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Quality and yield of snap bean lines locally developed in Kenya

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Key words: Snap beans, pod quality, marketable pod yield, disease resistance.

Abstract

Snap bean varieties with high yields of extra fine and fine yield are preferred to avoid heavy postharvest losses and reduced consumer appeal. The objective of this study was to select snap bean populations and lines developed for multiple disease resistance for high pod quality and yield. Six groups of snap beans populations at different generations and 49 snap bean lines including local checks were evaluated for their yield performance at KARI-Thika and Mwea for two seasons. Data collected included duration to flowering and maturity, pod length and width, number of pods per plant, marketable pod yield and pod quality (extra fine, fine and bobby). There were significant differences among the genotypes with respect to days to flowering, days to maturity, pod length, pod diameter, marketable pod yield and pod quality. Climbing snap bean took the longest duration to flower and mature compared to bush snap beans. Snap bean populations and lines with higher number of pods per plant, pod length and pod diameter than the local checks were recorded. Climbing lines had a highest pod diameter of 11mm among the snap bean lines. HAB 423 had the highest pod yield of 15.1 t/ha while Star 2053 was the best yielding parent check with pod yield of 11.5 t/ha. Star 2053 had the highest proportion of extra fine pod yield (92.6%) while SB-08-3-2 population had the highest proportion (85.8%) among the populations and lines. Therefore, it is evident that locally develop snap bean varieties with multiple disease resistance and high yields of acceptable quality can be achieved.

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Introduction

Snap bean (*Phaseolus vulgaris* L.) is a major vegetable export crop in Kenya and ranks second to cut flowers in terms of foreign exchange earnings generated from the dynamic horticultural sub-sector. From 2004 to 2010, Kenya exported an average 19,000 metric tonnes of snap bean per year with a value of more than Ksh 26.2 billion in total (HCDA, 2011). Almost 100,000 people make an income from French beans and another 500, 000 derive income directly from exports of snap beans. Production is mainly by small to medium scale farmers. Low yields of snap bean are realised in Kenya of 6 to 8 tons ha^{-1}. However, high yields ranging from 15 to 20 tons ha^{-1} have been achieved in developing countries in South America and south East Asia through use of well adapted variety and proper management (Ndegwa *et al.,* 2009). Snap bean farmers face several constraints such as pests, diseases, post harvest losses and inadequate extension services (Wasonga *et al.,* 2010).

Varieties commonly grown in developing countries are introductions from temperate countries and these varieties may not be well adapted to tropical environments (Ndegwa *et al.,* 2009).The commercial bush snap bean varieties currently grown locally are susceptible to foliar fungal disease. The varieties have been observed also to flower in a single flush, have a concentrated pod set, short harvest duration of 3-4 weeks with yields ranging between 6 and 8 tons ha^{-1} (Ndegwa and Muchui, 2001). Development of resistant snap bean lines with the desired export quality, more productive and have a longer harvesting period could increase the productivity of snap bean farming. This could also help farmers access European Union market which is increasingly becoming difficult as a result strict safety and quality standards (Monda *et al.,* 2003). However, such varieties are yet to be developed for eastern Africa. Efforts to improve snap bean varieties have been reported by Arunga *et al.,* 2010 using dry bean. The study reported that dry bean combined well with snap bean and therefore they can be can be used in snap bean breeding programmes. The objective of this study was to evaluate snap bean populations and lines for pod quality and pod yield.

Materials and methods

Experimental sites

Field experiments were conducted at the Kenya Agricultural Research Institute in Thika (KARI-Thika) and on farmer's field at Mwea in Kenya. KARI-Thika is located in co-ordinates 0° 59' South and 37° 04' East at an elevation of 1548 m above sea level. It experiences bimodal pattern of rainfall with an annual mean of 1000 mm. Long rains occur between March and May while short rains occur between October and December with a mean of 142 mm and 116 mm, respectively. The mean annual maximum and minimum temperatures are 25.1 and 13.7°C, respectively (Ndegwa *et al.,* 2009). Mwea is located at 37° 20' East and 0° 41' South at an elevation of about 1159m above sea level. It experiences bimodal rainfall with an annual mean of 1037 mm with long rains occurring between March and May while short rains are between October and December with a mean of 71 mm and 50 mm, respectively. The mean annual maximum and minimum temperatures at long rain season is 27.8 °C and 15.6 °C during short rain season (Ndungu *et al.,* 2004).

Plant materials and experiment design

Snap bean populations were developed from BelDakMi, L227, Beltigrade RR2, Awash 1, BelMiNeb and Roba-1 lines with genes for resistance to rust and G2333 with genes for resistance to anthracnose. These lines were crossed with ten susceptible commercial varieties namely Amy, Paulista, Morelli, Morgan, Julia, Foskelly, Teresa, Vernandon, Kutuless and Alexandria. Fifty one F_1 populations were developed and advanced to F_5 and F_6 generations by bulk population method. Evaluation and selections of single plants for pod yield and pod quality were done on these populations at F_5 and F_6 generation for two seasons during year 2009 and 2010. Other materials evaluated were thirty three bush and six climbing snap bean lines. Ten snap bean varieties were also included as checks during the evaluation. The experiment was laid out in a randomized complete block design. The experiment was replicated three times at each site and for two seasons.

Determination of duration to flowering and maturity.

Data collected from the field experiment were growth vigour, days to flowering and days to maturity. Duration to flowering was recorded as the number of days after planting to the date when 50% of plants had one or more flowers. Duration to maturity was measured as the number of days after planting to the date when 50% of the plants had reached physiological maturity (Van and pastor-Corrales, 1987).

Determination of pod quality and yield.

At green pod maturity, thirty plants per plot were randomly selected and harvested 3 times per week at one day interval for 8 weeks. The pods were graded into three standard categories defined by their pod diameter and length as extra fine (6 mm), fine (6-8mm) and bobby (>8 mm) and length of the pods above 10 cm (HCDA, 2011). Weight for each grade category was obtained at each harvest, and the cumulative total weight obtained at the end of the harvest period. The pod yield was averaged to give pod yield per plant which was then multiplied by the number of plants in one hectare to obtain pod yield per hectare. After grading the samples five pod of extra fine, fine and bobby grade were randomly selected during the second harvest for assessment of pod characteristics like colour, shape, pod length (cm) and pod diameter (mm).The number of pods per plant was estimated by taking an average of total number of pods from five randomly selected plants per plot at maturity. Pod width and length were determined by measuring by passing the pods through holes of 6 mm, 8 mm and 12 mm diameters for extra fine, fine and bobby pods respectively of a bean ruler manufactured by Royal Sluis.

Data analysis

Quantitative data collected from the experiment were subjected to combined analysis of variance (ANOVA) using the PROC ANOVA procedure of GenStat (Lawes Agricultural Trust Rothamsted Experimental Station 2006, Version 9). Differences among the genotypic means were compared using the Fisher's protected LSD test at 5% probability level.

Results

There were significant differences among the snap bean population and lines for days to flowering (Table 1). SB-08-3-1 population at F_5 generation was the earliest to flower (37.0 days) among the populations. Climbing lines and KSB lines generally flowered late when compared to the other lines. Among the climbing lines HAV 131 was the earliest (40.8 days) snap bean line to flower. Among the parents used as checks Morgan was the earliest to flower (36.3 days) while Star 2053 was the latest to flower (39.1) (Table 1). Significant differences were recorded for days to maturity among the snap bean populations and lines (Table 2). SB-08-5-6 population at F_5 generation took the shortest duration to mature (75.1 days) among the populations evaluated. HAB 401 was the earliest to mature (76.1 days) among the snap bean lines. Generally climbing lines were latest to mature when compared to the other lines with climbing line HAV 131 taking the longest duration to mature (81.7 days). Among the parent lines, Morelli took the shortest duration to mature (75.3 days) while Julia was the latest to mature (79.7 days) (Table 2).

There were significant differences recorded for pod length among the snap bean population and lines except among the populations at F_4 generation (Table 3). SB-08-303 had the longest pods (12.5 cm) among the populations. HAB 404, HAB 419 and HAB 438 had the longest pods (12.3 cm) among the snap bean lines. Among the parent lines Samantha had the longest pods (11.9 cm) while Amy had the shortest pods (9.4 cm) (Table 3). Significant differences were also recorded for pod diameter among the snap bean population and lines except among the climbing lines (Table 3-6). Pod diameter ranged from 0.7 cm to 0.9 cm among the populations and 0.6 cm to 0.9 cm among bush lines. Climbing snap bean lines generally had high pod diameter ranging from 1.0 cm to 1.1 cm. KSB 11 snap bean line had the lowest pod diameter among the snap bean lines. Pod diameter ranged from 0.6 cm to 0.8 cm among the parent lines (Table 3).

Significant differences were recorded for number of pods per plant among the snap bean population and lines (Table 4). SB-08-3 at F_4 generation had the highest number of pods per plant (11.4 cm) among the populations. HAB 501 had the highest pods per plant per plant among the snap bean lines. Among the parent, Morelli had the highest pods per plant (9.8) while Julia had the lowest number of pods per plant (6.9) (Table 4).

There were significant differences for pod yield among the snap bean populations and lines (Table 5). SB-08-5-3 at F_6 generation had the highest pod yield of 10222.2 kg ha^{-1} among the populations. HAB 423 had the highest pod yield of 15104.4 kg ha^{-1} among the snap bean lines. Among the parent lines, Star 2053 had the highest pod yield of 11527.8 kg ha^{-1} while Paulista had the least pod yield of 3781.7 kg ha^{-1}(Table 5).

Table 1. Days to flowering, days to maturity, pod length, pod diameter, number of pods per plant, pod yield, extra fine, fine and bobby pod yield of F_5 snap bean population.

Genotype	Df	Dm	Pod length	Pod width	pods/ plant	Pod yield	Extra fine	Fine	Bobby
	Days		Cm		no.	Kg ha^{-1}			
SB-08-3-1	37.5	75.9	9.9	0.9	10.8	5916.7	1805.6	3444.4	666.7
SB-08-3-10	37.9	77.5	11.2	0.7	8.6	6194.4	4555.6	1638.9	0.0
SB-08-3-11	37.6	76.0	11.0	0.8	8.6	6602.9	555.6	4938.5	1111.1
SB-08-3-12	37.0	76.1	11.5	0.9	11.0	9714.4	688.9	8916.7	111.1
SB-08-3-13	37.3	76.3	10.7	0.8	9.6	9166.7	7833.3	1000.0	0.0
SB-08-3-14	39.6	78.1	11.3	0.9	10.6	6847.2	3680.6	2833.3	333.3
SB-08-3-15	38.0	75.9	11.3	0.7	10.6	4583.3	666.7	2805.6	555.6
SB-08-3-16	37.4	75.7	10.7	0.8	10.4	3935.9	2435.9	1055.6	444.4
SB-08-3-17	38.2	77.5	10.6	0.9	9.8	3750.0	1527.8	777.8	1444.4
SB-08-3-18	37.7	76.6	11.2	0.8	9.2	7103.9	208.3	3895.6	3000.0
SB-08-3-19	40.1	78.5	11.0	0.8	8.7	4401.1	226.7	2626.7	1547.8
SB-08-3-2	37.5	77.9	11.1	0.8	11.1	4680.6	4013.9	666.7	0.0
SB-08-3-20	37.4	76.6	11.5	0.9	8.2	6481.5	0.0	4814.8	1666.7
SB-08-3-21	39.1	76.8	11.8	0.7	8.3	7527.8	5750.0	1611.1	166.7
SB-08-3-22	38.1	76.9	10.8	0.8	9.1	4742.8	0.0	4113.9	628.9
SB-08-3-3	39.0	75.8	11.0	0.8	11.4	4722.2	833.3	2333.3	1555.6
SB-08-3-4	37.4	76.8	10.5	0.7	8.5	7070.7	1333.3	4981.8	755.6
SB-08-3-5	37.6	77.0	11.0	0.9	10.8	5388.9	1111.1	3388.9	888.9
SB-08-3-6	37.8	77.2	10.8	0.8	10.6	4753.3	0.0	3087.8	1666.7
SB-08-3-7	37.6	76.8	11.0	0.8	10.7	5074.1	0.0	1967.4	3106.7
SB-08-3-8	38.0	76.6	11.6	0.9	10.2	5349.2	3782.2	1571.4	0.0
SB-08-3-9	38.3	77.3	11.0	0.7	11.2	4836.6	1111.1	2225.5	1500.0
Checks									
Amy	38.4	78.4	9.4	0.6	8.2	6625.0	5736.1	888.9	0.0
Julia	39.1	79.7	10.0	0.6	6.9	5944.4	3638.9	1055.6	0.0
Menakelly	37.5	77.8	10.1	0.7	8.2	5500.0	4388.9	444.4	666.7
Morelli	36.9	75.3	9.9	0.7	9.8	7991.5	3833.3	3491.5	666.7
Morgan	36.3	76.5	9.7	0.7	7.8	5660.0	753.3	4348.4	555.6
Paulista	36.9	78.8	10.5	0.6	7.8	3781.7	892.9	2111.1	777.8
Samantha	36.9	78.5	11.9	0.8	7.4	8267.7	4388.9	2527.8	138.9
Star 2053	38.4	77.4	10.8	0.7	7.3	11527.8	10680.0	785.7	0.0
Teresa	38.3	75.9	11.2	0.8	8.3	10541.7	3416.7	5125.0	0.0
Vernadon	37.4	76.2	9.6	0.7	9.3	5837.2	982.2	3190.6	342.2
Mean	37.9	77.0	10.8	0.8	9.3	6266.3	2526.0	2770.8	759.3
LSD $_{0.05}$ Genotype	0.7	1.7	NS	0.1	1.2	1487.4	1831.9	2048.9	775.2
CV %	0.2	0.2	1.7	2.9	0.7	6.7	20.7	5.6	14.4

Df= days to flowering, Dm= days to maturity, LSD= least significant difference at 0.05 probability level, CV= coefficient of variance.

There were significant differences recorded for extra fine, fine and bobby pod yield among the snap bean population and lines except among backcrosses population for fine pod yield (Table 5-6). SB-08-3-2 population in F_5 generation had the highest proportion (85.8%) of its yield extra fine among the populations.

KSB 7 had the highest proportion of extra fine pod yield (59.3 %) among the snap bean lines (Table 5). Among the parent lines Star 2053 had the highest proportion of extra fine pod yield (92.6%). SB-08-5-4 at F_5 generation had the highest proportion of fine pod yield (97.3%)

among the snap bean populations while HAB 501 had the highest proportion of fine pod yield (95.3%) among the snap bean lines. Among the parent checks, Morgan had the highest proportion of fine pod yield (76.8%) (Table 6). SB-08-3-8 at F_5 generation had the highest proportion of bobby pod yield (61.2%) among the populations evaluated while HAB 425 BM had the highest proportion of bobby pod yield (77.4%) among the snap bean lines. Among the parents Paulista had the highest proportion of its yield as bobby (20.6%) (Table 6).

Table 2. Days to flowering, days to maturity, pod length, pod diameter, number of pods per plant, pod yield, extra fine, fine and bobby pod yield of F_6 snap bean population.

Genotype	Df	Dm	Pod length	Pod width	pods/ plant	Pod yield	Extra fine	Fine	Bobby
	days		Cm		no.	kg ha^{-1}			
SB-08-3-22	38.5	77.1	10.2	0.9	7.4	5619.0	0.0	3396.8	2220.0
SB-08-5-1	38.2	77.4	10.7	0.8	9.4	7638.9	388.9	6694.4	0.0
SB-08-5-10	38.3	77.8	11.2	0.9	9.3	6000.0	1666.7	3666.7	222.2
SB-08-5-12	38.1	75.2	10.3	0.8	8.3	4847.8	1566.7	1723.3	1002.2
SB-08-5-13	38.8	76.0	11.2	0.9	8.5	5738.1	238.1	4277.8	0.0
SB-08-5-14	38.4	77.5	11.1	0.8	7.8	8611.1	555.6	2448.9	2555.6
SB-08-5-15	39.8	77.5	9.9	0.8	7.8	5250.0	2083.3	1805.6	805.6
SB-08-5-16	39.1	77.4	11.1	0.8	7.7	8666.7	0.0	4472.2	4194.4
SB-08-5-17	37.4	77.8	10.3	0.8	8.1	7722.2	0.0	7053.3	0.0
SB-08-5-18	39.2	76.9	12.1	0.8	9.1	5995.6	0.0	5166.7	831.1
SB-08-5-19	39.8	77.0	10.4	0.9	7.6	7539.7	3095.2	3333.3	555.6
SB-08-5-2	38.3	77.3	10.3	0.8	10.3	8805.6	0.0	8083.3	166.7
SB-08-5-20	39.6	75.8	10.6	0.9	9.3	4311.1	888.9	2755.6	111.1
SB-08-5-21	39.1	76.8	12.2	0.9	8.9	8920.6	1793.3	7125.1	0.0
SB-08-5-3	39.3	77.5	11.0	0.8	10.3	10222.2	0.0	9111.1	0.0
SB-08-5-4	38.4	77.3	9.8	0.8	10.3	9722.2	0.0	9472.2	250.0
SB-08-5-5	39.0	76.8	10.4	0.8	9.5	7451.0	0.0	6506.5	388.9
SB-08-5-6	37.7	75.1	10.8	0.8	8.9	4916.7	0.0	1916.7	1111.1
SB-08-5-7	38.9	76.4	10.5	0.8	8.9	7333.3	1333.3	6155.6	1177.8
SB-08-5-8	37.8	77.0	11.2	0.8	7.9	9666.7	5000.0	888.9	0.0
SB-08-5-9	38.3	75.8	10.3	0.8	10.1	6569.4	0.0	5347.2	0.0
Checks									
Amy	38.4	78.4	9.4	0.6	8.2	6625.0	5736.1	888.9	0.0
Julia	39.1	79.7	10.0	0.6	6.9	5944.4	3638.9	1055.6	0.0
Menakelly	37.5	77.8	10.1	0.7	8.2	5500.0	4388.9	444.4	666.7
Morelli	36.9	75.3	9.9	0.7	9.8	7991.5	3833.3	3491.5	666.7
Morgan	36.3	76.5	9.7	0.7	7.8	5660.0	753.3	4348.4	555.6
Paulista	36.9	78.8	10.5	0.6	7.8	3781.7	892.9	2111.1	777.8
Samantha	36.9	78.5	11.9	0.8	7.4	8267.7	4388.9	2527.8	138.9
Star 2053	38.4	77.4	10.8	0.7	7.3	11527.8	10680.0	785.7	0.0
Teresa	38.3	75.9	11.2	0.8	8.3	10541.7	3416.7	5125.0	0.0
Vernadon	37.4	76.2	9.6	0.7	9.3	5837.2	982.2	3190.6	342.2
Mean	38.3	77.0	10.6	0.8	8.6	7005.1	1702.2	4002.1	643.3
LSD $_{0.05}$ Genotype	0.8	1.7	1.3	0.1	1.3	1679.5	1797.2	2244.0	1074.6
CV %	0.2	0.5	0.7	2.4	1.5	3.0	19.1	5.5	21.7

Df= days to flowering, Dm= days to maturity, LSD= least significant difference at 0.05 probability level, CV= coefficient of variance.

Discussion

The results showed that the snap bean populations and parent varieties flowered almost at the same time. KSB group of snap bean lines and climbing snap bean lines were late flowering which delayed early pod set and harvesting. Emam *et al.,* (2010) reported that late flowering allows photosynthates to fuel vigorous vegetative growth which subsequently produces photosynthates to enable an increased number of pods to develop. Late flowering would increase the risk of damage from early autumn frosts at northern latititude, but this is not a problem in tropical region (Mohamed *et al.,* 2007). Results showed that the variation in duration to maturity among snap bean populations existed and there were populations that matured earlier than some parents. However climbing lines were late maturing which could be attributed to late flowering.

Climbing beans are known to mature late because they do not set their flowers in a single flush as bush bean. This characteristic makes climbing snap beans to be of interest to farmers because it allows prolonged harvesting duration.

Table 3. Days to flowering, days to maturity, pod length, pod diameter, number of pods per plant, pod yield, extra fine, fine and bobby pod yield of backcross snap bean population.

Genotype	Df	Dm	Pod length	Pod width	pods/plant	Pod yield	Extra fine	Fine	Bobby
	days		cm		no.	kg ha^{-1}			
SB-08-301	38.6	77.1	11.1	0.8	6.8	3361.1	0.0	3138.9	222.2
SB-08-302	39.2	79.3	10.5	0.8	8.8	2837.8	0.0	1944.4	895.6
SB-08-303	37.2	75.5	12.5	0.9	8.7	4406.7	476.2	2819.4	1111.1
SB-08-304	38.5	77.4	10.7	0.8	6.7	3432.8	1340.0	721.7	1437.8
SB-08-305	39.4	77.6	11.9	0.8	7.6	4272.7	606.1	2755.6	911.1
SB-08-306	38.9	77.3	9.9	0.9	6.7	4321.1	887.9	2765.6	113.1
SB-08-307	37.4	74.7	10.8	0.8	7.3	3920.6	476.2	1222.2	2222.2
SB-08-308	38.9	77.8	10.8	0.8	9.3	3763.9	0.0	3208.3	555.6
Checks									
Amy	38.2	78.4	9.4	0.6	8.2	6625.0	5736.1	888.9	0.0
Julia	39.1	79.7	10.0	0.6	6.9	5944.4	3638.9	1055.6	0.0
Menakelly	37.5	77.8	10.1	0.7	8.2	5500.0	4388.9	444.4	666.7
Morelli	37.5	76.0	9.9	0.7	9.8	7991.5	3833.3	3491.5	666.7
Morgan	36.3	76.5	9.7	0.7	7.8	5660.0	753.3	4348.4	555.6
Paulista	37.1	78.8	10.5	0.6	7.8	3781.7	892.9	2111.1	777.8
Samantha	36.9	78.5	11.9	0.8	7.4	8267.7	4388.9	2527.8	138.9
Star 2053	39.1	77.4	10.8	0.7	7.3	11527.8	10680	785.7	0.0
Teresa	38.1	75.9	11.2	0.8	8.3	10541.7	3416.7	5125.0	0.0
Vernadon	37.4	76.2	9.6	0.7	9.3	5837.2	982.2	3190.6	342.2
Mean	38.1	77.3	10.6	0.7	7.9	5745.5	2447.6	2340.0	617.8
LSD $_{0.05}$ Genotype	0.7	2.0	1.3	0.1	1.1	1388.7	2325.0	NS	534.5
CV %	0.6	0.5	3.0	3.0	0.8	4.0	30.3	19.1	11.3

Df= days to flowering, Dm= days to maturity, LSD= least significant difference at 0.05 probability level, CV= coefficient of variance.

There were population and lines that had pods that could meet the export standards. Among the parent lines, Samantha had the longest pods 11.9 cm. This implies that Samantha could be a useful parent for developing varieties with longer pod length. Pod length of the other commercial varieties was slightly shorter than the optimum size. This indicates that conditions in the test sites such as long period of moisture stress, low soil fertility and modest fertilizer application rates may have influenced expression of this trait. Only genotypes with a mean pod length above 10 cm were selected so that they should meet market standards as indicated by Muchui (2001).

All the parent lines had pods diameter below 8 mm with Amy, Julia and Paulista having the least pod diameter of 6mm, implying that they are a good source of thin pod characteristic that could be used in breeding programs to develop snap bean lines with thin pods.

A significant general combining ability (GCA) for pod diameter in Amy was reported by Arunga *et al.*, (2010) demonstrating the role of additive gene effect for this trait in snap beans. Climbing lines had the highest pod diameter than bush lines when they were harvested at regular interval. This indicates that climbing snap bean could be harvested more often than the bush to avoid overgrown pods or they should be crossed with bush snap bean to incorporate thin pod characteristic. Mohamed and Somsiri (2007) reported that beans with indeterminate growth habit have smaller seeds hence less pod diameter which improves the quality of snap bean pods when compared with determinate beans. However, the results showed that climbing lines used in this study had thicker pods. Such variation in results may arise due to the background genetic differences in these varieties.

Table 4. Days to flowering, days to maturity, pod length, pod diameter, number of pods per plant, pod yield, extra fine, fine and bobby pod yield of HAB snap bean lines.

Genotype	Df	Dm	Pod length	Pod width	pods/ plant	Pod yield	Extra fine	Fine	Bobby
	days		cm		no.	kg ha^{-1}			
HAB 173	37.1	78.4	11.1	0.7	7.7	7466.9	555.6	4889.1	2022.2
HAB 229	38.1	77.3	12	0.7	11.4	7716.9	0.0	6030	1665.8
HAB 240	36.2	77.9	11.2	0.7	7.0	10915.0	1111.1	7692.8	1888.9
HAB 401	36.4	76.1	10.5	0.8	10.0	7488.1	0.0	5821.4	1666.7
HAB 403	38.0	77.4	10.8	0.7	10.6	7095.6	0.0	5780	1315.6
HAB 404	37.9	77.5	12.3	0.8	9.0	9259.2	1666.7	5659.2	1933.3
HAB 405	36.9	76.2	11.2	0.7	9.8	10650.8	1428.6	7416.7	1805.6
HAB 406	37.1	78.0	11.1	0.7	6.2	6638.9	3583.3	1388.9	1666.7
HAB 408	37.4	79.0	11.8	0.8	8.4	9375	0.0	7597.2	1777.8
HAB 411	37.3	78.1	11.9	0.7	9.8	4761.9	0.0	3873	888.9
HAB 414	36.8	77.4	11.9	0.8	8.3	10904.8	0.0	9904.8	1000
HAB 419	37.5	77.4	12.3	0.8	9.1	9652.8	0.0	7986.1	2333.3
HAB 420	37.1	78.2	11.9	0.8	9.9	4111.1	0.0	3222.2	888.9
HAB 423	36.7	77.9	11.6	0.8	8.2	15104.4	166.7	13250	1666.7
HAB 425 BM	37.8	78.6	11.3	0.7	8.7	8555.6	0.0	1933.3	6622.2
HAB 425 W	36.8	77.2	11.1	0.8	9.8	8008.5	833.3	4397.4	2777.8
HAB 426	36.3	76.6	10.9	0.7	9.4	9453	553.3	6680	2222.2
HAB 428	38.1	77.9	11.9	0.8	9.2	11040	3333.3	6168.9	1537.8
HAB 438	37.5	78.3	12.3	0.7	8.4	6460.3	0.0	2888.9	3571.4
HAB 442	38.8	79.4	11.1	0.8	10.1	7944.4	0.0	5861.1	2083.3
HAB 449 BR	37.6	78.4	10.6	0.8	10.0	4362.2	833.3	2595.6	933.3
HAB 449 W	36.7	76.7	12.1	0.8	8.6	9037.8	0.0	6862.2	2173.3
HAB 462	37.0	78.4	11.5	0.7	8.4	11194.4	0.0	9916.7	1277.8
HAB 465	37.0	77.5	11.2	0.7	9.5	7194.4	0.0	5805.6	722.2
HAB 467	37.4	77.9	11	0.9	9.3	7847.2	1250.0	5263.9	1333.3
HAB 501	37.4	77.8	11.2	0.7	11.6	10902.8	0.0	10391.7	511.1
HAB 54	36.8	77.1	11.9	0.7	8.9	8511.9	0.0	6289.7	2222.2
Checks									
Amy	38.4	78.4	9.4	0.6	8.2	6625.0	5736.1	888.9	0.0
Julia	39.1	79.7	10.0	0.6	6.9	5944.4	3638.9	1055.6	0.0
Menakelly	37.5	77.8	10.1	0.7	8.2	5500.0	4388.9	444.4	666.7
Morelli	37.5	75.3	9.9	0.7	9.8	7991.5	3833.3	3491.5	666.7
Morgan	36.3	76.5	9.7	0.7	7.8	5660.0	753.3	4348.4	555.6
Paulista	37.1	78.8	10.5	0.6	7.8	3781.7	892.9	2111.1	777.8
Samantha	36.9	78.5	11.9	0.8	7.4	8267.7	4388.9	2527.8	138.9
Star 2053	39.1	77.4	10.8	0.7	7.3	11527.8	10680.0	785.7	0.0
Teresa	38.3	75.9	11.2	0.8	8.3	10541.7	3416.7	5125.0	0.0
Vernadon	37.4	76.2	9.6	0.7	9.3	5837.2	982.2	3190.6	342.2
Mean	37.4	77.7	11.2	0.7	8.9	8198.1	1460.2	5133.4	1439.4
LSD $_{0.05}$ Genotype	0.7	1.5	1.3	0.1	1.2	2319.6	1774.5	3183.5	1111.8
CV %	0.1	0.4	2.4	3.2	2.4	7.7	25.7	6.7	5.3

Df= days to flowering, Dm= days to maturity, LSD= least significant difference at 0.05 probability level, CV= coefficient of variance.

Some snap bean populations and lines had more pods than snap bean parents suggesting that there an improvement in the number of pods per plant could be achieved through selection. Among the parent lines, Morelli had the highest pods per plant and also it was the earliest to flower and Julia had the lowest number of pods and it took the longest duration to mature. This suggests that the number of pods in bush snap beans is not influenced by their duration to maturity. According to Mohamed (2007) cultivars that flowering late set more pods due to increased number of flowers that set pods.

HAB 423 was the highest yield line which was higher than the best yielding variety Star 2053. Jian *et al.,* (2010) working with soybean found that there had been a progressive increase in yield with release of new varieties over a period of fifty six years. Similarly Star 2053 produced higher yield because it was released recently compared to other varieties used in this study. This also indicates that pod yield could be increased further through single plant selection from the populations. Generally commercial snap bean parents concentrated their pod yield on extra fine and fine pod yield (Ndegwa *et al.,* 2009)

unlike most of populations that had more of their yield as fine and bobby pod yield because they were largely heterozygous. This may have resulted from the inheritance of poor pod characteristics of the donor parent with genes for resistance. The possibility of improving the snap populations to meet market standards is demonstrated by the potential of SB-08-5-4 population and HAB 501 line to produce 97.4% and 95.3% of their pod yield respectively as fine pod yield in this study. A variety with a potential to produce at least 1:1 ratio of extra fine and fine grade pods is recommended for growing in order to meet the specification of export markets (Muchui *et al.*, 2001).

Table 5. Days to flowering, days to maturity, pod length, pod diameter, number of pods per plant, pod yield, extra fine, fine and bobby pod yield of KSB snap bean lines.

Genotype	Df	Dm	Pod length	Pod width	Pods/ plant	Pod yield	Extra fine	Fine	Bobby
	days		cm		no.	kg ha^{-1}			
KSB 10 BR	42.5	78.9	9.7	0.7	9.0	8666.7	2000	5555.6	555.6
KSB 10 W	42.0	80.3	11.2	0.7	9.6	5275.6	555.6	3722.2	1000.0
KSB 11	44.2	80.7	10.9	0.6	8.7	3105.6	0.0	1410.0	1695.6
KSB 3	42.6	79.3	11.7	0.7	7.5	7113.3	333.3	5366.7	1413.3
KSB 4	41.6	78.5	10.6	0.7	4.5	3833.3	2226.7	493.3	1111.1
KSB 7	39.9	78.5	10.5	0.7	5.2	6420.6	3809.5	1888.9	722.2
Checks									
Amy	38.4	78.4	9.4	0.6	8.2	6625	5736.1	888.9	0.0
Julia	39.1	79.7	10.0	0.6	6.9	5944.4	3638.9	1055.6	0.0
Menakelly	37.5	77.8	10.1	0.7	8.2	5500	4388.9	444.4	666.7
Morelli	37.5	76.0	9.9	0.7	9.8	7991.5	3833.3	3491.5	666.7
Morgan	36.3	76.5	9.7	0.7	7.8	5660	753.3	4348.4	555.6
Paulista	37.1	78.8	10.5	0.6	7.8	3781.7	892.9	2111.1	777.8
Samantha	36.9	78.5	11.9	0.8	7.4	8267.7	4388.9	2527.8	138.9
Star 2053	38.9	77.4	10.8	0.7	7.3	11527.8	10680	785.7	0.0
Teresa	38.3	75.9	11.2	0.8	8.3	10541.7	3416.7	5125.0	0.0
Vernadon	37.4	76.2	9.6	0.7	9.3	5837.2	982.2	3190.6	342.2
Mean	39.5	78.3	10.5	0.7	7.8	6630.8	2977.3	2650.4	602.8
LSD $_{0.05}$ Genotype	0.5	2.1	1.3	1.3	1.0	1841.4	2468.9	1865.1	537.0
CV %	0.3	0.3	4	2.4	3.2	3.2	24.4	27.3	33.4

Df= days to flowering, Dm= days to maturity, LSD= least significant difference at 0.05 probability level, CV= coefficient of variance

Conclusion

The observation indicates that commercial snap bean varieties like Amy, Julia and Paulista are good donors of thin pod characteristic and can be used in breeding programs. However, some snap bean lines and populations with multiple disease resistance did not meet the pod quality of the commercial bush varieties due to inheritance of pod characteristics of the donor parent for disease resistance. Also there is potential of increasing yield of snap bean in eastern Africa by developing resistant varieties that are well adapted to the region. Consequently a rigorous evaluation for pod quality is required on any resistance snap bean line developed. Development of climbing snap bean varieties could provide high yields with a shorter harvesting interval than the bush lines.

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Table 6. Days to flowering, days to maturity, pod length, pod diameter, number of pods per plant, pod yield, extra fine, fine and bobby pod yield of climbing snap bean lines.

Genotype	Df	Dm	Pod length	Pod width	pods/ plant	Pod yield	Extra fine	Fine	Bobby
	days		cm		no.	kg ha^{-1}			
HAV 130	41.2	79.2	11.4	1.1	9.9	7944.4	0.0	7388.9	555.6
HAV 131	40.8	81.7	10.5	1.1	9.1	4142.2	0.0	2293.3	1848.9
HAV 132	43.6	81.2	10.6	1.0	9.4	7333.3	0.0	6333.3	1000.0
HAV 133	42.3	81.4	10.6	1.0	8.6	9527.8	3750.0	5444.4	333.3
HAV 134	42.7	80.5	10.5	1.1	9.5	6444.4	333.3	4666.7	1444.4
HAV 135	41.4	81.3	10.6	1.1	11.2	9311.1	416.7	7833.3	1055.6
Checks									
Amy	38.1	78.4	9.4	0.6	8.2	6625.0	5736.1	888.9	0.0
Julia	39.1	79.7	10.0	0.6	6.9	5944.4	3638.9	1055.6	0.0
Menakelly	37.5	77.8	10.1	0.7	8.2	5500.0	4388.9	444.4	666.7
Morelli	37.5	75.3	9.9	0.7	9.8	7991.5	3833.3	3491.5	666.7
Morgan	36.3	76.5	9.7	0.7	7.8	5660.0	753.3	4348.4	555.6
Paulista	37.1	78.8	10.5	0.6	7.8	3781.7	892.9	2111.1	777.8
Samantha	36.8	78.5	11.9	0.8	7.4	8267.7	4388.9	2527.8	138.9
Star 2053	39.4	77.4	10.8	0.7	7.3	11527.8	10680	785.7	0.0
Teresa	38.0	75.9	11.2	0.8	8.3	10541.7	3416.7	5125.0	0.0
Vernadon	37.1	76.2	9.6	0.7	9.3	5837.2	982.2	3190.6	342.2
Mean	39.2	78.6	10.5	0.8	8.7	7273.8	2700.7	3620.6	586.6
LSD $_{0.05}$ Genotype	0.6	2.1	1.3	NS	1.2	1686.7	1837.5	1820.6	523.7
CV %	0.3	0.3	3.3	2.7	0.2	6.5	33	35.6	11.9

Df= days to flowering, Dm= days to maturity, LSD= least significant difference at 0.05 probability level, CV= coefficient of variance.

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