0	554.0	18.0	98.2
NY-142		2.0	5.0	2.5	0.0	438.0	219.0	7.4	99.5
KK-40	Avg no. seeds/fruit	5.0	19.4	3.9	0.5	2299.3	462.0	15.8	100.0
NY-142		3.0	9.8	3.1	1.5	926.8	294.5	9.8	99.5
KK-30	100 seed weight (g)/accession	17.0	48.7	5.8	4.0	5981.0	554.0	18.0	98.2
NY-142		2.0	5.0	2.5	0.0	438.0	219.0	7.4	99.5
KK-40	Avg 100 seed weight (g)/plant	5.0	19.4	3.9	0.5	2299.3	462.0	15.8	100.0
NY-142		3.0	9.8	3.1	1.5	926.8	294.5	9.8	99.5
KK-40	Germination test %/accession	5.0	19.4	3.9	0.5	2299.3	462.0	15.8	100.0
NY-154		1.0	2.3	2.3	0.0	387.0	260.0	10.3	91.0
KK-40	Germination test %/plant	5.0	19.4	3.9	0.5	2299.3	462.0	15.8	100.0
NY-154		3.3	10.4	3.0	0.8	1110.8	356.3	12.6	96.5

Character measured: NFA, TFW, AFW, NRF, TNS, ANSF, 100SW, GT%

Avg = Average; AFW = Average fruit weight; ANSF = Average number of seeds per fruit; NFA = Number of fruits per accession; NRF = Number of rotten fruits; TFW = Total fruit weight; TNS = Total number of seeds; 100SW = 100-seed weight; GT% = Germination test percentage

On-Farm Seed Bulking and Farmer Training

The number of male and female farmers trained to bulk seeds was not significantly different among the 10 subcounties during mother and baby trials, as well as seed bulking stages. The χ^2 = 214 (df=42; N=10, *P*=0.316). The female farmers trained were more in five subcounties, and male farmers were more in four subcounties. In Nyeri South equal male and female farmers were trained. In Kakamega East and South, Mathira West and Butere more male farmers were trained, while in Mathira East and Butere-Mumias more female farmers were trained (Figure 3). Of the 214 farmers trained, 114 were female and 100 were male. The number of farmers trained was 132 in Kakamega, compared to 82 in Nyeri over the three years of the study (Figure 4).

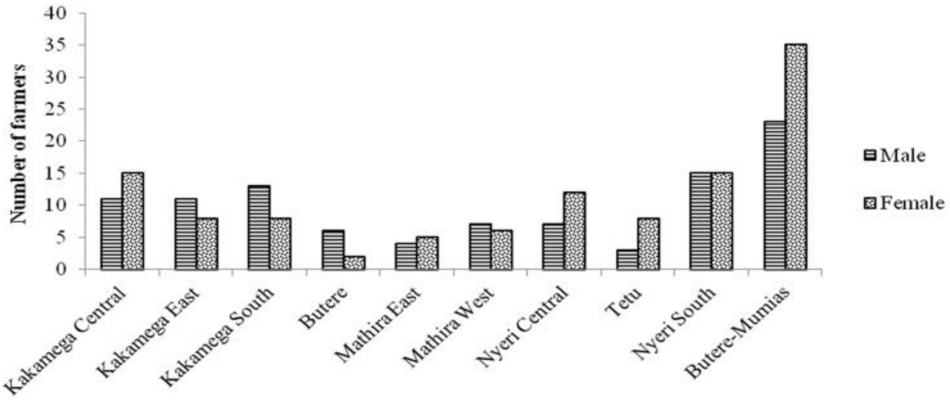

FIGURE 3: Male and female farmers trained in for three years in Kakamega and Nyeri subcounties

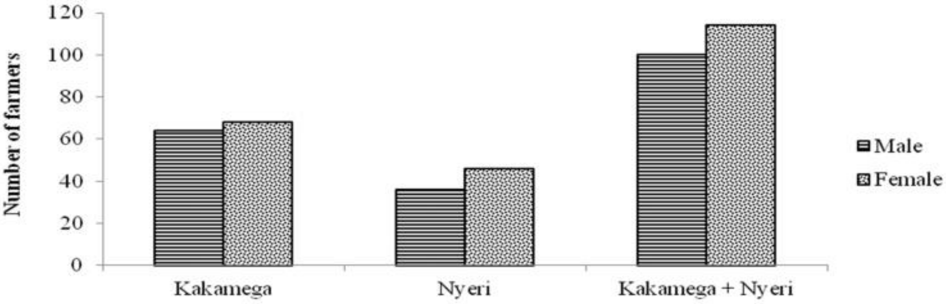

FIGURE 4: Comparison of male and female farmers trained in three years in Kakamega and Nyeri regions

DISCUSSION

Effect of Site on Fruit and Seed Yields

Total fruit number, weight and seed yield were high in Butere-Mumias. The differences in yields observed in the three sites were attributed to variations in agro-ecological zones, soil characteristics, rainfall, and temperature (Muungani *et al.,* 2007) patterns. Pumpkins come across many constraints that limit full expression of their growth and productivity (Sajjan and Prasad, 2009). Their yields are influenced by the growing conditions, genetics, soil, fertilization (Karklelienė *et al*., 2008), and variations due to cross pollination (Ahamed *et al.,* 2011). The average fruit weight was low in Butere-Mumias and Othaya sites. This was due to the many fruits produced in Butere-Mumias. The high number of fruits produced in Butere-Mumias compensated for the decreasing fruit weight through overall increase in total fruit yield (El-Hamed and Elwan, 2011). Shinyalu site had the highest average fruit weight and 100-seed weight. Large size and few fruits produced per site in Shinyalu increased average fruit and 100 seed weight. Studies by Chukwudi and Agbo (2014) reported that large-sized fruits had higher 100-seed weight than small-sized fruits. Othaya site produced the lowest number and weight of fruits. This was as a result of fruit flies that pierced young developing fruits at an early stage of development. The pierced fruits ended up rotting or deforming owing to secondary microbial infection. Shinyalu site produced higher total number of fruits per area, weight and seeds compared to Othaya. This was attributed to the number of fruits produced per accession in each site. Pumpkin yields vary, depending on soil conditions, climate and genetic factors (Srbinoska *et al*., 2012). Shinyalu and Othaya research sites were located in different agro-ecological zones, and hence climactic conditions could have interacted with genetic factors to influence yields differently. Flowering, fruiting, seed production and growth of pumpkins is affected by environmental and genetic factors, as well as paternal and maternal conditions (OECD, 2012).

Germination percentage was positively correlated with average fruit weight and 100-seed weight per site. Shinyalu site had the highest average fruit and 100-seed weight, as well as germination percentage. Othaya site had the lowest average fruit and 100-seed weight, as well as germination percentage. The average number of seeds was high in Shinyalu site due to high average fruit weight per accession. Large-sized fruits have higher total number of seeds than medium or small-sized ones (Chukwudi and Agbo, 2014). The number of rotten fruits was varied for the three sites with the lowest number occurring in Shinyalu. In Othaya site, fruit rots were common due to fruit flies. The sites were located in different agroecological zones with varying soils and environmental conditions. Environment has an influence on pest and disease pressures due to climatic differences between locations (Gilbert *et al*., 2006).

Effect of Accession on Fruit and Seed Yields

In the present study, accessions significantly varied in all quantitative characters. The observed variation suggests extensive genetic variation of accessions. Rich genetic diversity within and among species ensures vitality by building capacity to withstand biotic and abiotic stressors under changing and unpredictable environmental conditions (Porth and El-Kassaby, 2014). Accession KK-30 produced the highest fruit number, weight and seeds per accession. The ability of species to adapt and survive in different environmental conditions resides in their genetic diversity (Singh *et al*., 2014). Genotype and environment interaction help to optimize yield (El-Hamed and Elwan, 2011). Thus, selection of ecologically and genetically diverse plants is a vital strategy in seed bulking. Adapted accessions are essential for restoring self-sustaining ecosystems with the diversity required to provide resiliency in the face of climate change and other environmental perturbations (Youtie *et al*., 2012). Selection of genetically diverse accessions underscores the importance of seed quality in plant establishment and yield (Chukwudi and Agbo, 2014).

The number and weight of seeds per fruit among accessions increased with an increase in average fruit weight. Seed quality in pumpkins is affected by fruit size (Majuju, 2010). Chukwudi and Agbo (2014) reported high individual seed weights from large fruits. High germination (100%) percentage was observed in accession KK-40 due to high weight of 100 seeds. Large food reserves in heavy seeds support high seedling establishment (Chukwudi and Agbo, 2014), by stimulating rapid and synchronous seedling emergence prerequisite for successful establishment, uniform plant growth and development (Bhardwaj and Kumar, 2012). High average germination percentage resulted in all bulked accessions. This was attributed to proper seed selection used that excluded seeds stored for more than one year, had pests and diseases, were not of uniform size and shape, dull-coloured or black spotted seeds. The selection ensured only high quality seed was bulked.

Effect of Accession and Site on Fruit Quality

There were no rotten fruits in accessions KK-35 and KK-45 bulked in Shinyalu site. Fruit rots occur due to cracks created by pests on young fruits or due to soil borne pathogens on mature fruits. The absence of fruit rots in the two accessions was attributed to cucurbitacin-mediated interactions. Cucurbitacins function as chemical defense compounds against insects, fungi and herbivores. Cultivated varieties of pumpkins are bred to express low levels of cucurbitacins. However, plants in wild populations express high levels of cucurbitacins and if a cultivated plant is visited by bees carrying pollen from plants in a wild population, higher levels of the toxicant can be produced in the fruit (OECD, 2012). There could be a possibility that cucurbitacin was introduced by bees because Shinyalu site was near Kakamega forest. Othaya site had the highest number of fruit rots as a result of secondary infections by fungi that entered the fruits through avenues created by fruit flies that were common in the site. The differences in the number of fruit rots in the three sites were attributed to differences in agro-climatic zones (Selvi *et al.,* 2012). The sites were variable in nutrient amounts, soil characteristics, rainfall and temperature (Muungani *et al.,* 2007).

Effect of Environment and Genetics on Yields

In the study, one or two fruits were observed in some of the accessions. This was attributed to the suppressing effect of the first formed fruits on the development of fruits formed subsequently, because the first fruit becomes an active sink that draws water and nutrients from other parts of plants (Roopa, 2006) curtailing further fruiting. The variation in the weight of 100 seed among accessions was attributed to environmental and genetic factors. Seeds contain the genetic code that is expressed under favourable conditions (Chukwudi and Agbo, 2014). Quality is influenced by internal and environmental factors during seed development (Ghanbari *et al*., 2007), and by paternal and maternal conditions, and origin of the paternal genotype (OECD, 2012). Seeds resulting from large amounts of pollen reaching styles are heavy and more vigorous than those produced when smaller amounts of pollen reach the styles. Environmental conditions interfere with pollination and fruit set by influencing pollinator activity. Honeybees are less active when it is hot and dry (OECD, 2012).

Training of Regional Farmers

Most male farmers were trained in Kakamega East and South, and Butere because of cultural believes entrenched in the community about pumpkins. A myth that pumpkins may fail to produce fruits if cultivated by women had an influence on the number of females trained. Socio-economic characteristics of households, mainly gender and the occupation of household head had an influence on pumpkin production. Males who do farming as their main occupation influenced the crop calendar. More females were trained in Kakamega Central due to the nearness of the area to Kakamega town. The cultural beliefs were not strictly adhered to because the residents were cosmopolitan. Majority of farmers trained in Butere-Mumias were females because it was mainly a sugarcane growing zone. Males were mostly involved in sugarcane farming which fetched good money (Masayi and Netondo, 2014). Men considered pumpkin a low value crop compared to sugarcane. Pumpkin was grown in marginal areas such as kitchen waste dumping sites, former cattle sheds and demolished mud hut sites which did not interfere with sugarcane and allowed women to engage in pumpkin farming (Masayi and Netondo, 2014).

In Nyeri, the number of male and female farmers trained varied across the locations. Economic reasons were the driving force for planting pumpkins due to nearness of Karatina, Nyeri and Othaya towns. There were more women trained than men in Nyeri Central and Tetu. Most farmers in Nyeri Central had small parcels of land due to close proximity to Nyeri town. The farmers used kitchen gardens to farm. Kitchen gardens are mostly managed by women, thus the high number of females trained. In Tetu, pumpkins were mainly grown by women for domestic consumption. Women were engaged in feeding the household. Pumpkins improve the welfare of women and children, who are otherwise mostly affected by malnutrition (Masterson, 2007). They play a key role in nutrition and are excellent sources of proteins, vitamins and minerals (Masayi and Netondo, 2014). A belief that pumpkins were largely for women and children and not for men also contributed to high involvement of women in pumpkin production. These beliefs contributed to the large number females trained than male farmers in Nyeri.

Generally the number of women trained for three years was more compared to men in Kakamega and Nyeri. Pumpkin was considered a "woman's" crop and not a mainstream crop. This factor consigned the production of pumpkins into the hands of women, who have hitherto continued to sustain its production (Ondigi *et al*., 2008). Socio-cultural values based on gender factors have promoted certain pumpkin production practices and hindered its overall progress in cultivation and expansion (Ondigi *et al*., 2008). The high number of females trained in seed bulking was also attributed to the new Constitution of Kenya which empowered women. Land rights for women were the key determinants in household welfare. Women's independent control of land leads to improved welfare. Resources are used more towards household needs than those under men's control. Women's land rights lead to increased productivity, efficiency, equality and empowerment by giving an economic base from which to challenge gender oppression in the household and society at large (Masterson, 2007). Women are the providers of food for their families. They participate in cultivating food and cash crops to provide income to purchase items they cannot produce. Men mainly control increased cash income and they are less likely to engage in less profitable farming (Kiriti and Tisdell, 2003).

Farmers are significant players in the seed industry. Shortage of seeds for planting is the most important constraint to small-scale farmers in Kenya. The farmers obtain seeds through formal and informal channels, with the latter channel constituting the largest source for smallholder farmers (Barnett *et al*., 2011). Many farmers purchase little new seeds every season. Their seed sources are own-saved seeds, from the local market, seed traders, government (through drought recovery programs in the ministry of agriculture), and neighbors (Muhammad *et al*, 2003). Informal seed supply systems are increasingly coming under pressure due to drought, crop failure and unconducive storage conditions, which are eroding both the quantity of seeds and number of cultivars available to farmers. The local landraces are increasingly becoming unavailable in many communities. Interventions to strengthen informal seed supply systems, such as seed banks and multiplication, should be promoted (Lewis and Mulvany, 1997). The effective mechanism for production of pumpkin is to involve small-scale farmers in schemes to produce seed for their own use (Muhammad *et al*, 2003). To ensure a sustainable increase in the production of pumpkins, it is necessary to train farmers on the cultural attributes of seed selection, planting, harvesting, storage and conservation (Ondigi *et al*., 2008). The weak research-extension-farmer linkages are major limitations to adoption of improved local pumpkin cultivars (Barnett, *et al.*, 2011). The linkages need to be strengthened to inform farmers on recommended practices to maximize pumpkin yields (Muhammad *et al*, 2003).

CONCLUSION AND RECOMEMNDATIONS

This study found sufficient seed yield variation in naturalized and preferred pumpkin accessions in Kakamega and Nyeri that could be exploited. Consequently, KK-30, KK-35, KK-40 and KK-45 are recommended for adoption and development into commercial pumpkin seed and fruit production cultivars. Regional farmers should be mobilised and empowered to commercially produce and conserve the preferred, but endangered pumpkin produce and germplasm.

ACKNOWLEDGEMENTS

This research was supported by research funds provided by the KAPAP to whom we are indebted. Authors are grateful to all agriculture staff in Kakamega and Nyeri counties for their cooperation, and to all farmers who participated in the evaluation and seed bulking activities. The authors acknowledge Dr. D. Andika, Misters Wilson, Mwangi and Jeffrey for their assistance during seed bulking.

REFERENCES

Ajayi, S.A. (2007) Current trends in seed science: Implications for Sub-Saharan Africa. *Afri. Crop Sci. Conference Proceedings*, **8**, 79-85.

Ayieko, M.W. and Tschirley, D.L. (2006) Enhancing access and utilization of quality seed for improved food security in Kenya. Egerton University Tegemeo Institute. WPS 27/2006.

Barnett, C., Chisvo, M. and Pinto, Y. (2011) Country case studies on the pass value chain strategy/approach and its impact/effect on smallholder farmer yields in Africa. East Africa Synthesis Report (Kenya, Tanzania, Uganda). Institute of Development Studies.

Berg, T. (1996) Dynamic management of plant genetic resources: Potentials of emerging grass-roots movements. Study No. 1. Studies in Plant Genetic Resources, Plant Production and Protection Division. FAO. Italy.

Bhardwaj, R.K. and Kumar, S. (2012) Studies on correlation between yield and seed characters in cucumber, *Cucumis sativus* L. *Intern. J. Farm Sci.* **2**(1), 54-58.

Chukwudi, U.P. and Agbo, C.U. (2014) Leaf and fruit yield performance of *Telfairia Occidentalis* Hook F. (Fluted Pumpkin) as influenced by fruit size. *Not. Sci. Biol.*, **6**(4), 509-514.

Cromwell, E. (1996) Governments, farmers and seeds in a changing Africa. CABI, London.

El-Hamed, K.E.A. and Elwan, M.W.M. (2011) Dependence of pumpkin yield on plant density and variety. *American J. Plant Sci*., **2**, 636-643.

Ellis-jones, J., Stenhouse, J., Gridley, H., Hella, J. and Onim, M. (2008) Baseline study on vegetable production and marketing. Cameroon Vegetable Breeding and Seed System for Poverty Reduction in Africa. Pp. 2.

Ghanbari, A., Nadjafi, F., and Shabahang, J. (2007) Effects of irrigation regimes and row arrangement on yield, yield components and seed quality of pumpkin (*Cucurbita pepo* L.). *Asian J. Plant Sci.,* **6**(7), 072-1079.

Gilbert, R.A., Shine Jr., J.M., Miller, J.D., Rice, R.W. and Rainbolt, C.R. (2006) The effect of genotype, environment and time of harvest on sugarcane yields in Florida, USA. *Field Crops Research,* **95**, 156-170.

Jaetzold, R. and Schmidt, H. (1983a) Farm management handbook of Kenya. Natural conditions and farm information. Vol. II/C. East Kenya. Ministry of Agriculture, Nairobi, Kenya.

Jaetzold, R., and Schmidt, H. (1983b) Farm Management Handbook of Kenya. Natural conditions and farm information. Vol. III. West Kenya. Ministry of Agriculture, Nairobi, Kenya.

Kassam, A. H., Velthuizen, H.T., Fischer, G.W. and Shah, M.M. (1991) Agro-ecological land resources assessment for agricultural development planning. A case study of Kenya, p. 9-31. Resources data base and land productivity. Technical Annex 1, Land Resources. Land and Water Development Division, FAO and IIASA, Rome.

Kimenye, L. (2013) Improving access to quality seeds in Africa. Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) and CABI publication, Pp. 1-6.

Kiriti, T. and Tisdell, C. (2003) Commercialization of agriculture in Kenya: Case study of policy bias and food purchases by farm households. In: Working Paper No. 32 on Social Economics, Policy and Development. The University of Queensland, Pp. 1-23.

Lewis, V. and Mulvany, P.M. (1997) A Typology of community seed banks. Natural Resources Institute (NRI), University of Greenwich, Central Avenue and Intermediate Technology Development Group, Myson House, United Kingdom. NRI Project A0595.

Longley, C., Jones, R., Ahmed, M.H. and Audi, P. (2001) Supporting local seed systems in southern Somalia: A developmental approach to agricultural rehabilitation in emergency situations. Agriculture Research and Extension Networks. Network Paper No. 115.

Louette, D. and Smale. M. (1998) Farmers' seed selection practices and maize variety characteristics in a traditionally-based Mexican community. CIMMYT Economics Working Paper No. 98-04. Mexico, D.F.: CIMMYT.

Maharjan, S.K., Gurung, A.R. and Sthapit, B.R. (2011) Enhancing on-farm conservation of agro-biodiversity through community seed bank: An experience of western Nepal. *The Journal of Agriculture and Environment.* **12**, 132-139.

Majuju, C. (2010) Zimbambwe seed sector: A baseline study/survey on Zimbambwe seed sector for use in the rationalization and harmonization of the seed regulations and policies in the COMESA member states. Seed services, Agric. Research Centre, Fifth Street Extn., Harare, Pp. 5-6.

Masayi, N. and Netondo, G.W. (2014) Effects of sugarcane farming on diversity of vegetable crops in Mumias division, Western Kenya. *Int. J. Biodivers. Ecosyst*., **2**(1), 1-10.

Masterson, T. (2007) Female land rights, crop specialization, and productivity in Paraguayan Agriculture. Working Paper No. 504. The Levy Economics Institute of Bard College, Pp. 1-28.

Mugo, S., Likhayo, P., Karaya, H., Gethi, J., Njoka, S., Ajanga, S., Shuma, J. and Tefera, T. (2007) Screening maize germplasm for resistance to maize weevil (*Sitophilus zeamais* (Motsch.) and larger grain borer (*Prostephanus truncatus* (Horn)) pests in Kenya. CIMMYT and KARI. Nairobi, Kenya.

Muhammad, L., Njoroge, K., Bett, C., Mwangi, W. Verkuijl, H. and De Groote. H. (2003) The seed industry for dryland crops in Eastern Kenya. Mexico, D.F.: CIMMYT and Kenya Agricultural Research Institute (KARI).

Muyanga, M., Ayieko, M. and Gem, A. (2005) Analysis of agricultural productivity in Kenya. A World Bank Agricultural Policy Review Technical Background Paper, May 2005.

Naik, M.L., Prasad, V.M. and Rajya, L.P. (2015) A study on character association and path analysis in pumpkin (*Cucurbita moschata* Duch. ex Poir.). *Internat. J. Adva. Res.* **3**(1), 1030-1034.

Nyoro, J.M., and Ariga, J.M. (2004) Preparation of an inventory of research work undertaken in agricultural/rural sector in Kenya. Paper for the World Bank, July, 2004.

OECD (2012) Consensus document on the biology of *Cucurbita* L. (squashes, pumpkins, zucchinis and gourds). Series on Harmonisation of Regulatory Oversight in Biotechnology, No. **53**. ENV/JM/MONO Pp. 31.

Ondigi, A.N., Toili, W.W., Ijani, A.S.M. and Omuterema, S.O. (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. *Afr. J. Env. Sci. Tech*., **2**(9): 296-304.

Onyango, M.O.A (2007) Seed production and support systems for African leafy vegetables in three communities in Western Kenya. *Afr. J. Food, Agr. Nut. Dev.* **7**(3), 1-16.

Onyango, M.O.A. and Onyango, J.C. (2005) Conservation and seed production of African leafy vegetables at Maseno University Botanic Garden, Kenya. *Afr. Crop Sci. Conference Proceedings*, **7**, 1201-1204.

Porth, I. and El-Kassaby, Y.A. (2014) Assessment of the genetic diversity in forest tree populations using molecular markers. *Diversity*, 6, 283-295.

Rashid, M.A. and Singh, D.P. (2000) A manual on vegetable seed production in Bangladesh. AVRDC-USAID Bangladesh Project. Horticulture Research Centre Bangladesh Agricultural Research Institute, Joydebpur, Gazipur-1701. Bangladesh.

Roopa, V. (2006) Influence of postharvest handling techniques on seed quality and storability of muskmelon (*Cucumis melo* L.). M.Sc. Thesis, University of Agricultural Sciences, Dharwad.

Selvi, N.A.T., Jansirani, P., Pugalendhi, L. and Nirmalakumari, A. (2012) Per se performance of genotypes and correlation analysis in pumpkin (*Cucurbita moschata* Duch. ex Poir). *Electronic J. Plant Breed*. **3**(4), 987-994.

Singh, K., Kadyan, S., Panghal, M. and Yadav, J.P. (2014) Assessment of genetic diversity in *Tinospora Cordifolia* by Inter-Simple Sequence Repeats (ISSR) and Expressed Sequence Tagged-Simple Sequence Repeats (Est-SSR). *Int. J. Pharm. Pharm. Sci*., 6(10), 520-524.

Srbinoska, M., Hrabovski, N., Rafajlovska, V. and Sinadinovic-Fiser, S. (2012) Characterization of the seed and seed extracts of the pumpkins *Cucurbita maxima* D. and *Cucurbita pepo* L. from Macedonia. Maced. *J. Chem. Chem. Eng.*, 31 (1), 65–78.

Youtie, B., Shaw, N., Fisk, M. and Jensen, S. (2012) A Strategy for maximizing native plant material diversity for ecological restoration, germplasm conservation and genecology research. 8th European Conference on Ecological Restoration held on 9-14/09/2012. Česke Budejovice, Czech Republic.