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Full Length Research Paper

Comparing the yield components of three most popular commercial watermelon cultivars in Kenya with one newly introduced cultivar and one landrace

Bernard Mukiri Gichimu*, Barack Otieno Owuor and Mathwes Mito Dida

Department of Botany and Horticulture, Maseno University, Maseno, Kenya.

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High yield is a major goal for watermelon (*Citrullus lanatus*) breeders. The objective of this study was to compare the yield components of some watermelon accessions available in Kenya and to identify high yielding accession(s) for recommendation to Kenyan growers and for use in breeding programs. A field trial involving five cultivated watermelon accessions in Kenya namely 'Sugarbaby', 'Crimson Sweet', 'Charleston Gray', 'Yellow Crimson'; and one local landrace (GBK-043014) from Kakamega district in Western Kenya, was conducted at Maseno University Research Fields between September 2007 and May 2008. The experiment was laid out in a Randomized Complete Block Design with three replications. Data was collected on yield and yield components of the accessions and subjected to analysis of variance using SAS version 9.1. Differences were declared significant at 5% level based on Least Significant Difference. The landrace demonstrated the highest yield potential while 'Yellow Crimson' which is a newly introduced commercial cultivar performed much better compared to other commercial cultivars. Selection of desirable traits in these accessions has priority for the future breeding programs. 'Yellow Crimson' was also recommended to Kenyan growers as the commercial cultivar with highest yield potential.

Key words: Yield potential, watermelon, commercial cultivars, landrace, Kenya.

INTRODUCTION

Watermelon (*Citrullus lanatus*) is one of the most widely cultivated crops in the world (Huh et al., 2008). Its global consumption is greater than that of any other cucurbit. It accounts for 6.8% of the world area devoted to vegetable production (Guner and Wehner, 2004; Goreta et al., 2005). China is the leading country in production of watermelon followed by Turkey, United States, Iran and Republic of Korea (Huh et al., 2008; Wehner and Maynard, 2003). There are over 1,200 varieties of watermelon worldwide (Miles, 2004) and a wide variety of watermelons have been cultivated in Africa (Zohary and Hopf, 2000). Several of these varieties have been recommended for Kenyan range of climate. These include 'Sugarbaby', 'Crimson Sweet', 'Charleston Gray', 'Chilean Black 'Congo', 'Fairfax' and 'Tom Watson' (Tindall, 1983). However, among these seven cultivars, only the first three are available in Kenyan markets with 'Sugarbaby' being the most popular (HCDA, 2006). This makes demand of watermelon in Kenya to be higher than production resulting in the fruit being very expensive and only affordable to rich people. To meet the local demand and potential surplus for export, production of watermelon in Kenya obviously needs to be increased (HCDA, 2006).

There is an ongoing need for increased yield and quality of watermelon to better meet market demands (Levi et al., 2001a). This must be done considering consumer preferences, yield potential, desired earliness, fruit size and shape, disease and pest resistance among others (Marr and Tisserat, 1998). Like other cucurbits, watermelon cultivars display a wide range of fruit morphology (Langer and Hill, 1991). They vary in fruit size, fruit number, fruit shape, flesh colour, rind colour and seed colour (Zohary and Hopf, 2000). Although modern bred watermelons produce very large fruits up to 10 kg in weight, there are a number of hard-fleshed smaller and more pri-

*Corresponding author. E-mail: wacikubm@gmail.com. Tel: +254 721 552757.

mitive genotypes that are cultivated for their fruit which is used for the production of jam and pickles (Langer and Hill, 1991). There are also seedless varieties and super-sweet round ones that fit nicely into the refrigerator (Wolford and Banks, 2005). Owing to their different genetic composition, different varieties of watermelon will respond differently to various stresses resulting in significant differences in yield (Marr and Tisserat, 1998). Some watermelon cultivars with a potential of producing giant fruits can as well produce very small fruits when grown in unfavorable edaphic and climatic conditions (Kovatch, 2003; Warren et al., 1990). In order to come up with the best variety for a given agro-ecological zone, it is essential to conduct a performance trial with common varieties in that area and including some additional varieties to test for more desirable traits and to introduce new varieties (Marr and Tisserat, 1998).

Although many watermelon cultivars have been developed throughout the world during the last century, there is little information regarding their ancestries (Levi et al., 2001b). In Kenya, for example, some watermelon landraces have been identified in different parts of the country but there is scant data available comparing them with the modern cultivars. The factors which result in farmers preferring local landraces over modern varieties are not therefore very well understood. The available information suggests that modern varieties often lack additional characters which farmers consider important (Hardon and Boef, 1993). These include yield, maturity period, resistance to pests and diseases and tolerance to biotic and abiotic constrains (Dorp and Rulkens, 1993).There is therefore need to evaluate the agronomic performance of various watermelon accessions in Kenya in order to generate comparative data for local crop development. This data will be essential to validate suggested comparative advantages of landraces over modern cultivars or vice versa, and may provide new options for plant breeding. The objective of this study was to compare the yield components and hence the yield potential of the three most popular commercial watermelon cultivars in Kenya with one newly introduced cultivar and one local landrace.

MATERIALS AND METHODS

The study was carried out at Maseno University Research fields. The site lies along Kisumu-Busia highway in Maseno Division, Nyanza Province, Kenya within the upper Midland 1 agro-ecological zone (Jaetzold and Schimidt, 1982). Maseno lies at latitude 0° 1'N – 0°12'S and longitude 34°25'E –34°47'E and it is approximately 1500 m above the sea level. The area receives a bimodal mean annual rainfall of 1750 mm (Mwai, 2001) with the first rainy season falling between March and July; and second season falling between September and early December. No month, however, is completely dry (Jaetzold and Schmidt, 1982). The mean annual temperature is 28.7°C (Mwai, 2001) with the hottest season occurring between January and April (Jaetzold and Schmidt, 1982). The soils are classified as dystric nitisols. They are well-drained, deep reddish brown, slightly friable clay with pH ranging between 4.5 and 5.4. Soil organic carbon and phosphorous content are 1.8% and 4.5 mg/kg respectively (Mwai, 2001).

Five cultivated watermelon in Kenya were used in this study. These included 'Sugarbaby', 'Charleston Grey', and 'Crimson Sweet', which are the most popular commercial cultivars in Kenya; 'Yellow Crimson' which is a newly introduced commercial cultivar from United States; and one landrace (GBK-043014) from Kakamega district (altitude 1250 – 1500 m ASL) in Western Kenya. Seeds of the landrace were obtained from National Genebank of Kenya (Muguga) in March 2007 and were grown at Maseno University Horticultural Fields for seed bulking before proceeding to the main study. Commercial cultivars were obtained from East Africa Seeds, Kenya except 'Yellow Crimson' which was obtained from Rispern Seeds, INC. Beecher, Illinois. 'Yellow Crimson' was included in the study because it has also been noted in some local supermarkets although the seed is not readily available in seed shops here in Kenya.

The seeds were directly sown in the field at a spacing of 1.5 x 1.5 m. Since watermelon is reported to have poor germination, five to ten seeds were planted per hole but were thinned to one seedling three-four weeks after planting. Organic manure and NPK fertilizer were applied in the planting holes before sowing at the recommended rate of thirty (30) t/ha and 200 Kg/ha, respectively. Two rows of 'sugarbaby' were used as guard rows around the experimental field. Other agronomic practices including irrigation, weeding and top dressing were conducted uniformly and as re-quired in all plots. No chemicals or any other method of pest and disease control were employed. The first season experiment was conducted between September and December, 2007 followed by the second season experiment between January and May, 2008. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data was collected on yield and yield components including total number of female flowers per plant, main vine length, number of branches on the main vine, fruit number and fruit weight. The data was subjected to analysis of va-riance (ANOVA) using SAS version 9.1 (SAS Institute, 2005) and differences declared significant at 5% level. Least Significant Difference ($LSD_{5\%}$) was used to separate the means. Linear correlation was done to compare the relationship between variables. The SAS procedure PRINCOMP was then used to perform a principle component (PC) analysis using variable data and accessions plotted on two dimensions using the first two principle components (PC1 and PC2). Descriptive statistics (mean, standard deviation, and coefficient of variation), were generated using the SAS procedure, UNIVARIATE.

RESULTS

Yield components that were evaluated include the length of the main vine, number of branches on the main vine, total number of female flowers per plant, fruit number and fruit yield. All accessions were runners. The length of the main vine was found to vary significantly ($p<0.001$) between accessions in both seasons. The Kakamega landrace had significantly ($p<0.05$) the longest main vine averaging 434 and 461 cm in first and second season respectively. Main vine lengths in cultivated accessions were very close with 'Yellow Crimson' having the longest main vine averaging 231 and 256 cm in first and second season respectively, which was significantly different ($p< 0.05$) from the shortest main vine of 'Crimson Sweet' which averaged 201 and 200 cm in first and second experiment respectively. 'Charleston Gray' had a main vine length which averaged 225 and 241 cm while that of 'Sugarbaby' averaged 215 and 240 cm in first and second season respectively and the two were not significantly (p>

Table 1. Variation in yield and yield components.

Accession	Main Vine Length (cm)	Branch Number	No. of female flowers	Fruit Number	Fruit Weight (Kg)
Sugarbaby	227.86[c]	6.83[c]	8.78[c]	2.39[c]	2.05[b]
Yellow Crimson	243.56[b]	9.39[b]	10.67[b]	3.45[b]	3.01[a]
Crimson Sweet	200.56[d]	5.11[d]	6.11[d]	0.89[e]	1.44[d]
Charleston Gray	232.83[bc]	6.56[cd]	8.33[c]	1.50[d]	1.77[c]
Landrace	447.67[a]	11.33[a]	12.56[a]	5.67[a]	1.99[bc]
$LSD_{5\%}$	15.616	1.646	1.7078	0.578	0.235
CV (%)	34.19	37.14	25.77	27.89	29.41
SD	92.495	2.913	2.394	1.797	0.603

NB: Means followed by the same letter are not significantly different

0.05) different from each other. Combined season analysis also gave highly significant ($p<0.01$) variations between accessions. Kakamega landrace had significantly ($p<0.05$) the longest main vine averaging 448 cm while 'Crimson Sweet' had significantly ($p<0.05$) the shortest main vine averaging 201 cm (Table 1). 'Sugarbaby', 'Charleston Gray', and 'Yellow Crimson' recorded a combined season main vine length of 228, 233, and 244 cm respectively (Table 1). Seasonal differences in vine length were significant ($p<0.01$) but accession x season interactions were not ($p>0.05$). There was a strong ($R=0.915$, $R^2=0.84$) and highly significant ($p<0.001$) positive correlation between main vine length and fruit number (Figure 1).

There was significant ($p<0.05$) and highly signi-ficant ($p<0.001$) variation among accessions in number of branches on the main vine in first and second season respectively. The Kakamega landrace and 'Yellow Crimson' had significantly ($p<0.05$) the most branched main vine with both having an average of 9 branches in the first season. However, the branches of the landrace increased significantly in the second season to an average of 14 branches compared to 10 branches of 'Yellow Crimson'. 'Charleston Grey' and 'Sugarbaby' had 6 and 5 branches respectively in the first season which increased to 7 and 9 branches respectively in the second season. The main vine of 'Crimson sweet' was significantly ($p<0.05$) the least branched in both seasons averaging 4 and 6 branches in first and second season respectively. In combined season analysis, highly significant ($p<0.001$) variation in branch number was also observed. Kakamega landrace (043014) recorded significantly the highest number of branches (11 branches) followed by 'Yellow Crimson' with an average of 9 branches (Table 1). On the other hand, 'Crimson Sweet' recorded the lowest number of branches (5 branches) while 'Sugarbaby' and 'Charleston Gray' both recorded an average of 7 branches (Table 1). Seasonal differences in branch number were highly significant ($p<0.001$) but accession x season interactions were not ($p>0.05$). There was a strong ($R=0.98$, $R^2=0.96$) and highly significant ($p<0.001$) positive correlation between the number of branches on the main vine and fruit number (Figure 1).

The number of female flowers was found to vary highly and significantly ($p<0.001$) bet-ween accessions. In both seasons, the Kakamega landrace produced significantly ($p<0.05$) the highest number of female flowers averaging 11.79 and 13.33 flowers/ plant in first and second season, respectively. The land-race was significantly ($p<0.05$) different from 'Yellow Crimson' which followed closely with an average of 9.67 and 11.67 flowers/plant, in first and second season, respectively. 'Sugarbaby' produced an average of 8.11 flowers/plant in the first season and 9.45 flowers/plant in the second season and was not significantly ($p>0.05$) different from 'Charleston Gray' which produced 7.77 and 8.89 flowers/plant in the first and second seasons respectively. 'Crimson Sweet' consistently recorded the lowest number of female flowers averaging 6.43 and 5.79 flowers/plant in the first and second seasons, respectively. There was a strong ($R=0.97$, $R^2=0.94$) and highly signi-ficant ($p<0.001$) positive correlation between the number of female flowers and fruit number (Figure 1).

Highly sig-nificant ($p<0.001$) variation in fruit number was observed among accessions in both seasons. In the first season, the Kakamega landrace was significantly ($p<0.05$) the highest yielder with an average of 5 fruits/per plant (22222 fruits/ha), followed by 'Yellow Crimson' with an average of 3 fruits/plant (13333 fruits/ha). 'Sugarbaby', Charleston Gray' and 'Crimson Sweet' yielded 2 fruits/ plant (8889 fruits/ha), 1.11 fruits /plant (4933 fruits/ha) and 1 fruit/plant (4444 fruits/ha) respectively and were not significantly ($p>0.05$) different. The trend was similar in the second season in which the yields of all accessions were significantly ($p<0.05$) different. The landrace again yielded the highest [6.22 fruits/ plant (27644 fruits/ha)] followed by 'Yellow Crimson' [3.67 fruits/plant (16311 fruits/ha)], 'Sugarbaby' [2.78 fruits/ plant (12355 fruits/ ha)], 'Charleston Grey' [1.89 fruits/ plant (8400 fruits/ha)] and 'Crimson Sweet' [0.78 fruits/ plant (3467 fruits/ha)] in that order. In combined season analysis, highly significant ($p<0.001$) variation was also observed. The Kakamega landrace (043014) emerged significantly the best yielder with 5.67 fruits/plant (25200 fruits/ha) followed by 'Yellow Crimson with 3.45 fruits/plant (15333 fruits/ha) (Table 1). 'Sugarbaby' and 'Charleston Gray' recorded

Table 2. The first two principle components (PC) of the five accessions.

Accession	PC1	PC2
Main Vine Length	0.434945	-.515915
Branch Number	0.481256	0.084453
No. of female flowers	0.498136	0.019085
Fruit Number	0.495849	-.143184
Fruit Weight (Kg)	0.291907	0.840139
Eigen Value	3.91368353	0.93367878
Proportion	0.7827	0.1867
Cumulative	0.7827	0.9695

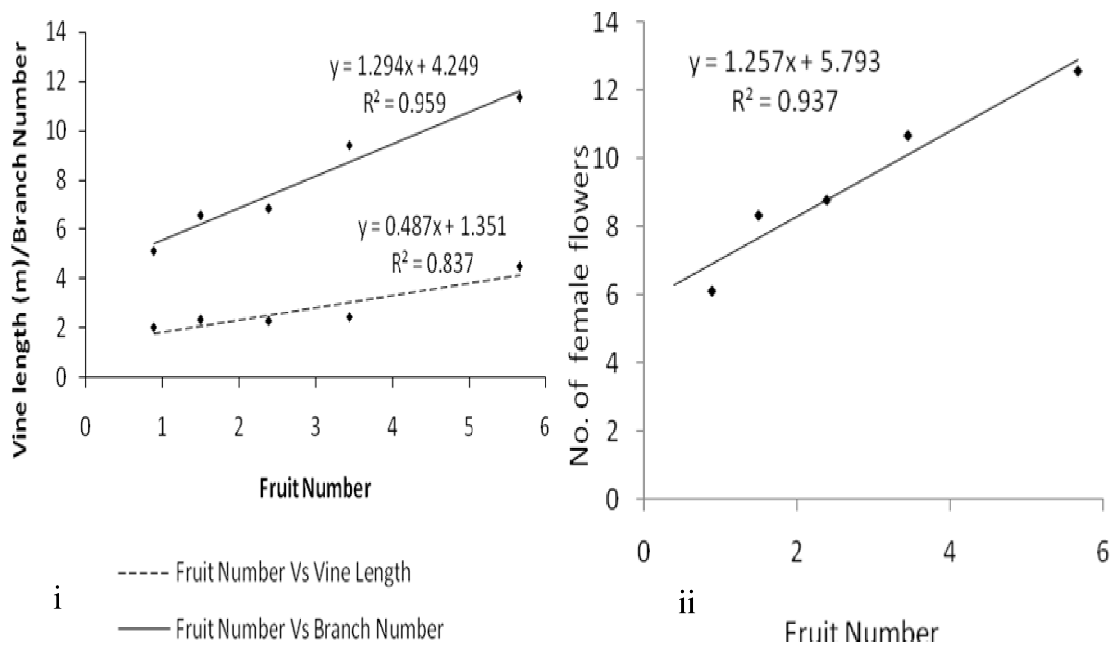

Figure 1. (i) Linear Correlation between fruit number and vine length/branch number. (ii) Linear Correlation between fruit number and total number of female flowers.

an average fruit yield of 2.39 fruits/plant (10622 fruits/ha) and 1.5 fruits/plant (6667 fruits/ha) respectively, while ‘Crimson Sweet’ recorded the lowest yields of 0.89 fruits/plant (3956 fruits/ha) (Table 1). Seasonal differences in fruit number were also highly significant ($p<0.01$) but accession x season interactions were not ($p>0.05$).

Highly significant ($p<0.001$) variation in fruit weight was observed among the cultivated accessions in both seasons. ‘Yellow Crimson’ had significantly ($p<0.05$) the biggest fruits averaging 2.72 and 3.3 kg in first and second season respectively, which averaged 3.01 kg (Table 1) when the two seasons were combined. The fruits of the Kakamega landrace (043014), ‘Sugarbaby’ and ‘Charleston Grey’ did not differ significantly ($p>0.05$) in weight. They averaged 1.83, 1.82 and 1.60 kg in the first season and 2.28, 2.14 and 1.94 kg in the second season respectively, which averaged 1.99, 2.05 and 1.77 kg respectively in combined season analysis (Table 1). In ($p<0.05$) the smallest fruits among the cultivated accessions averaging 1.21 and 1.67 kg in first and second season respectively, which averaged 1.44 kg in combined season analysis (Table 1). Seasonal differences in fruit weight were highly significant ($p<0.001$) but accession x season interactions were not ($p>0.05$).

Results of the principle component analyses (PCA) for the yield components indicated that the first two PCs explained 78.3 and 18.7% (a total of 97%) of the total diversity (Table 2). The two-dimensional presentation of all accessions grouped by seasons (1 and 2) is presented in Figure 2. The landrace (LR) separated clearly from the rest and was located on the upper part of the PCA graph (Figure 2). ‘Yellow Crimson’ (YC) also separated from other commercial cultivars and was placed at the middle of the PCA graph below the landrace (LR). ‘Sugarbaby’

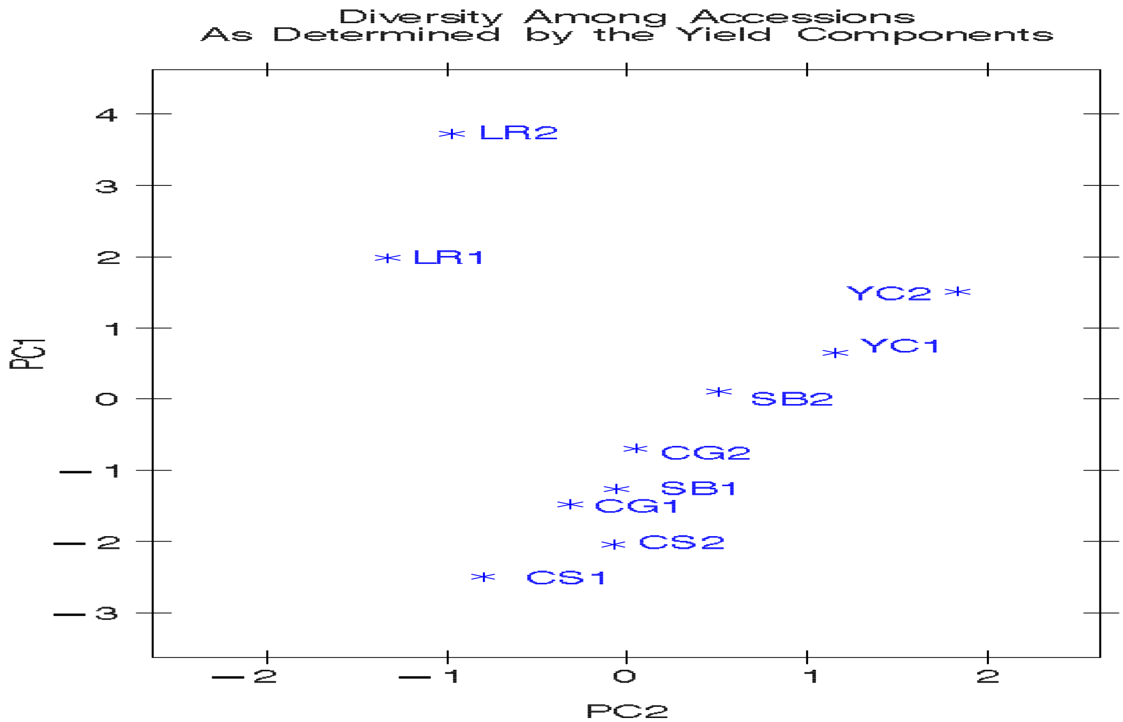

Figure 2. Principle Component (PC) analysis plot of first two principle components, depicting the diversity among accessions.

(SB), 'Charleston Gray' (CG) and 'Crimson Sweet' (CS) were placed in that order on the lower part of the PCA graph. There was significant difference between seasons with season 2 performing consistently better than season 1both seasons, 'Crimson Sweet' produced significantly

DISCUSSION

Evaluated accessions portrayed a wide range of variation in yield and yield components. Highly significant (p< 0.001) variation in length of the main vine was observed between accessions in both seasons. This concurs with the results of Dittmar (2006) who also reported differences in vine vigor and growth among watermelon cultivars. The landrace had significantly (p<0.05) the longest main vine as compared to cultivated accessions. This considerably long vine of the landrace along with its extensive branching could be one of the factors responsible for its relatively high yields. 'Yellow Crimson', which is a newly bred cultivar had significantly (p<0.05) the longest main vine among the commercial cultivars while 'Crimson Sweet' had significantly (p<0.05) the shortest main vine. Main vine length, however, did not vary much amongst commercial cultivars as compared to the landrace whose vine length was more than double that of 'Crimson Sweet'. Warren et al. (1998) noted that watermelon vines if left undisturbed will normally attain a length of between 360 and 480 cm. The vine lengths of all inbred cultivars were therefore below average and this could have contributed largely to their low yields. Warren et al. (1998) reported that watermelon plants with longer vines also produce higher yields than those with shorter vines. This was confirmed by a strong and highly significant positive correlation that was observed between main vine length and fruit number (Figure 1i).

The main vines of Kakamega landrace and 'Yellow Crimson' were significantly (p<0.05) the most branched with some of the branches even managing to produce sub-branches. However, the landrace was found to produce more sub-branches than 'Yellow Crimson' and its sub-branches also bore female flowers which successsfully developed into fruits thus resulting in higher yields. There was strong and highly significant correlation between the total number of female flowers and the fruit number (Figure 1ii) indicating that flower formation and successful pollination is crucial for high fruit yields in watermelon. The main branches of 'Yellow Crimson' produced very few sub-branches which produced a few female flowers which hardly developed to mature fruits. The landrace therefore ultimately managed to produce more fruits than 'Yellow Crimson' even though the two accessions produced approximately equal number of branches from their main vines. 'Charleston Gray', 'Sugarbaby' and 'Crimson sweet' produced relatively fewer branches with considerably very few if any sub-branches which hardly produced any fruits hence their low yields. Warren et al. (1998) indicated that watermelon plants with many branches produce higher yields than those with few branches or those whose branches has been pruned. This was confirmed by a strong and highly significant correlation that was observed between branch number and fruit number (Figure 1i). The high yields of the landrace were also attributed to its apparently well adaptation to climatic and edaphic conditions of Maseno, probably because of the close proximity of Maseno to Kakamega.

Although the landrace produced more fruits than 'Yellow Crimson', its total yield in kilograms was just slightly above that of the latter which emerged significantly ($p<0.05$) the best yielder among the commercial cultivars. The high fruit yields of these two accessions were attributed to their relatively higher disease and pest tolerance/resistance as was observed in the field, and their vigorous growth with more foliage, extensive branching and longer vine length. They also produced more sub-branches than the rest of the accessions resulting in more foliage. Warren et al. (1998) indicated that more watermelon foliage translates into high photosynthetic and assimilation rates and ultimately to more fruits, and any reduction in foliage will reduce watermelon yields. They added that watermelon plants with longer vines also produce higher yields than those with shorter vines. Since watermelon flowers develop in the nodes of the plants, additional branching on some watermelon accessions creates more locations for the flowers to be developed (Dittmar, 2006). High yields of 'Yellow Crimson' may also be attributed to its tolerance to acidic soils and its wider geographic adaptability as reported by Anon. (2001). Development of new varieties with wide range of geographic adaptability that include soils, temperatures and moisture conditions is one of the primary goals of breeding (Hall, 2004). The production of other commercial cultivars was below average; ranging from 1-2 fruits which were relatively small compared to 'Yellow Crimson'. McFarlane (2007) reported that watermelon fruits vary in weight from less than 4 to over 18 kg depending on the variety but none of the accessions in this study fell in this range. This could have been caused by poor agro-ecological conditions that these accessions were exposed to including acidic soils of Maseno, as indicated by Mwai (2001). In addition, the low fruit yields of commercial cultivars as compared to the landrace may be attributed to their higher susceptibility to melon fly which significantly reduced fruit yield. Generally, all the four commercial cultivars produced relatively small fruits and this could have been caused by poor edaphic conditions (especially acidic pH) at Maseno where the fruits were grown, as reported by Kovatch (2003) and Warren et al. (1990).

The results of principle component analysis demonstrated significant diversity between accessions. The landrace (LR) was located on the uppermost part of the PCA graph (Figure 2) because it recorded the highest va-lues in all the yield components except fruit weight. Fruit weight had the most contribution to PC2 and the least to PC1 while other yield components contributed the most to PC1 and the least to PC2. The landrace can therefore be said to have a higher yield potential than commercial cultivars. 'Yellow Crimson' (YC) performed consistently better than other commercial cultivars. This cultivar was developed recently and has probably been selected for high yields unlike the other three which were developed over fifty years ago. Seasonal differences that were observed across the board were attributed to different rainfall patterns that were experienced in both seasons. Season one was a short rain season while season two was a long rain season.

Conclusion

This study was the first report comparing the yield components of three most popular commercial watermelon cultivars in Kenya with a newly introduced cultivar and one Kenyan landrace. The landrace emerged to be the best performer though it contained some undesirable traits, such as poor taste and too many seeds. This acession has not been selected for low cucurbitacin content and taste. However, since it contains more desirable than undesirable agronomic traits, it can be improved for production especially in Western and Nyanza provinces of Kenya. Although 'Yellow Crimson' which is a relatively new variety hardly known to many Kenyan watermelon growers was found to be the best performer among the commercial cultivars. Its good performance was attributed largely to its apparently wider geographic adaptation, which enabled it to grow more vigorously and ultimately resulting in high fruit yield. The fruit was also very sweet and watery. It was therefore recommended for adoption by Kenyan growers and seed companies should make efforts of availing its seeds to growers. 'Sugarbaby', though being an old cultivar just like 'Charleston Gray' and 'Crimson Sweet' portrayed better performance than the latter two cultivars. It appeared to have a wider climatic adaptation and this could be the major reason why it is the most popular watermelon in Kenya and also in the world apart from its good and wider consumer acceptance (Johnson, 2007). If this cultivar can be improved for better disease and pest resistance, it still has great potential.

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