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Yield components of vegetable pigeon pea cultivars

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ABSTRACT

Yield potential of twelve medium maturity vegetable pigeon pea (*Cajanus cajan*) cultivars was evaluated at two locations, Kiboko and Kambi ya Mawe in eastern Kenya during 2012 and 2013 cropping years. Pigeon pea pod numbers, seeds per pod, seed mass; grain yield and shelling percentage were quantified in three replicated plots, arranged in a randomized complete block design. Significant differences ($P<0.05$) in grain yield (Kg/ha) was recorded among cultivars and cropping seasons. Yield of vegetable pigeon pea cultivars varied between locations as grain weight, pod length and seed mass were greater at Kiboko than Kambi ya Mawe location. Similarly, significant ($P<0.05$) and positive correlation coefficients between grain yield and pods plus grain as well as shelling percentage were recorded, indicating that this is an important variable for cultivar selection in vegetable pigeon pea. The cultivars ICEAP 00068, ICEAP 00540, ICEAP 00554, ICEAP 00902, and MZ 2/9 showed high yield potential under rain-fed conditions, while ICEAP 00902, ICEAP 00068, ICEAP 00557, ICEAP 00554 and MTHAWAJUNI had good yield response when supplemental water was applied. Under both rain-fed and supplementary water applications, the yield response of the cultivars KAT 60/8, ICEAP 00068, ICEAP 00554, and ICEAP 00902 ranged from 1,315 to 4,702 Kg per hectare. Selective deployment of cultivars can greatly improve its productivity and utilization in the dry agricultural regions.

Additional Index Words: *Cajanus cajan*, cultivars, vegetable pigeon pea, yield components, shelling percentage, eastern Kenya

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Pigeon pea (*Cajanus Cajan)* is a perennial leguminous crop and one of the most important pulses in the dry areas of eastern Kenya (Kimani et al., 1994). The crop is grown in regions where moisture deficiency is a constraint to other crop production or locations where annual rainfall amounts are less than 1,000 mm (Okoko et al., 2002). The eastern region of Kenya is the most important pigeon pea production area and accounts for approximately 90% of total crop production in Kenya. The deep tap root system allows the plant to tolerate drought and utilize residual moisture during dry seasons and drought-prone regions of eastern Kenya and other parts of the world (Gwata and Silim, 2009). It is estimated that the yield potential of pigeon pea grain is approximately 1 ton ha^{-1}, and its market potential is increasing. Because of its nutritious content, pigeon pea is often used to supplement cereal-based diets and consequently, it is used extensively by many smallholder farmers in Kenya.

It has been documented that nitrogen fixation rate by pigeon pea may be in excess of 235 Kg N ha^{-1} and its assimilation per unit of crop biomass exceeds that of many other leguminous crops (Chauhan 1990). This is attributed to numerous soil borne microorganisms that are associated with the rhizosphere of pigeon pea and involved in nitrogen fixation and release of phosphorous in the soil. Pigeon pea has been shown to grow adequately in many soil types (Vertisols, Alfisols, Oxisols) with a pH in the range of 5.0 to 7.5, which is readily available in eastern Kenya and many other topical regions. Pigeon pea may be grown as an intercrop with sorghum, millet, or maize or it can be grown as a monocrop, and a long-term hedgerow crop (Daniel and Ong, 1990; Odeny 2007).

In Kenya, pigeon pea can be used for a variety of purposes. The foliage of (green leaves and immature leaves) can be harvested and deposited in soil as green -manure to enhance soil nitrogen and organic matter content (Odeny 2007). However, the main utilization of pigeon pea is dry, de-hulled, split seed for cooking. The tender, green seeds or pods can be used for vegetable consumption. Alternatively, the dry seeds may also be used in the formulation of animal feed, while green leaves could easily serve as animal fodder in some regions (Kimani et al., 2001). In view of protein deficiency in the marginal dry regions, pigeon pea can be used to meet the dietary and nutritional requirements of small-holder farmers and utilized as substitute for animal protein.

Due to the increasing market potential for fresh pigeon peas in rural and urban regions of Kenya and for exportation to other countries, it is important to evaluate the yield potential of diverse cultivars (Jones et al., 2002). Phenotypic variation of selected traits of pigeon pea cultivars such as days to 50% flowering, plant height, primary and secondary branches, dry matter content, seeds per pod, seed weight (100 seed mass), harvest index, and shelling percentage have been shown to vary among cultivars of various maturity duration (Dundas 1990; Jones et al., 2001). However, little is known about the yield components of pigeon pea in the marginal dry regions of eastern Kenya. Although cultivars of medium maturity durations have been developed and are currently being adopted in eastern Kenya (Silim 2001 and Silim et al., 2007), a paucity of yield data exists with respect to cultivars harvested primarily for fresh pigeon pea yield and consumption.

Due to the recent increase of crop cultivation in diverse regions of Kenya, it is important to assess yield potential of pigeon pea cultivars of various maturity durations (Mwang'ombe et al., 1998). Cultivars that are both suited for vegetable consumption as well as grain yield and early to medium maturity would be ideally suitable for small-holder farmers in the region. Therefore, the objective of this research was to assess yield performance of pigeon cultivars at two locations in eastern Kenya as a prelude to wider adoption and utilization of the crop in the dry regions.

MATERIALS AND METHODS

Study Sites. The study was conducted at the Kenya Agricultural and Livestock Research Organization station at Kiboko (latitude 2^{o}10'S and longitude 34^{o}40'E at 975 m) and Kambi ya Mawe (latitude 1^{o}57'S and longitude 37^{o}40'E at 1250 m altitude). The long-term average rainfall at Kiboko and Kambi ya Mawe locations are between 500-900 mm per year. The two locations are characterized by moderate temperatures during January, February, and March with mean air temperatures of 26^{o}C at Kiboko and 25^{o}C at Kambi ya Mawe. Both locations have lower temperatures during June, July and August with mean temperatures at Kiboko and Kambi ya Mawe locations of 21.6^{o}C and 22.5^{o}C, respectively (Odeny 2007). Kiboko Research Station is 975m above sea level, under eco-climatic zone V (Michieka and van der Pouw 1977). The soils are well drained, very deep, dark reddish brown to dark red, friable sandy clay to clay (Acri -Rhodic Ferrassols) developed from undifferentiated basement system rocks, predominantly banded gneisses (CYMMIT, 2013). The location receives a mean annual rainfall of 561 mm and is characterized by bimodal distribution of rainfall with the greatest amount of rain in April and November (Table 1). The location has average temperature of 24^{o}C. Kambi ya Mawe is a sub-station of Kenya Agricultural Research Institute (KARI) Katumani, and has an elevation of 1,250 meters above sea level. The soils are very deep, dark brown in color, and consist of friable sandy clay loam to sandy clay (Siderius and Muchena, 1977), with low organic carbon contents (0.5 – 1.0%) and a slightly acidic in nature (pH 5.7–6.9). Kambi ya Mawe has mean annual temperatures of 21- 23°C and mean annual rainfall 500–600 mm. This location is characteristic of about 50% of eastern Kenya. The previous crop at the two test locations were fallow rotation.

Pigeon pea cultivars. Twelve medium duration pigeon pea cultivars consisting of ICP 7035B, ICEAP 00068, MTHAWAJUNI, MZ 2/9, KAT 60/8, ICEAP 00540, ICEAP 00557, ICEAP 00911, ICEAP 00902, ICEAP 00554, ICEAP 00850 and KIONZA) were evaluated for yield components in this study. KIONZA, a local early maturing cultivar, grown extensively by farmers in the region for grain and green vegetable consumption was used as the control (check) cultivar.

Experimental design and agronomic practices. A randomized complete block design was used and treatments were replicated three times at both locations. The plot sizes measured 4.0 m x 4.8 m (length x width), with 4 rows per plot at a row spacing of 1.2m x

0.3m. The blocking effect was done due to limitation of contiguous land area for all three replications. Pigeon pea cultivars seed were planted in furrows and plant stands were subsequently thinned to a single plant per hill at two weeks after germination. Experimental plots were weeded by hand hoes. The total pigeon pea population consisted of 27,760 plants per hectare. Normal agronomic practices recommended for the region were followed. No fertilizers were applied to the crop, which was also consistent with agronomic practices of the region (Silim et al., 2006, Nganyi 2009).

The plants were protected from pests including termites (*Odontermes* spp. and *Microtermes* spp.), pod borers, *Moruca testulalis* (Geyer) and *Helicoverpa armigera* (Hubner), pod suckers (*Clavigralla* spp) and pod flies, *Melanogromyza obtusa* (Malloch) by applying pesticides including Imidacloprid (Bayer Crop Sciences AG, Monheim, Germany); and chlorpyrifos (Dow AgroSciences, Hertfordshire, U.K.), a broad-spectrum non-systemic, pyrethroidalpha-cypermethrine) and dimethoate (Cheminova A/S, Lemvig, Denmark), a systemic organophosphate. The pesticides were applied uniformly using a 20 liter knapsack sprayer as needed. The requirement for insecticide application was determined by assessing insect presence, populations and damage based on weekly field scouting. Additional water was applied with sprinklers on pigeon pea at Kiboko location (196 mm at crop season and 104 mm at ratoon season) to evaluate if additional water can affect shoot and overall crop growth. The amount of water application was based on precipitation at the location.

Data collection. Yield variables were recorded during the crop and ratoon seasons based on the guideline outlined in descriptors for pigeon pea (International Board for Plant Genetic Resources and International Crops Research Institute for Semi-Arid Tropics, 1993). The crop season indicates emergence of pigeon pea seed at planting and its growth to maturity (October to March). The ratoon season refers to the crop that emerges from re-growth of previous plant stubbles without replanting (April to August). The yield parameters included pod length and width (cm), pods per plant at harvest, seeds per pod, 100 fresh seed weight (gm), pod + grain weight (gm), threshed grain weight (gm), and shelling percentage. Environmental data such as rainfall and ambient temperatures were collected at both locations. Daily ambient temperatures (^{o}C) were recorded by a Temp/RH sensor (Onset Hobo Data loggers, Bourne, MA). Rainfall was recorded using atipping bucket rain gauge (Spectrum Technologies Inc., Plainfield, IL).

Data analysis. The data collected during the study were analyzed using Genstat (12th edition; VSN International, Hempstead, UK) and Statistical Analysis System (SAS Institute Inc., Cary, N. Carolina, US). Ambient temperature, relative humidity and rainfall data were averaged by Proc Means of SAS. General Linear Model (GLM) was utilized to assess yield performance at each location separately and as a combined analysis across locations and seasons (Gomez and Gomez, 1984). Cultivar means were compared by least significant difference (LSD) statistics at $P<0.05$ (Ott, 1988). The relationship between crop yield components and yield as well as plant characteristics and environmental data were assessed by correlation analysis and the significance of correlation coefficients were also computed.

RESULTS

Environmental data. The crop season comprised of October through March, while the ratoon season was between April to August. At Kambi ya Mawe, ambient temperature ranged between 23-25 °C, with a mean of 24 °C during October to March (crop season). During the ratoon season (April to August), ambient temperatures range were 20-24 °C, with a mean of 22 °C for the 6 months (Table 1). At Kiboko location, temperatures ranged from 24-27 °C, with a mean of 25 °C during the crop season. During the ratoon season, ambient temperatures were 21-26 °C, with a mean of 23 ° C. During the crop season, the total rainfall at Kimba ya Mawe and Kiboko were 592 and 215 mm, respectively. Total rainfall at the ratoon season were 715.1 mm and 532 mm at Kambi ya Mawe and Kiboko, respectively. Although blocking of the experiments occurred at the sites, data were analyzed across sites and the blocking effects had negligible effects on the results and consequently not reported.

Pod numbers per plant. Yield parameters were not affected by blocking of experiments as the block effect was not significant ($P>0.05$). There was significant ($P<0.01$) differences in the number of pods per plant between locations (Table 2). The interaction of seasons by cultivars was also significant ($P<0.05$). The average number of pods per plant at Kambi ya Mawe were 100 and 116 for the crop and ratoon seasons, respectively (Table 3). At Kiboko, significantly ($P<0.05$) greater pod numbers were recorded. Mean pod numbers per plant at Kiboko were 131 and 148 during the crop and ratoon seasons, respectively (Table 3). The number of pods per plant during the ratoon season exceeded that of the crop season at both locations. At Kambi ya Mawe, KIONZA (the check cultivar), had the greatest number of pods except for ICP 7035B during the crop season while MZ 2/9 had the greatest number of pods at ratoon season (Table 3). At Kiboko, ICEAP 00911 and ICEAP 00540 had the greatest pod numbers per plant at crop and ratoon seasons, respectively (Table 3). At Kambi ya Mawe, the

Table 1. Mean monthly temperature and total rainfall during the two years and long-term average at Kambi ya Mawe and Kiboko in Eastern Kenya.

	Temperature (°C)						Rainfall (mm)					
Months	KYM 6 years (2007-2012)[y]	KYM 10 years (2003-2013)	KYM (2011-2012)	Kiboko (2011-2012)	KYM (2012-12)	Kiboko (2012-13)	KYM 6 years (2007-2012)	KYM 10 years (2003-2013)	KYM (2011-2012)	Kiboko (2011-2012)	KYM (2012-12)	Kiboko (2012-13)
October	24	25	24	25	24	25	22.2	19.0	29.1	9.0	21.8	0.0
November	24	25	24	26	24	26	130.2	103.8	171.1	21.4	171.0	21.4
December	24	24	23	24	23	24	70.4	89.8	206.1	99.6	207.2	108.4
January	25	25	26	24	23	25	28.3	41.3	0.0	6.0	54.5	29.4
February	25	26	25	25	24	25	16.4	21.4	7.6	24.0	12.3	0.0
March	25	26	25	26	25	27	60.6	95.7	1.7	16.5	125.0	55.8
Mean (Crop Season)	24.8	25	25	25	24	25	328	371	416	177	592	215
April	25	26	24	25	24	26	75.1	90.2	187.4	201.2	112.0	278.0
May	25	24	23	24	23	23	30.7	19.4	28.5	51.8	7.8	36.0
June	23	22	21	18	21	21	2.8	2.4	25.7	23.5	1.5	0.0
July	22	21	21	21	20	21	0.0	0.5	0.4	0.0	1.1	3.0
August	22	22	22	22	20	22	1.4	1.1	9.7	1.2	0.9	0.0
Mean (Ratoon Season)	23	23	22	22	22	23	110	113.6	251.7	277.7	123.3	317

[y]KYM = Kambi ya Mawe

cultivars with the lowest pod numbers per plant were ICEAP 00850 and KIONZA at crop and ratoon seasons, respectively. At Kiboko, ICEAP 00554 and KIONZA had the least number of pods per plant for crop and ratoon seasons, respectively. KIONZA, a long duration local cultivar, exhibited delay in flowering and maturity. Hence, no growth of KIONZA cultivar was observed at both locations during the ratoon

Table 2. Analysis of variance (mean squares) on the effect of cultivars, locations, and cropping seasons on pigeon pea yield parameters in 2011-2012 and 2012-2013 cropping years.

Source of variation[t]	**Pods per Plant**[u] **(number)**	**Seeds per Pod**[v] **(number)**	**Seed mass (100 seed)**[w] **(g)**	**Grain yield (Kg/ha)**[x]	**Pods+grain (Kg/ha)**[y]	**Shelling (%)**[z]
Blocks	710ns	1.03ns	55.7ns	101689ns	2354128ns	63.6ns
Locations	35426**	12.1**	149.7**	412101**	208970**	409**
Cultivars	2472ns	1.9**	203.4**	194083**	526837**	65.8*
Locations x cultivars	1655ns	0.49ns	7.3*	908172ns	2642513ns	80.8*
Seasons	10126*	0.61ns	393**	198811**	108853**	356*
Seasons x cultivars	3409*	0.51ns	10.5*	600132ns	215035ns	17ns
Locations x cultivar x season	3259ns	0.1956ns	0.1693ns	656586ns	1989583ns	8.13ns
CV $\%_z$	33.38	12.8	7.53	28.6	26.82	10.87
SE[z]	41.29	0.69	1.95	721.2	129	5.74

[t]Variation used in the analysis of variance and numbers refer to mean squares. Cultivars were designated fixed, while locations and seasons as random effects.
[U]Pods per plant were assessed at crop maturity.
[V]Number of seeds per pod were evaluated at harvest.
[W]Seed mass was determined at harvest from a sample of 100 randomly selected seeds.
[x]Yield (Kg/hectare) was assessed at harvest.
[y]Shelling percentage of crop cultivars were evaluated at maturity.
CV = coefficient of variation, SE = standard errors of the mean, * and ** = significant at P<0.05 and P<0.01, respectively; ns = non-significant.

Table 3. Mean number of pods per plant and seeds per pod of pigeon pea cultivars evaluated at Kiboko and Kambi ya Mawe locations in Eastern Kenya during a two year period.

	Kambi ya Mawe		Kiboko	
Cultivars[u]	Crop[v] (pod numbers)	Ratoon[w] (pod numbers)	Crop[v] (pod numbers)	Ratoon[w] (pod numbers)
ICP 7035B	132.3+11.48	123.6+11.27	203.7+59.42	138.5+9.87
ICEAP 00068	93.2+12.06	62.9+18.19	139.0+31.26	139.3+8.09
ICEAP 00850	85.2+17.17	122.5+24.72	98.3+28.42	164.3+19.91
ICEAP 00554	98.4+23.48	118.0+16.79	65.3+16.37	167.1+2.07
ICEAP 00557	89.3+21.43	129.1+16.36	101.9+33.02	153.6+4.3
ICEAP 00540	87.2+4.34	73.4+28.53	96.1+9.91	183.5+31.26
KAT 60/8	85.3+16.41	101.9+15.34	130.3+26.39	153.5+19.45
MTAWAJUNI	89.2+8.40	106.4+11.72	116.7+16.86	125.8+16.30
MZ 2/9	115.2+33.54	165.3+10.13	113.6+11.24	139.9+12.66
ICEAP 00911	113.1+ 12.65	109.0+8.97	205.3+31.52	141.2+11.42
ICEAP 00902	95.0+20.36	164.2+14.43	175.3+58.55	131.3+25.44
KIONZA[x]	116.0+36.23	0.0[y]	129.3+18.22	0.0[y]
Means	100.0+28.7	116.0+28.64	131.2+43.67	148.923.03
LSD(0.05)	61.6	61.7	90.6	48.03
Cultivars	Seeds/pod (numbers)	Seeds/pod (numbers)	Seeds/pod (numbers)	Seeds/pod (numbers)
ICP 7035B	5.1+0.11	5.0+0.21	6.0+0.47	5.7+0.33
ICEAP 00068	5.1+0.29	5.0+0.33	5.7+0.43	6.3+0.34
ICEAP 00850	5.0 +0.19	5.3+0.40	5.7+0.37	6.3 +0.32
ICEAP 00554	5.2+0.22	5.7+0.37	6.0 +0.12	6.3+0
ICEAP 00557	5.1+0.29	5.0+1.0	6.0+0.08	6.0+0.33
ICEAP 00540	5.1+0.11	6.0+0.31	5.3 +0.33	5.7+0.31
KAT 60/8	5.2+0.12	5.3+0.22	5.3+0.34	5.7+0.30
MTAWAJUNI	4.8+0.22	4.7+0.33	5.3+0.33	5.0+0
MZ 2/9	4.9 +0.29	5.0+0.17	5.3+0.27	5.3+0.33
ICEAP 00911	4.9 +0.11	5.3+0.21	5.0+0	6.0+0
ICEAP 00902	5.2+0.13	4.7+0.31	5.7+0.33	5.7+0.26
KIONZA[x]	7.0+0.09	0.0[y]	7.0+0.11	0.0[y]
Means	5.2+0.29	4.8+0.70	5.7+0.36	5.8+0.37
LSD(0.05)	0.52	2.05	1.0	0.77

[u]Cultivars were assessed for pod numbers per plant and seeds per pod. Data refer to means and associated standard errors.
[v]Crop season (indicates crop emergence from pigeon pea seed at planting and its growth to maturity - October to March) and [w]ratoon season (refers to crop emergence from re-growth of previous plant stubbles without replanting - April to August).
[x]Local cultivar (check).
[y]No growth was recorded.
LSD = least significant difference.

season as it was affected by the reduced amount of rainfall (terminal drought). At Kambi ya Mawe, average pods per plant ranged from 85.3 (KAT 60/8) to 132.3 (ICP 7035B) at crop season and from 62.9 (ICEAP 00068) to 164.2 (ICEAP 00902) at ratoon season. At Kiboko, the average pods per plant ranged from 65.3 (ICEAP 00554) to 205.3 (ICEAP 00911) at crop season and from 1258.3 (MTHAWAJUNI) to 183.5 (ICEAP 00540) during the ratoon season (Table 3). Pods per plant were negatively and significantly correlated (-0.46) to ambient temperature at ratoon cropping season (Table 4).

Seed numbers per pod. Cultivars and locations had significant (*P<0.05*) effects on seeds per pod (Table 2). The average number of seeds per pod at Kambi ya Mawe and Kiboko varied slightly and at Kambi ya Mawe generally ranged from 4.8 to 7.0 at crop season and from 4.7 to 6.0 at ratoon season (Table 3). At

Table 4. Correlation coefficients (r) of mean ambient temperatures with yield variables at different growth stages of vegetable pigeon pea at Kiboko and Kambi ya Mawe in eastern Kenya during the 2012 and 2013 cropping years.

Locations	Growth Phases[y]	Pods per plant	Seeds per pod	Grain weight	Pods+ grain	Mass of 100 Seeds	Shelling %[z]
Kambi ya Mawe	Vegetative	0.19	0.83**	-0.16	-0.08	0.60**	-0.52*
Kambi ya Mawe	Flowering	-0.29	-0.66**	-0.03	-0.04	-0.53*	0.16
Kambi ya Mawe	Podding	-0.17	-0.87**	0.23	0.15	-0.56*	0.54*
Kambi ya Mawe	Ratoon	0.13	0.28	-0.11	-0.07	-0.46*	-0.03
Kiboko	Vegetative	-0.03	-0.12	0.12	0.07	0.09	0.06
Kiboko	Flowering	-0.07	-0.51*	0.13	0.15	-0.65**	-0.02
Kiboko	Podding	0.02	-0.65**	0.18	0.14	-0.69**	0.08
Kiboko	Ratoon	-0.46*	0.12	0.11	-0.04	0.13	0.27

[y]Vegetative = period of plant shoot growth, flowering = duration of flower development, podding = period at which pods were formed, and ratoon = re-growth of plants from previous crop stubbles of pigeon peas (subsequent to harvest).

[z]Shelling percentage was computed as proportion of a given mass of seeds in a given mass of pods.

* and ** = significant at $P < 0.05$ and $P < 0.01$, respectively.

Kambi ya Mawe, the cultivars with the greatest seeds per pod for both seasons were KIONZA and ICEAP 00540. At Kiboko, average seeds per pod ranged from 5.3 to 7.0 at crop season and from 5.3 to 6.3 at ratoon season, respectively (Table 3). The cultivars ICP 7035B, ICEAP 00554, and ICEAP 00557 had the greatest (6.0) and identical seeds per pod at crop season, while ICEAP 00068, ICEAP 00850, and ICEAP 00554 had the greatest mean number of seeds per pod (6.3) at ratoon season. Similarly, seeds per pod were positively correlated to ambient temperature during the vegetative growth of the crop (Table 4). Similarly, it was significantly ($P<0.05$) and negatively correlated for days to flowering (r=0.65/0.51).

Seed mass - weight of 100 seeds (g). The interaction of cultivars by locations had significant ($P<0.05$) effect on seed mass (Table 2). Similarly, the interaction of seasons by cultivars were also significantly ($P<0.05$) different (Table 2). A comparison of cultivars revealed that average seed mass were greatest on MZ 2/9 at crop (31.6g) and ratoon (40.3g) seasons at Kambi ya Mawe. The cultivar ICEAP 00554 had the lowest seed mass in both seasons (Table 5). At Kiboko location, cultivar KIONZA (36.9g) and MZ 2/9 (38.5g) had the greatest seed mass for crop and ratoon seasons, respectively. For the two seasons above, ICEAP 00850 and KAT 60/8 had the least seed mass (Table 5). With the exception of KIONZA that did not produce any yield during the ratoon season, the seed mass generally ranged from 19.4 to 40.3g, at both locations and cropping seasons. The mass of 100 seeds was positively and significantly ($P<0.05$) correlated to vegetative growth of the crop at Kambi ya Mawe, but negatively correlated with many other yield components or variables at both locations (Table 4).

Shelling percentage. The interaction of cultivars by locations was significant ($P<0.05$) for shelling percentage (Table 2). The shelling percentages were generally similar among locations and cropping seasons (Table 5). At Kambi ya Mawe, MZ 2/9 had the greatest mean shelling percentage at crop (63.1) and ratoon (62.9). The cultivars KIONZA and ICEAP 00540 had the lowest shelling percentages for crop and ratoon seasons, respectively (Table 5). At Kiboko location, KAT 60/8 had the highest and ICEAP 00850 the lowest shelling percentages in both seasons. The shelling percentages of pigeon pea at Kambi ya Mawe ranged from 44.0% to 63.1% while at Kiboko, shelling percentages ranged from 44.6% to 62.9 % (Table 5). Significant ($P<0.05$) correlation coefficients between shelling percentage and grain yield were recorded (Table 7).

Grain and pod yield. Grain yield varied as a main effect with respect to location, cultivar, and season (Table 2). At Kambi ya Mawe, the lowest grain yield was recorded with cultivar ICEAP 00850 (1,132 Kg/ha) and greatest with MZ 2/9 (2,905) during the crop season (Table 6). At Kiboko location, the greatest pigeon pea yield was recorded on the cultivar KAT 60/8 with mean values of 2,640 (kg/ha (crop season) and 4,702 kg/ha (ratoon season) (Table 6). During the ratoon season at Kiboko location, grain yield were significantly ($P<0.05$) greater than all the other seasons and ranged from 3,158 kg/ha (ICEAP 00902) to 4,702 Kg/ha on KAT 60/8 cultivar (Table 6). Grain yield was positively and significantly ($P<0.01$) correlated with weight of pods plus grain at both locations (Table 7). Grain yield was significantly ($P<0.05$) correlated with shelling percentage at both locations (Table 7). The number of pods per plant was also negatively correlated with seed mass at both locations. Late maturing genotypes with a mean of 122 days to flowering (DTF), gave low yields of 3,839 Kg/ha, compared to early maturing cultivars with a mean of 100 DTF, had

Table 5. Average seed mass and shelling percentage of pigeon pea cultivars assessed at Kiboko and Kimba ya Mawe in eastern Kenya during a two year period.

Cultivars[t]	Kambi ya Mawe Crop[v] Seed mass (g)	Kambi ya Mawe Ratoon[w] Seed mass (g)	Kiboko Crop[v] Seed mass (g)	Kiboko Ratoon[w] Seed mass (g)
ICP 7035B	22.6±0.22	27.8±0.46	24.5±1.29	27.2±0.41
ICEAP 00068	24.2±0.89	25.5±0.97	25.9±0.68	26.6±1.95
ICEAP 00850	19.8±1.16	23.1±1.12	22.3±1.18	26.9±1.63
ICEAP 00554	19.4±0.80	22.5±1.28	25.0±0	25.9±0.46
ICEAP 00557	21.1±1.60	25.2±0.83	24.5±2.23	27.3±0.48
ICEAP 00540	21.1±0.78	24.7±0.50	24.9±0.34	24.8±1.07
KAT 60/8	19.9±0.59	22.7±1.31	23.1±1.08	24.6±2.72
MTAWAJUNI	26.2±0.68	31.3±0.17	29.1±0.70	31.8±2.10
MZ 2/9	31.6±0.68	40.3±1.01	32.7±0.77	38.5±1.31
ICEAP 00911	20.0 ±0.39	23.7±0.67	24.0±0.48	25.6±1.07
ICEAP 00902	20.9±0.29	26.7±0.54	30.9±2.35	26.9±0.71
KIONZA[x]	31.1±1.06	0.0[y]	36.9±0.52	0.0[y]
Means	23.2±1.19	26.7±1.58	26.1±1.71	27.8±1.76
LSD(0.05)	2.54	3.3	3.5	3.7

Cultivars	Shelling (%)[u]	Shelling (%)	Shelling (%)	Shelling (%)
ICP 7035B	54.8±1.70	54.1±1.74	54.9±2.52	52.8±2.32
ICEAP 00068	55.1±0.37	52.1±3.38	52.5±8.17	48.1±7.0
ICEAP 00850	53.6±1.36	50.0±1.32	47.1±1.35	44.6 ±1.11
ICEAP 00554	53.6±2.68	51.7±2.02	54.0±4.52	51.3±3.49
ICEAP 00557	54.4±2.39	56.3±3.49	49.8±2.58	46.3±3.41
ICEAP 00540	56.8±1.54	47.5±1.75	51.8±1.82	48.1±1.52
KAT 60/8	59.7±2.06	49.8±1.80	60.7±1.66	55.3±0.69
MTAWAJUNI	57.9±4.02	52.9±3.99	56.0±4.26	52.4±3.61
MZ 2/9	63.1±6.47	62.9±3.47	47.2±2.66	48.2±1.22
ICEAP 00911	58.1±2.15	53.8±1.68	52.8±3.03	48.2±2.07
ICEAP 00902	56.3±1.32	55.2±2.16	52.5±3.61	48.7±2.11
KIONZA[x]	44.0±6.89	0.0[y]	51.2±4.65	0.0[y]
Means	55.6±4.76	48.85±4.25	52.5±5.65	49.4±4.57
LSD(0.05)	9.81	8.14	11.7	9.54

[t]Cultivars were assessed for seed mass. Seed mass was computed from samples of 1000 seeds in 3 replicates. Data refers to means and associated standard errors.
[u]Shelling percentage was computed as proportion of mass of seeds in a given mass of pods.
[v]Crop season (indicates crop emergence from pigeon pea seed at planting and its growth to maturity - October to March) and [w]ratoon season (refers to crop emergence from re-growth of previous plant stubbles without replanting - April to August).
[x]Local pigeon pea check cultivar grown in the region.
[y]No plant growth was observed.
LSD = least significant difference.

a mean yield of 5,754 Kg/ha. KIONZA, a local check cultivar took longer to attain 50 percent flowering (217 days at Kiboko and 181 days at KYM). Consequently, it was affected by the drought during the ratton season.

DISCUSSION

Pod numbers per plant. Differences in pod numbers among cultivars were recorded between seasons and locations. This suggests that different cultivars may produce greater number of pods depending on the seasons and locations indicating that production of pigeon

Table 6. Average grain yield at two locations in eastern Kenya during 2011-2012 and 2012-2013 cropping years.

Cultivar[u]	Kambi ya Mawe Crop[v] (Kg/ha)	Kambi ya Mawe Ratoon[w] (Kg/ha)	Kiboko Crop[v] (Kg/ha)	Kiboko Ratoon[w] (Kg/ha)
ICP 7035B	1,997±204.9	1,044±657.8	1,803±434.1	3,933±196.4
ICEAP 00068	2.455±155.3	2,580±263.2	2,587±368.3	3,274±237.2
ICEAP 00850	1,132±284.5	1,730±563.9	1,810±367.3	3,606±611.1
ICEAP 00554	1,309±529.8	2,210±623.9	1,899±400.9	4,321±815.5
ICEAP 00557	1,708±349.3	1,380±687.5	2,040±632.0	4,124±558.8
ICEAP 00540	2,010±289.0	1,613±545.4	1,887±187.7	3,545±558.8
KAT 60/8	2,069±214.0	1,315±800.6	2,640±460.4	4,702±467.5
MTAWAJUNI	2,388±483.4	1,566±442.5	2,718±252.3	4,639±425.5
MZ 2/9	2,905±284.7	3,054±418.0	3,444±844.9	4,119±556.8
ICEAP 00911	2.851±137.0	2,448±208.6	2,322±278.7	3,158±592.9
ICEAP 00902	1,648±462.0	2,642±369.8	2,229±334.9	3,926±251.9
KIONZA[x]	1,379±639.9	0.0[y]	1,843±260.5	0.0[y]
Means	1,988±522.1	1,962±933.5	2,269±564.1	3,941±621.6
LSD(0.05)	1,012	1,241	1,169	1,296

[u]Cultivars were evaluated for yield performance. Data refers to means and associated standard errors.
[v]Crop and [w]ratoon seasons in which yield were quantified from pigeon pea cultivars.
[x]Local pigeon pea (check) cultivar.
[y]No plant growth was observed.
LSD = least significant difference.

pea pods may be greater under certain environmental (temperature and rainfall) and genetic factors (cultivar variations). The negative correlation coefficients between yield and pods per plant at Kambi ya Mawe during the ratoon season may have been due to limited water which adversely affected pod yield. Under reduced rainfall, the number of pods per plant may be reduced due to flower abortion. Reduced number of pods per plant under rain-fed condition (limited rainfall) was thought to be due to flower abortion during the main flowering and pod abortion during period of rapid development after flowering (Kamel and Abbas, 2012; Patel and Mehta, 2001). Similarly, low moisture content in the soil during drought affects the anthesis stage due to lack of adequate water in plants, causing a drastic reduction in yield and yield components (Saleem et al., 2005). In other studies, significant (*P<0.05*) and positive correlations between the number of pods per plant and seed yield have been reported by Kumar and Hirochika (2001) on cowpeas (*Vigna ungiculata*), Sawargoankar et al., (2011), Baskaran and Muthiah (2007), and Kamel and Abass (2012) on chickpeas (*Cicer arietinum*). It has been postulated that yield reduction is attributed to a drop in pod numbers per plant, seeds per pod and seed mass or weight. Saleem et al., (2005), also noted that a high significant difference in pods per plant in Chickpea cultivars as a result of irrigation.

Seed numbers per pod. Low variation in the number of seeds per pod was detected within experiments. This suggests that genetic variation in seed numbers among the cultivars tested may not be great or this may not be an important criterion for grain yield when compared to seed weight. In other leguminous crop, significant (*P<0.05*) differences among cultivars for seed numbers per pod have also been reported by Roz-Rokh et al., (2009) on chickpeas. It was observed that chickpea plants with higher number of pods per plant resulted in higher competition for assimilates, consequently leading to lower number and size of seeds. In our research, the number of seeds per pod was positively correlated to pod length and width as well as mass of 100 seeds for crops harvested during the crop season. We postulate that increases in pod length may result in greater number of ovules which could have enhanced seed weight as a result of adequate space for seed growth and expansion. In other studies, Udensi and Ikpeme (2012) and Baskaran and Muthiah, (2007) documented similar results in pigeon pea. In this research, we observed a 12% increase in the number of seeds per pod at Kiboko compared to Kambi ya Mawe, perhaps attributed to water supplementation during crop growth. Increase in water applications (irrigation frequency) has been shown to increase the number of seeds per pod and mass of 100 seeds in French beans (*Phaseolus vulgaris*) and bush beans (Ahlawat and Sharma, 1989; Mozumder et al., (2005).

Seed weight or mass (100 seeds). Variation in seed

Table 7. Correlation coefficients of crop yield and yield components of vegetable pigeon pea cultivars during the 2012-13 cropping season.

Kambi ya Mawe[v]	**Grain Yield**[w]	**Pods / Plant**[x]	**Seed Mass**[y]	**Seeds/ pod**	**Shelling %**
Grain yield	-				
Pods + grain	0.96**				
Pods /plant	-0.21ns	-			
Seed mass	0.25ns	-0.39*	-		
Seeds/pod	-0.13ns	0.22ns	-0.18*	-	
Shelling %	0.53*	0.54*	0.51*	-0.17ns	-
Kiboko					
Grain yield	-				
Pods + grain	0.86**				
Pods /plant	0.19ns	-			
Seed mass	0.08ns	-0.44*	-		
Seeds/pod	-0.33ns	0.14ns	-0.38*	-	
Shelling %	0.56*	-0.17ns	0.09	-0.31ns	-

[v]Locations where cultivars were evaluated.

[w]Correlation coefficient (r values) of yield (Kg/ha) with various variables.

[x]Pods per plant correlated with seed mass, seeds/pod and shelling %.

[y]Seed mass (weight of 100 seeds) correlated with seeds/pod and shelling percentage.

mass was recorded for cultivars ranging from 19.4 to 31.6 at Kambi ya Mawe and from 23.1 to 36.9g at Kiboko during the crop season. This suggests that inherent differences among cultivars exist and may be attributed to genetic variation of cultivars. The variation in yield among cultivars and greater yield at Kiboko may be a result of environmental differences between the two locations. Patel and Mehta (2001) observed a significantly (*P<0.05*) lower mass of 100 seeds of pigeon pea grown under rain-fed condition. They attributed the low yield to moisture stress (inadequate water), affecting translocation of photosynthetic products from leaves to grain, and consequently resulting in small grain weight. Positive correlation between seed mass and seed yield in lentils (*Lens culinaris*) has been reported (Dixit 2005). The high seed mass recorded at Kiboko could have been a result of water application effect rather than temperature effect. Although Patel and Mehta (2001) observed that high mean temperatures favors pod growth and increased seed size, we noted greater seed mass (weight) at Kiboko compared to Kambi ya Mawe even if the mean temperatures during grain filling period between locations were negligible,(24°C at Kiboko and 23°C at Kambi ya Mawe). Therefore, this may not be attributed to only temperature effect.

Grain and pod yield. The increases in grain yield may be attributed to all of the combinations of the yield components as well as environmental (greater rainfall) at Kiboko during the crop and ratoon season's supplementary irrigation, and the genetic ability of each cultivar. The effects of supplementary irrigation on grain yield have been previously reported by Khourgami et al., (2012) on lentils, and Anwar et al., (2003) in chickpeas where grain yield and pods per plant increased 17% and 48%, respectively; subsequent to water supplementation. Khourgami (2012) observed a 1,559.9 Kg/ha while Oweis et al., (2004) indicated that under full irrigation, yield in chickpeas increased by 65%, while Zhang et al., (2000) observed a 100% increase compared to rain-fed chickpeas. Similar results have been observed by Zhang et al., (2000) on lentils and chickpeas while Felix, (2009) observed a 39% increase in yield of beans (*Phaseolus vulgaris*).

Elevated temperatures may also be a constraint pigeon pea yield as well as other leguminous crops. In this experiment, mean temperatures were moderate and therefore had minimal impact on yield and yield components. Gwata and Silim, (2009), Upadhayaya et al., (2006) and Snapp et al., (2003), observed that delay in flowering and maturity lead to increased susceptibility to terminal drought, thereby reducing yields. The significant positive correlations between grain yield and shelling percentage indicates this is a useful criterion for selection of grain yield in vegetable pigeon pea cultivars. This has also been reported by Berhe et al., (1998) in faba beans. Increased plant height also increased the number of pods per plant was increased during ratoon. The negative association between seed per pod and immature pods per plant in bush beans has been reported by Yorgancilar et al., (2001) who observed that number of seeds per pod was negatively and significantly associated with the number of immature pods per plant and 100 seed weight on bunch beans varieties.

CONCLUSIONS

The differences in cultivar yield among locations and cropping seasons suggest that both environmental factors and genetic components may be contributing factors to pigeon pea yield. The low variations in yield components among the cultivars within locations implies a narrow genetic diversity among the cultivars evaluated. The comparatively greater pigeon pea yield during the ratoon season at Kiboko may be attributed to the supplemental water applied. We recorded significant (*$P<0.05$*) correlation coefficients between grain yield and shelling percentage implying that this variable could be a predictor of vegetable pigeon pea yield. Components such as seed size, seed mass and pods per plant are selection criteria for pigeon pea cultivars. We identified cultivars with stable productivity under both rain-fed and supplemental water such as MZ 2/9, ICEAP 00911, ICEAP 00068, ICEAP 00902, Mthawajuni, ICEAP 00554, and KAT 60/8. The average grain yield ranged from 1,315 to 4,702 Kg ha^{-1} at both locations. Although early maturity duration is an important consideration for resource-constrained farmers, cultivars with diverse maturity dates (early, medium, and late) may be useful for yield enhancement under different scenarios. Selective deployment of the cultivars can greatly enhance yield potential and crop utilization.

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