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# QUALITATIVE, QUANTITATIVE AND QUALITY VARIATION OF NATURALIZED PUMPKIN ACCESSIONS IN MOTHER AND BABY TRIALS IN KENYA

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**ABSTRACT**

Pumpkin (*Cucurbita moschata* (Lam.) Poir.) is unsystematically produced in many tropical countries and development of standard cultivars using naturalised and adapted genetic resources has not yet been done. The present study evaluated naturalized pumpkin accessions yield in Kakamega, Embu and Nyeri in 2012 and 2013 and quality in Chuka in 2015 to identify superior ones that could be developed into commercial cultivars. The accessions were planted on-station in Kakamega and Embu for mother trials, on farmers' farms in Kakamega and Nyeri for baby trials, and on-station in Chuka for TSS assessment. Mother and baby trials and quality assessment plants were spaced at 2mx2m in a completely randomised design. Qualitative and quantitative data were subjected to Chi-square analysis and ANOVA, respectively. Significant differences were separated using LSD test at $P$=0.05. The qualitative and quantitative traits measured were significant ($P$<0.05) and higher in local accessions compared to the control exotic 'Sugar Baby'. The number of fruits per accession ranged from 1 to 9 in mother trials and 1 to 16 in baby trials. Accessions KK-40 and NY-154 produced highest 9 and 16 fruits, respectively, while NY-135, KK-21 and KK-22 produced 1 fruit each. Average fruit weight per plant was 4.2 kg for NY-130 and 0.2 kg for NY-77 in mother trials. Total fruit weight ranged from 0.2 to 15.9 kg in mother trials and 0.25 to 26.5 kg in baby trials. The highest 26.5 kg total fruit weight was for KK-30 in baby trials, and lowest 0.2 kg was for NY-77 in mother trials. Fruit firmness ranged from 3 to 10.2 kg/cm$^2$, while TSS ranged from 2.9 to 14% brix. Highest fruit firmness was 10.2 kg/cm$^2$ for KK-9, while flesh firmness was 3 kg/cm$^2$ for KK-46. Highest 14% brix was for KK-12 and KK-30, while lowest 2.9% brix was for KK-56. The significant and superior variation of naturalized pumpkin accessions in yield and quality, compared to the exotic 'Sugar Baby', presents material for selection and development into commercial, high value pumpkin production cultivars. The accessions perform better regardless of whether they are grown on-station or on-farm, meaning that what matters most is optimization of crop management practices. In this regard, KK-30 is recommended for selection and development into a standard cultivar, based on its highest yields and TSS.

**Keywords:** accession, agrobiodiversity, germplasm, fruit yield, quality, screening.

## 1. INTRODUCTION

Pumpkin cultivars grow well under varied agro-ecological zones, soil characteristics, rainfall and temperature (Muungani *et al*., 2007). They greatly vary, but their growth, yield and fruit quality are additionally influenced by growing conditions, fertilization and other factors. Consequently, selection of cultivars with suitable gene types is critical (Karklelienė *et al*., 2008). Genotype and environment interaction help to optimize yield and quality of crops. Thus, partitioning of phenotypic and genotypic variation of accessions requires evaluating performance in many sites (El-Hamed and Elwan, 2011).

Mother trials are evaluated under researcher-managed, recommended practices, or researcher-managed, farmer practices (Baluti *et al*., 2011).They are planted in the centre of farming communities to meet the production goals of farmers and the goals of the wider community (Twomlow and Lilja, 2004). Crop growth potential in a given location is further determined by genotype and climate, while actual crop yields result from the interactions of local growth-limiting and reducing factors (Tittonell *et al*., 2008). Thus, baby trials allow researchers to accommodate the full range of factors, players, nature, cause and potential effects of constraints in agro-ecosystems (Twomlow and Lilja, 2004).

In Kenya, pumpkins come across many problems that limit full expression of their growth and productivity (Sajjan and Prasad, 2009). They withstand adverse weather conditions (Oloyede, 2013), but their yields and quality are affected by growing conditions, genetics, soil and fertilizer (Karklelienė *et al*., 2008). Variation due to cross pollination with introduced exotic cultivars is high (Ahamed *et al*., 2011). There are no recommended pumpkin cultivars in Kenya. Consequently, many pumpkin genotypes with diverse characteristics are grown in different parts of the country (Ahamed *et al*., 2011).

Limited information is available on yield and quality, under varied management practices and agro-ecological zones, which could be used to delineate and standardize the accessions (Ahamed *et al*., 2011; Isutsa and Mallowa, 2013; Mwaura *et al*., 2014). Therefore, evaluation of accessions to determine those exhibiting better plant growth, yield and quality is very vital in overcoming this absence (Sajjan and Prasad, 2009). Kenya has a wide array of pumpkin genotypes that have not been evaluated (Karuri *et al*., 2010). Consequently, trials were conducted on-station and on-farm to evaluate the pumpkin

accessions, previously collected from varied agro-ecological zones, in comparison to exotic Sugar Baby cultivar, which served as a standard control.

## 2. MATERIALS AND METHODS

### 2.1 Research sites

Mother trials were planted at Kakamega and Embu Kenya Agriculture and Livestock Research Organizations (KALRO) station farms, while baby trials were planted in Kakamega and Nyeri on farmers' farms. KALRO Embu is located at 00° 32' S, 37° 27' E, 1560 m asl, has Nitisol soils and receives average 1000 mm annual rainfall (Jaetzold and Schmidt, 1983b).

KALRO Kakamega is located at 00° 34' S and 34° 49' E, 1700 m asl, has loamy soils and receives average 1200 mm annual rainfall. Kakamega farms were located at 00° 16' N, 34° 45' E, 1585 m asl and experienced 20°C average temperature and bi-modal rainfall, averaging 2012 mm annually. Its soils are classified as dystro-mollic Nitisol (Jaetzold and Schmidt, 1983a). Nyeri farms were located at 37º E, 0º 38´ S, 1810 m asl, with 19ºC mean temperature and bi-modal rainfall, averaging 1500 mm annually (Kassam *et al*., 1991). Its soils were well drained, extremely deep, dark-reddish brown, friable and slightly smeary clay with acid humic tops, which are described as andohumic Nitosols with umbric Andosols (Jaetzold and Schmidt, 1983a).

### 2.2 Evaluation of morphological characters

Mother trials were planted as 72 accessions in Kakamega and 79 accessions in Embu in a completely randomized design (CRD) with three replications. Each accession planted represented a research plot. Five plants per accession were tagged and their average data values were used in analyses. Baby trial accessions were planted as one accession for each farmer up to 72 accessions in Kakamega and 79 accessions in Nyeri in a CRD. Each farmer also planted the control 'Sugar Baby' cultivar. Each farmer planted a minimum of 5 plants of the allocated accession at 2 m x 2 m spacing.

Data recording started 20 days after planting up to maturity. Evaluation was conducted using some IPGRI descriptors for cucurbits. At maturity, each accession observed was harvested individually and planted once more. Data was recorded for two seasons on plant characteristics, leaf and fruit yields to obtain stability. Fruits were harvested when half of them started turning brown. Yield-determining and yield characteristics were recorded. Mother trials were compared using matrix ranking through focus group discussions. Household level questionnaires were used to record data for baby trials. Comparisons were made between mother and baby trials, exotic cultivar Sugar Baby, and local accessions.

### 2.3 Evaluation of fruit quality

Fruit firmness and total soluble solids (TSS) were measured on 125 accessions. TSS was measured using a hand-held refractometer (0 to 32% Brix), and fruit firmness using a hand-held sclerometer (0.5 to 12 kg/cm$^2$ d=0.1). The pressure head size of the sclerometer was 11 mm. The head was inserted 10 mm into external rind and internal flesh of fruits and readings recorded.

### 2.4 Data analysis

Quantitative and qualitative data were recorded for each accession and grouped in nominal and continuous categories. Qualitative data was numerically coded and expressed as modes and frequencies. Descriptive statistics were calculated on quantitative data. Qualitative data were subjected to Chi-square analysis. Quantitative data were subjected to analysis of variance using Statistical Analysis System program. Significance was determined using F-test at P=0.05 for both qualitative and quantitative data.

## 3. RESULTS

### 3.1 Mother trial qualitative characters

All accessions evaluated in this study were taxonomically classified and found to be *Cucurbita moschata* (Lam.) Poir. Nevertheless, code names have been used throughout this paper because cultivar names have not yet been assigned. Mother trial accessions in Kakamega and Embu were significant (P<0.000) in all qualitative characters (Table-1). Most accessions were vigorous in Kakamega and intermediate in Embu mother trials. Predominant flower colour was orange and fruit shape globular; the colour of immature fruit ranged from intermediate to dark-green and that of mature fruits from green to dark-green in most accessions. Fruit size varied from small to intermediate, while flowers in most accessions were monoecious and few were androecious.

**Table-1.** Chi-square analysis of mother trial qualitative characters frequency.

| Character | Observed | Expected | $\chi^2$ | df | *P*-value |
|---|---|---|---|---|---|
| Seedling vigour | 809 | 269.7 | 1.2 | 2 | 0.000 |
| Flower colour | 798 | 199.5 | 9.7 | 3 | 0.000 |
| Fruit shape | 585 | 83.6 | 1.4 | 6 | 0.000 |
| Fruit size | 585 | 73.1 | 4.1 | 7 | 0.000 |
| Fruit colour of immature fruit | 585 | 195.0 | 50.6 | 2 | 0.000 |
| Mature fruit colour | 585 | 83.6 | 4.9 | 6 | 0.000 |
| Sex type | 766 | 383.0 | 5.2 | 1 | 0.000 |

### 3.2 Baby trial qualitative characters

Most qualitative characters were significantly different, but fruit quality, market price and ranking of accessions were not (Table-2). Local accessions established better, while early flowering was common in exotic 'Sugar Baby'.Leaf quality was good in most local accessions, but medium in exotic 'Sugar Baby'. The preference among farmers was high for local accessions and low for exotic 'Sugar Baby'. Farmers mostly distributed the seeds of local accessions than of the exotic 'Sugar Baby'. Majority of respondent farmers intended to plant local landraces once more.

### 3.3 Evaluation of quantitative characters mother trials

There was significant difference in most quantitative characters, except in four for Kakamega and six for Embu trials (Table-3). Kakamega trials were high yielding than Nyeri ones, while Embu trials had highest in 100-seed weight (Figure-1). Accession KK-40 performance was highest for most of the characters (Table-4).

### 3.4 Baby trials

Most quantitative traits of baby trials were significantly different (Table-5). Germination percentage was highest in Nyeri, while number and total weight of fruits was highest in Kakamega (Figure-2). Accessions that had highest performance for each qualitative character are shown in Table 6. Accessions KK-30 and NY-154 had the highest total fruit weight and number, respectively.

**Table-2.** Chi-square analysis of the frequency of baby trial qualitative characters.

| Character | Observed | Expected | $\chi^2$ | df | *P*-value |
|---|---|---|---|---|---|
| Establishment | 238 | 79.3 | 6.9 | 2 | 0.032 |
| Flowering time | 235 | 78.3 | 86.1 | 2 | 0.000 |
| Fruit quality | 227 | 75.7 | 1.5 | 2 | 0.463 |
| Market price | 227 | 75.7 | 2.6 | 2 | 0.276 |
| Overall preference | 226 | 75.3 | 7.6 | 2 | 0.022 |
| Intention to plant | 227 | 113.5 | 41.4 | 1 | 0.000 |
| Pest and diseases | 229 | 76.3 | 7.0 | 2 | 0.031 |
| Taste | 226 | 75.3 | 11.1 | 2 | 0.004 |
| Cooking quality | 225 | 75.0 | 6.6 | 2 | 0.037 |
| Leaf quality | 231 | 77.0 | 15.6 | 2 | 0.000 |
| Seed distribution | 225 | 112.5 | 56.8 | 1 | 0.000 |
| Ranking of accessions | 226 | 75.3 | 4.6 | 2 | 0.099 |

**Table-3.** Mother trial quantitative characters analysis for accessions and regions.

| Characters | Min. | Max. | Total mean | *P*-value accessions | *P*-value Kakamega & Embu |
|---|---|---|---|---|---|
| Days to germination | 5 | 15 | 6.9 | 0.999 | 0.260 |
| Days to flowering | 26 | 122 | 66.7 | 0.000 | 0.000 |
| No. of female flowers | 1 | 10 | 2.7 | 0.000 | 0.000 |
| No. of male flowers | 11 | 182 | 73.5 | 0.000 | 0.000 |
| Number of nodes | 15 | 111 | 44.5 | 0.999 | 0.694 |
| Internode length | 6 | 25 | 14.6 | 0.000 | 0.000 |
| Days to fruit maturity | 29 | 120 | 88.2 | 0.730 | 0.428 |
| Average fruit weight (kg) | 0.4 | 4.2 | 1.4 | 0.018 | 0.000 |
| Total fruit weight | 0.4 | 15.9 | 3.2 | 0.000 | 0.000 |
| No. of fruits per accession | 1 | 9 | 2.3 | 0.000 | 0.000 |
| No. of leaves/accession | 84 | 392 | 190.1 | 0.000 | 0.000 |
| No. of seeds/fruit/accession | 41 | 773 | 263.2 | 0.000 | 0.000 |
| 100-seed weight (g) | 5.6 | 32.9 | 13.2 | 0.000 | 0.000 |
| Biological yield (g) | 100 | 934.2 | 349.5 | 0.285 | 0.000 |
| Yield (tons/ha) | 5 | 39.8 | 7.9 | 0.000 | 0.000 |
| Vegetation period (days) | 117 | 262 | 182.1 | 1.000 | 0.120 |
| Main vine length (m) | 1.5 | 17.3 | 5.5 | 0.475 | 0.000 |
| Fruit length (cm) | 7 | 35.1 | 18.5 | 0.000 | 0.000 |
| Fruit width (cm) | 7 | 24.5 | 14.6 | 0.000 | 0.000 |
| Germination percentage | 82 | 100 | 92.3 | 0.001 | 0.000 |

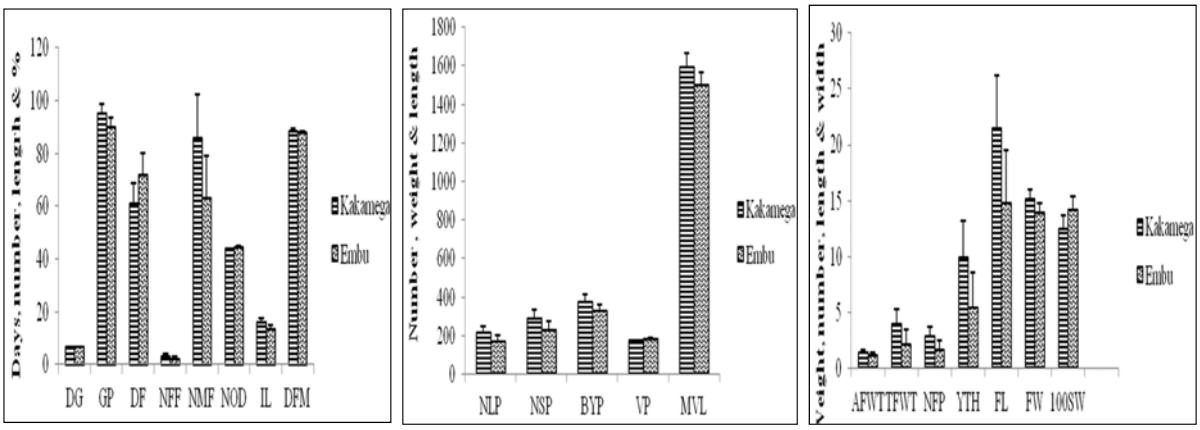


**Figure-1.** Kakamega and Embu mother trials quantitative evaluation results. Error bars represent standard deviation. DG = Days to germination, GP = Germination percentage, DF = Days to flowering, NFF = Number of female flowers, NMF = Number of male flowers, NOD = Number of nodes, IL = Internode length (cm), DFM = Days to fruit maturity, NLP = Number of leaves per plant, NSP = Number of seeds per plant, BYP = Biological yield per plant, VP = Vegetative period, MVL = Main vine length, AFWT = Average fruit weight (kg), TFW = Total fruit weight (kg), NFP = Number of fruits per plant, YTH = Yield (tons per hectare), FL = Fruit length (cm), FW = Fruit width (cm), 100SW = 100-seed weight (g)

**Table-4.** Accessions giving highest and lowest performance for each highlighted fruit and seed character in mother trials.

| Code | Characters | NFF | NMF | NFA | AFW | TFW | NLA | NSA | 100-SW | FL | FW |
|---|---|---|---|---|---|---|---|---|---|---|---|
| KK-40 | NFF | 10 | 181 | 9 | 1.8 | 15.9 | 392 | 264 | 10.95 | 14 | 17 |
| KK-45 | | 10 | 169 | 7 | 1.9 | 13.2 | 211 | 488 | 13.09 | 14 | 17.1 |
| NY-85 | | 1 | 48 | 1 | 1 | 1 | 177 | 189 | 13.7 | 13 | 15 |
| KK-40 | NMF | 10 | 181 | 9 | 1.8 | 15.9 | 392 | 264 | 10.95 | 14 | 17 |
| NY-131 | | 1 | 16 | 1 | 0.25 | 0.25 | 148 | 152 | 15.54 | 11.4 | 9.2 |
| KK-40 | NFA | 10 | 181 | 9 | 1.8 | 15.9 | 392 | 264 | 10.95 | 14 | 17 |
| KK-41 | | 1 | 38 | 1 | 1 | 1 | 180 | 134 | 14.15 | 17 | 11 |
| NY-130 | AFW | 2 | 56 | 1 | 4.25 | 4.25 | 191 | 189 | 25.89 | 20.4 | 19.7 |
| NY-77 | | 1 | 22 | 1 | 0.2 | 0.2 | 155 | 250 | 5.64 | 19 | 13 |
| KK-40 | TFW | 10 | 181 | 9 | 1.8 | 15.9 | 392 | 264 | 10.95 | 14 | 17 |
| NY-77 | | 1 | 22 | 1 | 0.2 | 0.2 | 155 | 250 | 5.64 | 19 | 13 |
| KK-40 | NLA | 10 | 181 | 9 | 1.8 | 15.9 | 392 | 264 | 10.95 | 14 | 17 |
| NY-150 | | 1 | 41 | 0.5 | 0.5 | 1 | 84 | 104 | 10.5 | 18.4 | 11.8 |
| KK-4 | NSA | 5 | 89 | 4 | 2.9 | 6.6 | 226 | 773 | 13.56 | 21.5 | 15 |
| Exotic | | 1 | 31 | 1 | 0.3 | 0.3 | 113 | 41 | 10.09 | 9.1 | 11 |
| NY-107 | 100SW | 4 | 98 | 2 | 2.75 | 5.5 | 222 | 362 | 32.86 | 20.6 | 16.6 |
| NY-139 | | 1 | 23 | 1 | 0.5 | 0.5 | 163 | 98 | 5.56 | 10.8 | 9 |
| KK-12 | FL | 5 | 111 | 4 | 2.3 | 8.2 | 323 | 657 | 13.36 | 31.9 | 17 |
| NY-74 | | 1 | 36 | 1 | 0.4 | 0.4 | 164 | 107 | 12.1 | 7 | 8 |
| Exotic | FW | 8 | 169 | 7 | 3 | 4 | 356 | 224 | 27.87 | 14.2 | 22 |
| NY-74 | | 1 | 36 | 1 | 0.4 | 0.4 | 164 | 107 | 12.1 | 7 | 8 |

NFF = Number of female flowers, NMF = Number of male flowers, AFWT = Average fruit weight (kg), TFW = Total fruit weight (kg), NFA = Number of fruits per accessions, NLA = Number of leaves per accession, NSA = Number of seeds per accession, 100SW = 100-seed weight (g),FL = Fruit length (cm), FW = Fruit width (cm)

**Table-5.** Baby trials quantitative data for accessions and regions.

| Characters | Min. | Max. | Total mean | *P*-value accessions | *P*-value KK and Nyeri |
|---|---|---|---|---|---|
| Days to germination | 5 | 14 | 8.1 | 0.018 | 0.137 |
| Germination percentage | 25 | 100 | 93.6 | 0.866 | 0.000 |
| Days to flowering | 32 | 84 | 60.9 | 0.000 | 0.000 |
| Days to fruit maturity | 76 | 141 | 110.9 | 0.000 | 0.294 |
| No. of fruits per plant | 1 | 16 | 4.4 | 0.000 | 0.000 |
| Total fruit weight | 0.2 | 26.5 | 4.9 | 0.000 | 0.000 |

KK = Kakamega

**Table-6.** Some of the accessions giving high and low performance for each highlighted character in baby trials.

| Code name | Character | DG | DF | DFM | NFA | TFW |
|---|---|---|---|---|---|---|
| KK-58 | Days to germination | 14 | 52 | 106 | 4 | 5.1 |
| KK-65 | | 14 | 72 | 126 | 10 | 17.3 |
| Exotic | | 14 | 77 | 136 | 9 | 10.4 |
| KK-20 | | 5 | 47 | 93 | 4 | 1.5 |
| KK-63 | | 5 | 54 | 96 | 3 | 4.1 |
| NY-86 | Days to flowering | 9 | 84 | 141 | 7 | 9.1 |
| Exotic | | 6 | 32 | 76 | 1 | 0.25 |
| NY-86 | Days to fruit maturity | 9 | 84 | 141 | 7 | 9.1 |
| Exotic | | 6 | 32 | 76 | 1 | 0.25 |
| NY-154 | No. of fruits / accession | 8 | 72 | 118 | 16 | 19.1 |
| KK-30 | | 9 | 72 | 127 | 15 | 26.5 |
| NY-88 | | 8 | 55 | 101 | 1 | 0.45 |
| KK-30 | Total fruit weight (kg) | 9 | 72 | 127 | 15 | 26.5 |
| KK-21 | | 7 | 49 | 96 | 1 | 0.25 |
| NY-149 | | 6 | 32 | 76 | 1 | 0.25 |
| Exotic | | 6 | 32 | 76 | 1 | 0.25 |

DG = Days to germination, DF = Days to flowering, DFM = Days to fruit maturity, NFA = Number of fruits per accession, TFW = Total fruit weight

### 3.5 Comparison of mother and baby trials

Mother and baby trials significantly differed in all quantitative characters. Mother trials were early in germination, whereas percent germination was high in baby trials. Flowering was early in baby trials, while fruit maturity was early in mother trials. Number of fruits ranged from 1 to 9 in mother trials and 1 to 16 in baby trials. Total fruit weight ranged from 0.25 to 15.9 kg in mother trials and 0.25 to 26.5 kg in baby trials. The number and total weight of fruits were highest in baby trials (Figure-3). Accessions with highest performance in both mother and baby trials are displayed in Table-7. Accession KK-30 and NY-154 had the highest total fruit weight and number of fruits, respectively.

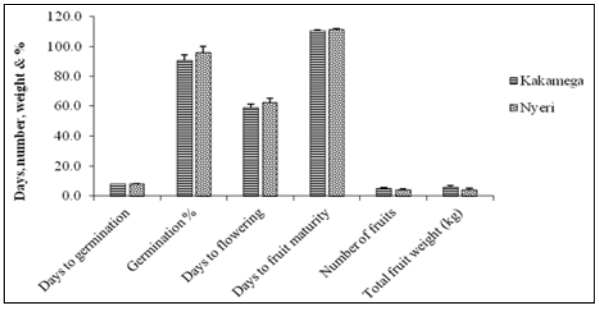


**Figure-2.** Kakamega and Nyeri baby trials quantitative evaluation results. Error bars represent standard deviation.

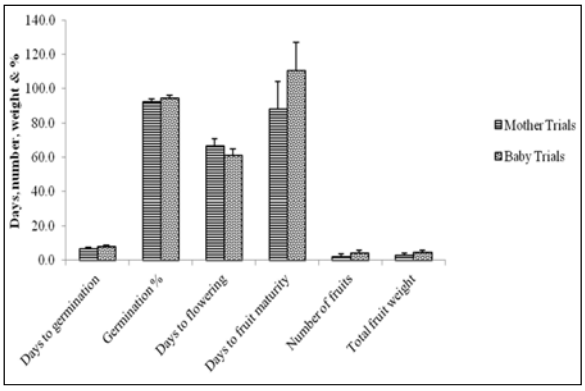


**Figure-3.** Comparison of mother and baby trials performance. Error bars represent standard deviation.

**Table-7.** Accessions giving high and low performance for each highlighted character in both mother and baby trials.

| Code name | Character | DG | DF | DFM | NFA | TFW |
|---|---|---|---|---|---|---|
| KK-54 | Days to germination | 15 | 122 | 122 | 9.0 | 9.8 |
| KK-11 | | 5.0 | 34.0 | 83.0 | 1.0 | 1.2 |
| KK-54 | Days to flowering | 15 | 122.0 | 122.0 | 9.0 | 9.8 |
| NY-79 | | 6.0 | 26.0 | 82.0 | 1.0 | 1.0 |
| NY-86 | Days to fruit maturity | 9.0 | 95.0 | 141.0 | 7.0 | 9.1 |
| NY-107 | | 6 | 53 | 29 | 1 | 1.60 |
| NY-154 | Number of fruits/accession | 8 | 117 | 118 | 16 | 19.10 |
| KK-21 | | 6 | 47 | 88 | 1 | 0.25 |
| KK-30 | Total fruit weight (kg) | 9 | 72 | 127 | 15 | 26.50 |
| KK-21 | | 6 | 47 | 88 | 1 | 0.25 |
| Exotic | | 6 | 32 | 76 | 1 | 0.25 |

DG = Days to germination, DF = Days to flowering, DFM = Days to fruit maturity, NFA = Number of fruits per accession, TFW = Total fruit weight

### 3.6 Comparison of local accessions and exotic cultivar mother trials

Local accessions and exotic 'Sugar Baby' were not significantly different in germination time, female and male flowers, nodes, internode length, fruit maturity time, fruits and leaves per accession, biological yield, vegetative period, main vine length and fruit width. They were significantly different in flowering time, average and total fruit weight, seed number, 100-seed weight, fruit length and germination percentage. Exotic 'Sugar Baby' had early flowering, high germination percentage and 100-seed weight, whereas local accessions had highest average and total fruit weight, seed number and fruit length (Figure-4).

### 3.7 Baby trials

Local accessions and exotic 'Sugar Baby' were not significantly different in germination percentage, but were significantly different in days to germination and fruit maturity, number and total weight of fruits. Exotic cultivar was early in germination, flowering and fruit maturity, whereas local accessions had high number and total weight of fruits (Figure-5).

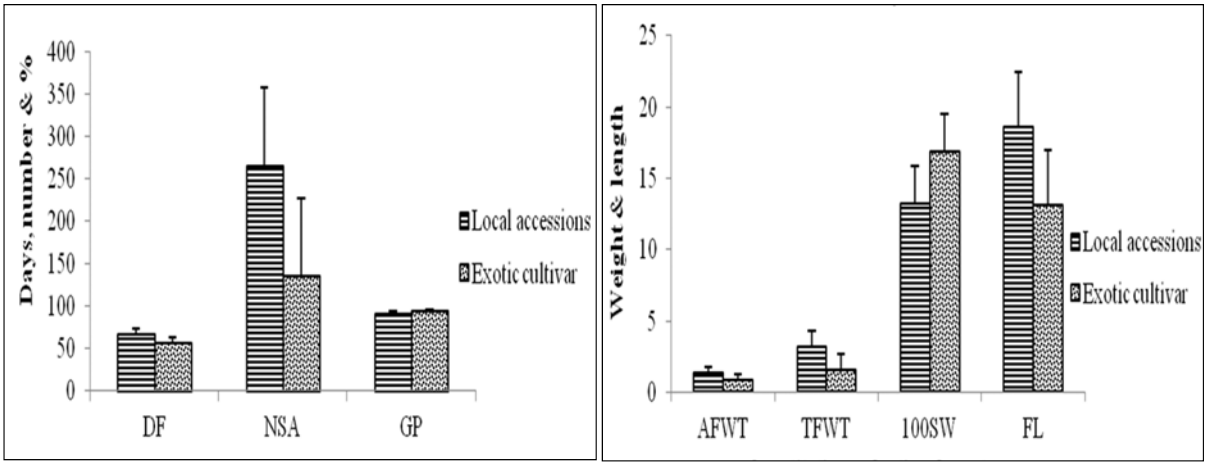


**Figure-4.** Comparison of local accessions and exotic 'Sugar Baby' performance in mother trials. Error bars represent standard deviation. DF = Days to flowering, NSP = Number of seeds per accession, GP = Germination percentage, AFWT = Average fruit weight (kg), TFWT = Total fruit weight (kg), 100SW = 100-seed weight (g), FL = Fruit length (cm). NB:Only significant characters are displayed in the Figure.

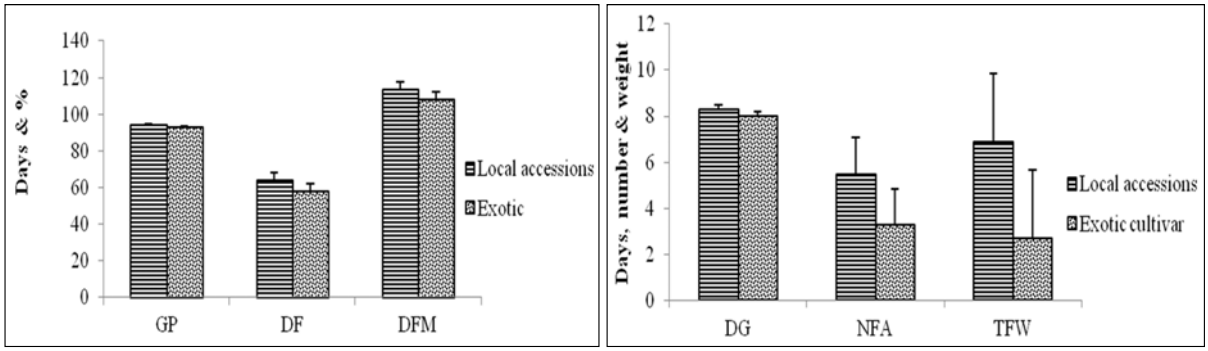


**Figure-5.** Comparison of local accessions and exotic 'Sugar Baby' performance in baby trials. Error bars represent standard deviation. GP = Germination percentage, DF = Days to flowering, DFM = Days to fruit maturity, DG = Days to germination, NFA = Number of fruits per accession, TFW = Total fruit weight (kg).

### 3.8 Total soluble solids and fruit firmness

Fruit rind firmness ranged from 4.5 to 10.2 kg/cm$^2$, while flesh firmness ranged from 3.0 to 7.3 kg/cm$^2$. TSS ranged from 2.9 to 14% brix. The mean fruit rind and flesh firmness was 7.7 and 5.6 kg/cm$^2$, and TSS 6.4% brix, respectively (Table-8). Local variegated and green-leafed accessions were significantly different in fruit rind firmness and total soluble solids (TSS).Local variegated accessions had 6.9% brix, while green-leafed accessions had 8.2 kg/cm$^2$ fruit rind firmness (Figure-6). Accession within subcounties significantly differed in TSS (Table 8; Figure 6). Accessions collected from Tetu had the highest TSS and those from Butere had the least TSS (Figure 6). The TSS was highest in accessions KK-30 and KK-12, and fruit rind firmness was highest in accession KK-9 (Table-9).

**Table-8.** Fruit firmness and total soluble solids of accessions.

| Characters | Min | Max | Mean | Accession *P*-value | VL and GL accession *P*-value | KK and NY *P*-value | Subcounty *P*-value |
|---|---|---|---|---|---|---|---|
| Fruit rind firmness (kg/cm$^2$) | 4.5 | 10.2 | 7.7 | 0.216 | 0.005 | 0.156 | 0.070 |
| Fruit flesh firmness (kg/cm$^2$) | 3.0 | 7.3 | 5.6 | 0.733 | 0.911 | 0.076 | 0.380 |
| Total soluble solids (% Brix) | 2.9 | 14.0 | 6.4 | 0.114 | 0.000 | 0.495 | 0.012 |

VL = Variegated-leafed, GL = Green-leafed, KK = Kakamega, NY = Nyeri

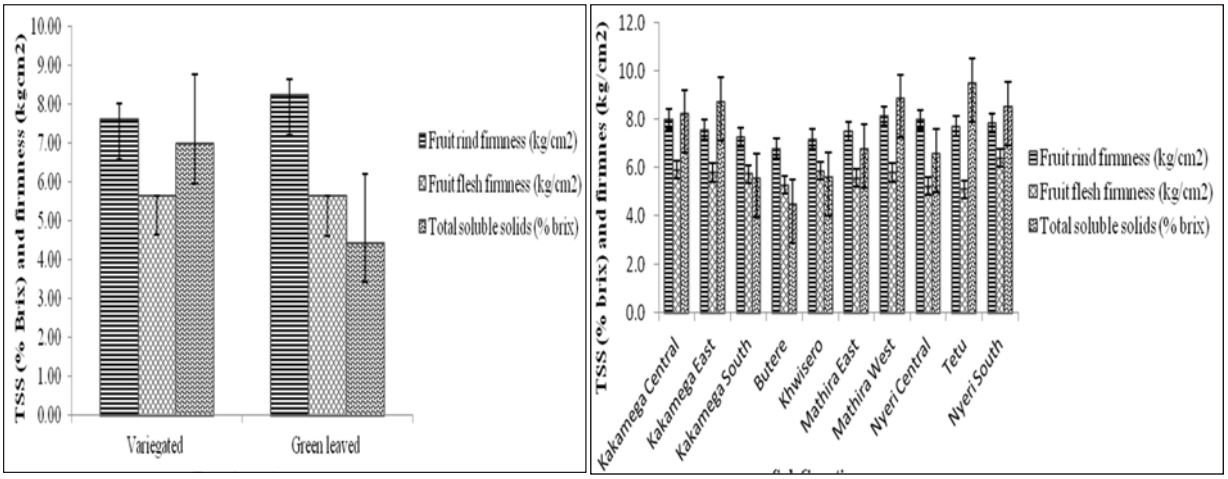


**Figure-6.** Fruit firmness and TSS for variegated and green-leafed accessions (L) and for sub-county accessions (R). Error bars represent standard deviation.

**Table-9.** Accessions giving high and low performance for each highlighted fruit quality character.

| Code name | Characters | Fruit rind firmness | Fruit flesh firmness | Total soluble solids |
|---|---|---|---|---|
| KK-9 | Fruit rind firmness (kg/cm$^2$) | 10.2 | 7.3 | 7.2 |
| KK-46 | | 4.5 | 3 | 3 |
| KK-9 | Fruit flesh firmness (kg/cm$^2$) | 10.2 | 7.3 | 7.2 |
| KK-33 | | 8.4 | 7.3 | 5.3 |
| KK-60 | | 8.1 | 7.3 | 5.3 |
| KK-46 | | 4.5 | 3 | 3 |
| KK-12 | Total soluble solids (% Brix) | 8.1 | 5.9 | 14 |
| KK-30 | | 8.5 | 6.4 | 14 |
| KK-56 | | 6 | 3.9 | 2.9 |

KK = Kakamega

## 4. DISCUSSIONS

### 4.1 Qualitative characters of mother trials

Seedling vigour in most accessions in Embu was intermediate due to delayed onset of rains and dry weather. Flower colour in most accessions was orange due to genetic factors (Maynard, 2007; Ahamed *et al*., 2011). The fruit shape that varied from globular, ovate, flattened, pyriform, elliptical to acorn, and intermediate fruit size in most accessions was similar to that reported previously (Gichimu *et al*., 2009; Ahamed *et al*., 2011; Onyishi *et al*., 2013). The present study observed intermediate to dark-green immature fruits and mostly green mature fruits as in other studies (Balkaya *et al*., 2010; Aruah *et al*., 2010; Ahamed *et al*., 2011; Mladenovic *et al*., 2014). The high 84% monoecious, compared to 17% androecious accessions in mother trial agreed with other studies (Ahamed *et al*., 2011). The four major domesticated pumpkin species are all monoecious (McCormack, 2005;Agbagwa *et al*., 2007). The few androecious plants observed in the present study were attributed to high temperatures, light intensity and long days during growing season (McCormack, 2005).

### 4.2 Qualitative characters of baby trials

The local accessions established better on farmers' farms due to their adaption to agro-ecological conditions there (OECD, 2012). The variation in flowering between local accessions and exotic 'Sugar Baby' were attributed to cultivar differences (Aruah *et al*., 2010). The local accessions were the most preferred due to their adaptation to local environmental conditions, pest and disease resistance, good taste of fruits and leaves, and cooking quality. Nonetheless, most of the farmers planted pumpkins for domestic or commercial purposes, without minding nutritional value (Ondigi *et al*., 2008). The qualities that most farmers appreciated in the local accessions were medicinal properties, sweet taste, soft leaves and firm cooked fruits. The farmers did not prefer the exotic 'Sugar Baby' because of the short growth cycle and susceptibility to pests and diseases. Most of the farmers intended to plant local accessions due to cultural factors dictating their agricultural practices (Ondigi *et al*., 2008). The availability of local accessions in the communities, poor performance and prevalence of pests and diseases contributed to the poor distribution of exotic 'Sugar Baby' seeds. Majority of the farmers devoted small portions of land to pumpkin cultivation, because it was not a priority food crop. Commercial reasons were the driving force for planting the pumpkins by most farmers, while in domestic consumption it was regarded as a supplementary food crop (Ondigi *et al*., 2008). Local accessions were ranked the best, while exotic 'Sugar Baby' the worst by most of the farmers.

### 4.3 Quantitative characters of mother trials

Germination percentage was highest among accessions in Kakamega due to good rains and other environmental conditions. Embu accessions took long to flower due to poor climactic conditions (Gichimu *et al*., 2009; Ahamed *et al*., 2011; Sunny and Nwonuala, 2013). Both Kakamega and Embu have varying seasonal temperature and rainfall conditions. Temperatures were high in Embu as a result of delayed and erratic rains. In the present study, flowers ranged from 11 to 197 male and 1 to 10 female, similar to previous observations (Aruah*et al*., 2010; Onyishi *et al*., 2013). High number of male and female flowers occurred in Kakamega due to the good rains received. The ratio of female to male flowers was mostly male probably due to hormonal, day length and temperature effects (McCormack, 2005; Maynard, 2007). The number of nodes varied from 15 to 111 nodes as in other reports (Jahan *et al*., 2012; Ara *et al*., 2013). Kakamega accessions had the longest internodes due to genetic effects (Maynard, 2007; Loy, 2013). The 29 to 141 days to fruit maturity agreed with previous studies (Ahamed *et al*., 2011; Maynard, 2007).

In the present study, the total fruit weight ranged from 0.2 to 15.9 kg, while average fruit weight was 0.2 to 4.2 kg, concurring with previous reports (Balkaya *et al*., 2010; Ahamed *et al*., 2011). The number of fruits that ranged from 1 to 9 also agreed with previous results

(Aruah *et al*., 2010). The number of leaves ranged from 84 to 394, similar to those obtained previously (Gwanama *et al*., 1998; Aruah *et al*., 2010). The 41 to 773 seeds were similar to those in other studies (Walters and Taylor, 2006; Aruah *et al*., 2010). The 100-seed weight that ranged from 5.6 to 32.9 g agreed with that obtained previously (Walters and Taylor, 2006; Aruah *et al*., 2010; Ahamed *et al*., 2011). The number of seeds produced by each fruit depends on pollination efficiency and growing conditions (OECD, 2012; McCormack, 2005). The number increases in proportion to the amount of pollen deposited on the stigma (Gavilanez-Slone, 2001). Fruit length varied from 7 to 35.1 cm, and width from 7 to 24.5 cm, with a mean of 18.5 cm and 14.6 cm, respectively. These results were similar to those obtained elsewhere (Balkaya *et al*., 2010; Aruah *et al*, 2011). Biological yield, vegetative period and vine length were not significantly different similar to other findings (Aruah *et al*., 2011). Embu accessions had the longest vegetative growth period due to the prolongation of the season and stimulation of plant growth by the short-rains that fell after a long dry spell.

**4.4 Quantitative characters of baby trials**

Baby trials were not significantly different in days to germination, but showed great variation in germination percentage due to differences in seed size. Germination percentage was high among accessions due to the many green-leafed accessions that had large and heavy seeds, with plenty of storage reserves that are utilized for efficient germination and growth (Sajjan and Prasad, 2009). Seed quality affects vigour, rate and uniformity of growth and emergence (Mavi and Demir, 2007). Early flowering and high yields resulted in Kakamega, owing to good environmental and seasonal factors (Maynard, 2007; OECD, 2012). Delayed onset of rains in Nyeri negatively affected plant establishment, growth, dry matter partitioning, reproductive growth and photosynthesis. High temperatures affect assimilate sources and sinks (Hasanuzzaman *et al*., 2013). Additionally, Aruah et al. (2010) reported variation in flowering as a result of cultivar differences.

Low average yields obtained in Nyeri were attributed to high number of green-leafed accessions that were prone to pest and disease attack, as well as production of one fruit on average per accession. Late maturity of fruits in Nyeri was attributed to genetic and poor environmental conditions that affected plant physiological processes (Hasanuzzaman *et al*., 2013). Growth rate varies from season to season, and the interval between pollination and fertilization (Maynard, 2007). Pollination improves earliness (Kemble *et al*., 2000). Early female flowers increase fruiting and maturity of pumpkins (Mohanty, 2002). The low mean number and total weight of fruits in Nyeri was attributed to environmental conditions and genotype. Wien *et al*. (2004) indicated that the number of fruits depended on the number of pistillate flowers produced and their successful pollination and fruit set, whereas environmental conditions influence whether a male or female flower is formed.

**4.5 Comparison of mother and baby trials**

Germination was early in mother trials due to supplemental irrigation whenever rains failed. Baby trials relied only on rainfall. On the other hand, germination percentage was high in baby trials. Soil and environmental condition differences in mother and baby trial sites caused these variations since the same accessions were planted (Jaetzold and Schmidt, 1983a; Kassam *et. al.,* 1991; Onyari *et al*., 2015). Baby trials were early in flowering due to genotype and environmental conditions. The two trials were planted under varying soil types, agro-ecological and climactic conditions (OECD, 2012). Accessions in mother trials matured in a short period of time due to good tending. Baby trials were high yielding due to differences in agro-ecological zone conditions (Muungani *et al*., 2007). Yields being polygenic in nature are influenced by environmental factors (Pandey *et al*., 2008). Besides, low yields were obtained in mother trials due to damage caused by moles and hail stones in Kakamega in seasons 1 and 2, respectively. Moles that destroyed a significant number of fruits and plants in season 1 were not foreseen in order to apply control measures. The uncontrollable hail stones tore leaves and caused fruit injuries in most accessions in season 2. Leaf tearing reduced photosynthetic area and assimilation rates, culminating in low fruit yield (Warren *et al*., 1998). The wounded fruits rotted due to secondary infection.

High plant population in mother trials due to land scarcity resulted in mineral nutrient competition among accessions. Local accessions produced many new laterals which developed into new sinks that burdened the sources. Training of accessions by coiling and heaping vines and laterals together curtailed free movement and spreading of accessions, and also caused disturbance. Training reduced the photosynthetic leaf area and restricted supplemental mineral nutrient uptake through internodal roots. Disturbance caused shock to plants, slowing down growth for a few days before accessions could recover normal growth once more. These factors contributed to low yields obtained among accessions in mother trials. On the other hand, accessions in baby trials freely spread, anchored onto intercrops using tendrils, and into the soil using internodal roots. Chukwudi and Agbo (2014) reported improved number of branches, leaves, vine length, and leaf area in trellised than non-trellised plants. Trellised plant leaves are exposed to greater light interception, leading to higher accumulation of photosynthates for vegetative growth. Pumpkins grow close to trees, walls, fences and structures on which shoots climb and trellis to get better sunlight exposure for maximum production of vines, leaves, side branches and carbohydrate assimilation that enhance yields (Chukwudi and Agbo, 2014). Internodal roots increase water and mineral uptake. Farmyard manure applied by most farmers in baby trials supplemented synthetic DAP fertilizer and probably activated microbes to release phyto-hormones that stimulated nutrient absorption, as well as plant growth (Aderi *et al.,* 2011).

**4.6 Comparison of local accessions and exotic cultivar**

Germination, flowering and fruit maturity were early in exotic 'Sugar Baby' due to varietal differences, genetic improvement, high seed size and weight, because they were all exposed to the same environmental conditions (Mohanty, 2002; Gichimu *et al*., 2009; Aruah *et al*., 2010; Chukwudi and Agbo, 2014). Early flowering of female flowers increases maturity (Mohanty, 2002), whereas adequate pollination improves earliness (Kemble *et al*., 2000). Local accessions yielded higher than the exotic 'Sugar Baby' due to adaptable growth habit and ability to overcome biotic and abiotic factors (Onyango and Onyango, 2005). Local accessions were also indeterminate in growth with long main vines and many lateral branches. Additional lateral branching created more locations for flowers and fruits to develop (Gichimu *et al*., 2009). The new lateral branches and leaves increased leaf area that is important in light interception, photosynthetic efficiency and response to fertilization and irrigation (Blanco and Folegatti, 2005). Warren *et al.* (1998) stated that plants with many branches produce higher yields than those with few branches. More foliage developed in the laterals translates into high photosynthetic and assimilation rates, and ultimately more fruits and yields. Exotic 'Sugar Baby' was determinate in growth habit, with short vines and few lateral branches that translated into low yields (Gichimu *et al.,* 2009). Additionally, the heavy disease and insect pressure and lack of adaptation in exotic 'Sugar Baby' contributed to the low yields (Wien *et al.,* 2004). Silvery-leafed plants repel aphids, reflect light and conserve water during dry periods (Brown, 2002). Local accessions had fruits with many seeds and greater size and fresh weight probably due to better adaptation to local growth conditions (Aruah et al., 2010).

**4.7 Variation of fruit quality among accessions**

Total soluble solids (TSS) obtained were similar to those reported in previous studies (Jacobo-Valenzuela *et al*., 2011; Gajewski *et al*., 2008). They were high among local accessions due to genotypic effects, because all accessions were planted under similar environmental conditions. Akter *et al*. (2013) reported higher genotypic variance than environmental variance in TSS. The high TSS suggests genetic and physiological potential for developing pumpkins with enhanced taste (Gajewski *et al*., 2008). In the present study, TSS was highest among accessions from Tetu and lowest in those from Butere, most likely due to environmental, as well as accession by environment interaction effects. A genotype may exhibit superior quality in one location or environment, but this may not be stable in other environments with different agro-ecologies, because performance of genotypes mainly depends on environmental interaction (Razim, 2011). Green-leafed accessions had high fruit rind firmness owing to possession of warts on the outer fruit surface. Hard rinds are controlled by dominant gene Hr, but are selected against because they make fruits difficult to cut (Brown, 2002). Fruit firmness is also influenced by cultural practices, fertilization, high temperature and water stresses (Fellman *et al*., 2013).

**5. CONCLUSION AND RECOMMENDATIONS**

Qualitative and quantitative characters of evaluated pumpkin accessions significantly vary. Local accessions yield higher than exotic 'Sugar baby', as demonstrated by 26.5 and 15.9 kg total fruit weight for KK-30 and KK-40, as well as 9 and 16 fruits per plant for KK-40 and NY-154, respectively, compared to 0.25 kg and 1 fruit per plant for exotic 'Sugar Baby'. Local pumpkins accessions are well adapted to environmental conditions and very useful in times of drought and scarce rainfall. The introduced green-leafed and exotic Sugar Baby cultivars are susceptible to insect pests and diseases. Most of their fruits abort prematurely leaving average of one per plant. The high TSS should be used to select accessions for development into tasty cultivars. Local accessions should be conserved to provide genetic material for pumpkin improvement, food security during droughty seasons, good nutrition for farmers, and medicinal values for humans.

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