Variety Trials

Plant Characteristics and Growth Parameters of Vegetable Pigeon Pea Cultivars

Ojwang J. David¹, Nyankanga O. Richard², Imungi Japheth³, and Olanya O. Modesto^{4,5}

ADDITIONAL INDEX WORDS. *Cajanus cajan*, plant height, pod development, flowering, maturity, eastern Kenya

SUMMARY. Pigeon pea (*Cajanus cajan*) is an important crop in dry land and semiarid regions and is a supplementary source of dietary protein for the economic resource-constrained farmers. The aim of this research was to evaluate growth parameters of 12 vegetable pigeon pea cultivars at two locations in eastern Kenya. The number of days from planting to flowering, plant height, primary and secondary branches, and pod length and width were quantified in experimental plots in a randomized complete block design with three replications. Significant differences ($P < 0.01$) in days to 50% and 70% flowering (DTF) and plant maturity (DTM), respectively, were recorded among cultivars at both locations. The average plant height was significantly ($P < 0.05$) greater at Kiboko than at Kambi ya Mawe. The number of DTF and DTM were also greater at Kiboko than at Kambi ya Mawe site, because of supplemental irrigation. Similarly, mean pod length and width at Kiboko location exceeded that at Kambi ya Mawe by 6% and 8%, respectively. Positive and significant ($P < 0.05$) correlation coefficients between grain yield and pods per plant were observed, indicating that pod number is a useful indicator of yield potential of vegetable pigeon pea. The cultivars ICEAP 00068, ICEAP 00540, ICEAP 00554, ICEAP 00902, KAT 60/8, and MZ 2/9 were identified for high-yield potential under rain-fed conditions, whereas ICEAP 00902, ICEAP 00068, ICEAP 00557, ICEAP 00554, KAT 60.8, and MTHAWAJUNI showed the greatest potential when supplemental water applications were made. The cultivars KAT 60/8, ICEAP 00068, ICEAP 00554, and ICEAP 00902 were suitable for production under both rain-fed conditions and additional water applications. Yield potential of pigeon pea in the dry regions can be greatly enhanced by using cultivars with good plant growth characteristics and shoot density.

Pigeon pea is the most important pulse for consumption in the semiarid areas of Kenya (Kimani 1991; Silim 2001). The crop grows in regions between latitudes 30°S and 30°N, where moisture availability is unreliable or inadequate and annual rainfall is less than 1000 mm (Okoko et al., 2002). The eastern region of Kenya is the most important pigeon pea production area and accounts for ≈90% of the total national production. Because of its drought

tolerance and utilization of residual moisture during dry seasons, pigeon pea is an important crop under rain-fed farming systems and extensively cultivated by millions of smallholder farmers in the tropics and subtropical regions of the world. Rain fed refers to farming systems that rely exclusively on rainfall amounts and patterns without any supplemental water applications for crop cultivation.

Besides its main utility in the form of dry, dehulled, split seed used

for cooking, its tender, green seeds are used as a vegetable. The crushed dry seeds are used as animal feed, while green leaves are used for fodder. The stems of pigeon pea may be reasonably used for fuel wood and baskets by farmers. Pigeon pea seed protein content of 21% average compares relatively well with that of other important grain legumes (Faris et al., 1987). In Kenya, pigeon pea is mainly grown for food and often used to supplement the cereal-based diets in rural areas where protein diets are deficient (Omanga and Matala, 1987). Because of their availability, its low cost and acceptability, pigeon pea has the opportunity to meet the dietary and nutritional requirements of eastern Kenya and substitute for animal protein in this region.

Cultivars for vegetable pigeon pea are grown in a normal field crop, but the pods are harvested green at the appropriate stage of maturity for its use as a vegetable. Green vegetable seeds of pigeon pea are richer sources of iron, copper, and zinc than the mature seed. There are large genotypic differences in protein content of pigeon pea. Depending on the stage of harvest and cultivar, the level of protein, sugars, crude fiber, and starch may also vary considerably. As a major food crop in regions with marginal rainfall and resource constraints, pigeon pea has the potential to increase income, food security, and nutrition among the smallholder households. Additionally, there is increasing market niche for fresh vegetable pigeon pea in rural and urban regions of Kenya and for export market (Saxena et al., 2010b). Therefore, expansion of area under pigeon pea cultivation and production of high yielding and high nutrient content cultivars would address nutrient deficiency and livelihood challenges in the region.

Even though medium duration pigeon pea cultivars have been developed and adapted to the eastern region of Kenya, adoption and performances of these cultivars for vegetable pigeon pea production are poorly documented (Silim, 2001). The cultivars developed have often met both green vegetable and dry grain market requirements for farmer's utilization. Concerted efforts to identify the cultivars with potential for high vegetable pigeon pea yield are lacking. Farmers have often harvested vegetable pigeon pea

from cultivars initially selected for grain production. The current production methods rely exclusively on natural rainfall often referred to as “rain-fed” conditions. Because of variation in rainfall amounts and timing of occurrence and duration of precipitation, grain yield differs substantially. There is urgent need to identify cultivars with potential for high vegetable yield and good acceptability to cater for the market. The objective of the present study was to identify vegetable pigeon pea cultivars with good plant characteristics and assess yield performance under rain-fed and supplementary irrigation in semiarid conditions of eastern Kenya.

Methods

The study was conducted at the Kenya Agricultural and Livestock Research Organization Kiboko Station and Kambi ya Mawe substation in 2012 and 2013 under supplementary irrigation and rain-fed field experiments, respectively. Kambi ya Mawe is located at latitude 1°57'S, longitude 37°40'E, and 1250 m altitude with mean rainfall of 550 mm/year. Kiboko is located at latitude 2°10'S, longitude 34°40'E, and 975 m altitude with mean rainfall of 561 mm/year. The two locations are characterized by moderate ambient temperatures during the month of January, February, and March with a mean air temperature of 26 °C at Kiboko and 25 °C at Kambi ya Mawe. Both locations have low temperatures during the months of June, July, and August with Kiboko recording mean temperature of 21.6 °C and Kambi ya Mawe of 22.5 °C (Shiferaw et al., 2008).

A total of 12 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 plant characteristics and yield in this study. KIONZA, a local cultivar, grown extensively by many farmers in the region for grain and green vegetable consumption due to its earliness, was used as the control cultivar in this study.

Randomized complete block design was used and treatments were replicated three times at Kiboko and Kambi ya Mawe locations. The experimental units (plots) measured 4.0 × 4.8 m (length × width), four rows per plot, with row spacing of 1.2 × 0.3 m. The total plant population of 27,760 plants/ha was used in this experiment. Normal agronomic practices recommended for the region were followed. Pigeon pea cultivars seed were then drilled along the furrow and later thinned to one plant per hill at 2 weeks after germination to give spacing between plants of 30 cm. Experimental plots were weeded by using a hand hoe. No fertilizers were applied to the crop, which was consistent with agronomic practices reported in the region (Nganyi, 2009; Silim et al., 2006). Plants were protected from pests such as termites (*Odontotermes* sp. and *Microtermes* sp.), pod borers (*Maruca testulalis* and *Helicoverpa armigera*), pod suckers (*Riptortus dentipes* and *Clavigralla* sp.), and pod flies (*Melanagromyza obtusa*) by applying pesticides such as imidacloprid (Bayer Crop Sciences, Monheim, Germany) and chlorpyrifos (Dow AgroSciences, Hitchin, UK), a broad-spectrum non-systemic, pyrethroid alpha-cypermethrin and dimethoate (Cheminova, Lemvig, Denmark), a systemic organophosphate. The pesticides were applied uniformly by using a 20-L knapsack sprayer as needed and when appropriate. The need for insecticide application was determined by assessing insect incidence, populations, and damage based on

weekly field scouting. In addition, supplemental water applications were made at Kiboko location to assess if additional water can affect shoot and overall growth of pigeon pea plants. The supplemental water was achieved by applying 196 mm of water on pigeon pea during the crop season and 104 mm during the ratoon season as sprinkler irrigation. The amount of water applied depended on weather condition and rainfall pattern.

Fourteen 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 the Semi Arid Tropics, 1993). The crop season indicates crop emergence from pigeon pea seed at planting and its growth to maturity. The ratoon season refers to the crop that emerges from regrowth of previous plant stubbles without replanting. These agronomic parameters were DTF, DTM, seeds per pod, final plant stand (number of plants), 100 fresh seed weight (grams), pod + grain weight (grams), threshed grain weight (grams), pod length and width (centimeters), pods per plant at harvest, the number of primary and secondary branches, plant height (cm), and shelling percent. Qualitative data included seed and pod color, which were collected in situ based on the guidelines outlined in descriptors for pigeon pea. Environmental data such as rainfall and ambient temperatures were continuously monitored and recorded with a temperature/relative humidity sensor (Hobo data loggers; Onset Computer Corp., Bourne, MA) and rainfall collected with a tipping bucket rainfall sensor attached to the data logger at both locations. The daily maximum and minimum temperatures (°C), and cumulative mean daily temperatures were obtained by averaging minimum and maximum air temperatures daily and at different phases of

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture, University of Nairobi, or Solidaridad of similar ones not mentioned.

¹Solidaridad, P.O. Box 42234-00100, Nairobi, Kenya

²Department of Plant Science and Crop Protection, University of Nairobi, P.O. Box 30197-00100, Nairobi, Kenya

³Department of Food Science, Nutrition and Technology, University of Nairobi, P.O. Box 30197-00100, Nairobi, Kenya

⁴Food Safety and Intervention Technology Research Unit, Eastern Regional Research Center, USDA-ARS, Wyndmoor, PA 19038

⁵Corresponding author. E-mail: modesto.olanya@ars.usda.gov.

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.3048	ft	m	3.2808
3.7854	gal	L	0.2642
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
28.3495	oz	g	0.0353
(°F - 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

growth following a previously described method (Lannucci et al., 2007; Silim et al., 2007). Environmental data were also recorded during several growth phases such as preflowering phase where cumulative mean temperatures from sowing to the date when 50% of the plants in a given plot had at least one open flower. Similarly, cumulative mean temperatures from the date when 50% of the plants in a given plot had at least one open flower (flowering phase) and when 75% of pods were mature were assessed. Cumulative mean temperatures from the date of 75% maturity to the date of last harvest (podding phase) were calculated.

The data collected during the study were analyzed using GenStat (12th ed.; VSN Intl., Hemel Hempstead, UK). General linear model was used to assess yield performance at each location separately and combined analysis across locations and seasons (Gomez and Gomez, 1984). Comparison of mean values of parameters for cultivars was further compared by Tukey's least significant difference statistics at $P < 0.05$ (Ott, 1993). The relationship between plant growth parameters and environmental data was assessed by correlation analysis and the significance of correlation coefficients.

Results

The monthly rainfall and daily temperatures at Kiboko and Kambi ya Mawe locations were recorded during the experiments. Bimodal rainfall was recorded at both locations, with the crop season from Oct. 2012 to Mar. 2013 (Fig. 1A) and the ratoon season from April to Aug. 2013 (Fig. 1B). At Kiboko location, a total of 532 mm of rainfall (215 mm during the crop season and 317 mm during the ratoon season) was recorded. The greatest amount of rainfall was received in Dec. 2012 and Apr. 2013. At Kambi ya Mawe location, a total of 715 mm of rainfall (592 mm during the crop season and 123.3 mm during the ratoon season) was recorded.

There were very minor variations in average ambient temperatures during the growth phases (vegetative, flowering, and pod development) of pigeon pea at both locations (Fig. 2). At Kambi ya Mawe, the average temperature during the preflowering phase was 23 °C compared with Kiboko location where the mean temperature was 25 °C. At flowering

Fig. 1. Total rainfall at Kambi ya Mawe and Kiboko locations in eastern Kenya during seasons A (main crop) and B (ratoon crop) of pigeon pea evaluation in a 2-year period. The bars with same letters indicate nonsignificant differences ($P > 0.05$) in total rainfall among seasons within and across months.

phase of plant growth, the mean temperature at Kambi ya Mawe was 24 °C, whereas Kiboko had mean temperature of 25 °C. During the pod development phase, mean ambient temperature at Kambi ya Mawe and Kiboko locations were 25 and 26 °C, respectively (Fig. 2). Overall, average temperatures across the growth phases were not significantly different ($P > 0.05$) between Kambi ya Mawe (24 °C) and Kiboko locations (25 °C). During the ratoon season, both locations had mean ambient temperature of 23 °C.

The mean plant height (cm) differed significantly ($P \leq 0.05$) among cultivars and locations (Table 1). The local control cultivar, KIONZA, was

generally taller than all the test cultivars at Kambi ya Mawe and Kiboko locations (Table 2). At the Kiboko location, the plant heights were taller in all cultivars regardless of the season of crop growth (Table 2). At Kambi ya Mawe, plant height was positively ($r = 0.85$) and significantly ($P < 0.05$) correlated with vegetative growth of pigeon pea (Table 3). This was, however, negatively correlated with flowering ($r = -0.57$) and podding ($r = -0.87$) of pigeon pea cultivars. At Kiboko location, significant negative correlations ($P < 0.05$) were recorded between plant height and flowering as well as pod length (Table 3).

The primary and secondary branches also varied. The combined

Fig. 2. Average temperatures at Kambi ya Mawe and Kiboko locations in eastern Kenya during seasons A (main crop) and B (ratoon crop) of pigeon pea evaluation in a 2-year period. The bars with same letters indicate nonsignificant differences ($P > 0.05$) in mean temperatures among seasons within and across months.

analysis of variance showed significant ($P < 0.01$) interaction effects of locations $\times$ cultivars for both primary and secondary branches (Table 1) and significant ($P < 0.05$) effect of cropping seasons on the above variables were recorded. During the crop and ratoon seasons, the cultivar with the greatest number of primary branches was ICP 7035B at Kambi ya Mawe (Table 4). At Kiboko location, the local control cultivar, KIONZA, had the greatest number of primary branches during the main cropping season, whereas ICP 7035B had the greatest number of primary branches at ratoon season. The number of secondary branches varied among cultivars. At Kambi ya Mawe, the greatest number of secondary

branches were recorded on cultivar ICP 7035B at both seasons (Table 4). At Kiboko, the cultivars KIONZA and ICEAP 00902 had the highest number of secondary branches (Table 4). The primary branches were positively and significantly ($P > 0.05$) correlated to secondary branches ($r = 0.61$) and seed per pod ($r = 0.56$) during crop season (data not shown). During the ratoon season, primary branches were positively correlated to secondary branches ($r = 0.57$). The flowering and pod development were negatively and significantly ($P < 0.05$) correlated with primary and secondary branches of pigeon pea cultivars at Kiboko location (Table 3).

Differences in the number of days from planting to flowering and

crop maturity were observed among pigeon pea cultivars. The interactions between locations by cultivars and cultivars by seasons were significant ($P < 0.05$) for number of days to flower development and plant maturity (Table 1). The average number of days to flower development in pigeon pea cultivars was generally earlier at Kambi ya Mawe (93.4 d) than at Kiboko location (121 d) for flower formation (Table 5). At Kiboko location, flower development was delayed by up to 28 d and plant maturity delayed by 34 d when compared with that at Kambi ya Mawe (Table 5). In the cultivar MZ 2/9, the duration to flower development at Kiboko location was delayed by 38 d and to plant maturity by 42 d when compared with Kambi ya Mawe location. On the pigeon pea cultivar ICEAP 00902, flower development was delayed by 20 d relative to plants grown at Kambi ya Mawe.

At Kambi ya Mawe, the duration to flower formation was positively and significantly ($P < 0.05$) correlated with plant maturity ($r = 0.98$), plant height ($r = 0.89$), pod length ($r = 0.61$), and pod width ($r = 0.41$) for the above parameters (Table 6). The days to plant maturity was significantly ($P < 0.05$) and positively correlated to plant height ($r = 0.88$), pod length ($r = 0.64$), and pod width ($r = 0.43$). At Kiboko site, the days to flower development was positively and significantly ($P < 0.05$) correlated to duration to plant maturity ($r = 0.88$), plant height ($r = 0.87$), pod length ($r = 0.43$), pod width ($r = 0.56$), primary branches ($r = 0.66$), and secondary branches ($r = 0.49$) (Table 6). The duration to plant maturity was positively and significantly ($P < 0.05$) correlated to flower formation ($r = 0.98$), plant height ($r = 0.84$), pod width ($r = 0.56$), and primary ($r = 0.65$) and secondary branches ($r = 0.48$).

The mean pod length and width of the tested cultivars at the two locations are shown in Table 7. Significant differences in pod length ($P < 0.05$) were recorded among cultivars and between the two locations. Although pod length was positively and significantly ($P < 0.05$) correlated to pod width ($r = 0.56$), it was negatively and significantly ($P < 0.05$) correlated to flowering ($r = 0.49$) during the crop season at Kambi ya Mawe (Table 6).

Table 1. Analysis of variance on the effect of cultivar, location, and cropping season on pigeon pea growth parameters in 2011–12 and 2012–13 cropping years in eastern Kenya.

Source of variation ^z	Plant ht ^y	Primary branches ^x	Secondary branches ^x	Time to 50% flowering ^w	Time to 75% flowering ^w	Pod length ^v	Pod width ^v
Location	132,692*	136**	696**	19,848**	6,818**	10.4**	0.335*
Cultivar	1.90*	21**	457**	10,091**	11,336**	2.99**	0.095*
Location × cultivar	0.49 NS	24**	277**	79.9**	172**	0.71 NS	0.0069 NS
Season	0.61 NS	309**	346*	199,759**	176,295**	1.63 NS	0.004 NS
Season × cultivar	0.51 NS	0.44 NS	0.38 NS	107**	80.81 NS	0.72 NS	0.014 NS
CV (%)	12.8	14.4	26.4	6.68	7.67	10.9	10.6
SE	0.69	2.38	7.66	4.42	7.17	0.86	0.123

^zVariations used in the analysis of variance. Cultivars were designated fixed, while locations and seasons as random effects. Data refer to mean square errors along with the significance of the F tests, which is indicated by *significant at $P < 0.05$ and **significant at $P < 0.01$ levels.

^yRefers to plant height (cm) assessed during the cropping cycle.

^xPrimary and secondary branches counts on average of 50 plants per replication within each genotype.

^wDays from crop planting when 50% and 75% of flowers were developed on pigeon pea genotypes.

^vLength and width of pods (cm) assessed when pods were mature.

Table 2. Mean plant height of pigeon pea cultivars grown at Kiboko and Kambi ya Mawe during the crop and ratoon seasons in 2011–12 and 2012–13 cropping years in eastern Kenya.

Cultivar	Kambi ya Mawe		Kiboko	
	Crop season	Ratoon season	Crop season	Ratoon season
	Mean plant ht (cm) ^z	Mean plant ht (cm) ^y	Mean plant ht (cm)	Mean plant ht (cm)
ICP 7035B	148.9	167.7	219.3	220.3
ICEAP 00068	174.7	177.3	235.0	260.7
ICEAP 00850	164.2	179.7	234.3	254.0
ICEAP 00554	173.8	194.3	225.0	243.0
ICEAP 00557	166.1	173.7	241.7	256.3
ICEAP 00540	155.4	176.0	227.3	211.3
KAT 60/8	156.9	177.7	206.3	239.7
MTHAWAJUNI	146.7	180.0	220.0	245.3
MZ 2/9	166.5	164.7	224.3	234.3
ICEAP 00911	156.9	201.7	221.7	202.7
ICEAP 00902	169.5	191.3	240.0	267.0
KIONZA*	244.0	— ^w	304.3	—
Mean	168.6	180.4	233.3	239.5
LSD(0.05) ^v	19.12	33.82	21.46	50.94

^zThe main cropping cycle (March to October) during which pigeon peas are seeded and cultivated; 1 cm = 0.3937 inch.

^yCrop that emerges from regrowth of previous plant stubbles without replanting.

^xControl cultivar.

^wMissing values. The absence of KIONZA from the ratoon season indicates that it does not regrow from the stubble.

^vTukey's least significant difference at $P < 0.05$.

Discussion

Lower temperature has been shown to be important for accelerating the time to flower and crop maturity in medium duration pigeon pea cultivars (Silim and Omanga, 2001). This is in agreement with the observation of accelerated flowering of the cultivars at Kambi ya Mawe, which was recorded at 93 d when the mean temperature was 23.8 °C (Table 5; Fig. 2). Delayed flowering at Kiboko location was recorded at 121 d when the average temperature was 25.5 °C. The flower development of KIONZA, a local cultivar with long duration maturity was

observed when the mean temperatures were low such as 22.3 °C at Kambi ya Mawe and 21.7 °C at Kiboko locations. It has been observed that long duration cultivars generally have greater days to flowering and maturity even under low temperatures and did not flower when mean temperatures reached 26 °C (Silim et al., 2006). The presence of elevated temperatures during flowering period may result in flower shedding, drop of immature pods as well as inhibition of flower and pod settings. This phenomenon is similar to that reported in broad bean (*Vicia faba*) in which fewer pods per plant

were recorded under elevated temperature conditions (Manzer et al., 2015).

Mean temperatures during the vegetative phase of growth of pigeon pea under rain-fed condition were positively and significantly ($P < 0.05$) correlated with days to flowering ($r = 0.92$), days to maturity ($r = 0.94$), plant height ($r = 0.85$), pod length ($r = 0.72$), pod width ($r = 0.49$) (Table 3), and the mass of 100-seed weight ($r = 0.59$). Plant height ($r = -0.69$), secondary ($r = -0.59$) and primary branches ($r = -0.58$) were negatively and significantly ($P < 0.05$) correlated with mean temperature at flowering under supplementary irrigation. Increases in mean temperatures during the flowering and pod development phases of plant growth significantly ($P < 0.05$) affected many of the yield variables for experiments at Kambi ya Mawe than at Kiboko location. Increases in mean temperatures during the flowering phase in vegetable pigeon pea may lead to reduction in the duration to flowering, maturity, and plant yield. This finding is supported by Prasad et al. (2003) who observed that decreased number of fruit set at higher temperature was mainly due to poor pollen viability, reduced pollen production, and poor pollen tube growth, all of which lead to poor fertilization of flowers in peanuts. Wang et al. (2006) associated grain yield reduction to reduced pollen viability, reduced number of seeds per plant and weight per seed in chickpea (*Cicer arietinum*). We hypothesize that such phenomena of elevated temperatures leading to

Table 3. Correlation coefficients (*r* values) of ambient temperatures and growth phases and yield variables of vegetable pigeon pea grown at two locations in eastern Kenya in 2012–13.

Location	Growth phase ^z	Plant ht	Pod length	Pod width	Time to 50% flowering (d) ^y	Time to 70% maturity (d) ^y	Primary branches (no.)	Secondary branches (no.)
Kambi ya Mawe	Vegetative	0.85**	0.72**	0.49*	0.92**	0.94**	0.28	0.05
	Flowering	-0.57*	-0.49*	-0.25	-0.68*	-0.72**	-0.18	-0.10
	Podding	-0.87**	-0.65*	-0.42	-0.98**	-0.98**	-0.27	-0.01
	Ratoon	0.06	0.29	0.07	— ^x	—	0.12	-0.07
Kiboko	Vegetative	0.01	-0.13	0.29	0.13	0.18	0.06	0.11
	Flowering	-0.69*	-0.32	-0.58*	-0.87**	-0.88**	-0.58*	-0.59*
	Podding	0.84**	0.38	-0.57*	-0.98**	-0.99	-0.64*	-0.52
	Ratoon	-0.28	-0.39	-0.17			-0.08	-0.01

^zVegetative = period of plant shoot growth, flowering = duration of flower development, podding = period at which pods were formed, ratoon = regrowth of plants from previous crop stubbles of pigeon pea (after harvest).

^yWhen 50% of flowers were developed and 75% of plant maturity was achieved.

^xMissing values.

*, **Significant at $P < 0.05$ and $P < 0.01$, respectively.

Table 4. Primary branches of pigeon pea cultivars evaluated at Kiboko and Kambi ya Mawe locations in eastern Kenya in 2011–12 and 2012–13 cropping years.

Cultivar ^z	Kambi ya Mawe		Kiboko	
	Crop season ^y	Ratoon season ^x	Crop season ^y	Ratoon season ^x
	Primary branches (no.)	Primary branches (no.)	Primary branches (no.)	Primary branches
ICP 7035B	17.0	20.2	16.3	18.9
ICEAP 00068	13.7	117.0	15.0	17.7
ICEAP 00850	13.7	116.8	16.3	18.7
ICEAP 00554	11.0	115.4	16.0	19.4
ICEAP 00557	12.0	114.1	19.3	21.9
ICEAP 00540	14.0	116.9	15.3	18.9
KAT 60/8	13.7	116.0	14.0	18.1
MTHAWAJUNI	12.0	115.1	15.3	18.6
MZ 2/9	14.7	117.6	11.7	14.7
ICEAP 00911	16.0	18.0	14.7	18.6
ICEAP 00902	15.3	18.7	17.7	20.7
KIONZA ^s	16.8	— ^w	23.3	—
Means	14.2	16.9	16.2	18.8
LSD(0.05) ^v	2.78	4.08	3.69	3.89

^zThe main cropping period during which pigeon pea plants are seeded and cultivated.

^yCrop that emerges from regrowth of previous plant stubbles without replanting.

^sControl cultivar.

^wMissing values.

^vTukey's least significant difference at $P < 0.05$.

reduced flower viability may be a factor in this study.

It has been reported that supplementary irrigation increases the plant height in pigeon pea plants by an average of 34.4 cm (Khourigami et al., 2012). The increase in plant height was associated with prolonged plant growth period and increased vegetative growth, leading to production of taller plants. The significant influence of locations and cultivars on plant height (Table 1) was supported by the observation made by Egbe and Vange (2008), which showed that pigeon pea plant heights are affected by maturity duration, cultivars, and environments. Reddy (1990)

observed that late-maturing long-duration cultivars are generally tall, because of their prolonged vegetative phase, whereas the short-duration or early-maturing cultivars are comparatively short in stature because of their short vegetative growth phase. In this study, we observed that pigeon pea plants at Kiboko location, which received supplemental water application, were comparatively taller than those at Kambi ya Mawe locations (Table 2). Although supplemental water applied during the crop and ratoon seasons was 196 and 104 mm, respectively, it is not possible to isolate the effects of site differences from those of supplemental

irrigation. The variation in the amount of supplemental water between the two seasons was based on the amount of rainfall received. Nevertheless, cultivars such as ICEAP 00557 and ICP 7035B performed well when additional water applications were made.

The positive correlations between plant height and crop yield during the ratoon season could be as a result of increases in the foliage (number of leaves) and production of more branches, leading to greater production of pods. Based on previous research (Udensi et al., 2010), these traits (plant height, leaves, and branches) seem to function in tandem with one another in soybean (*Glycine max*) and this may influence pigeon pea in a similar manner. Although tall plants, such as cultivar KIONZA produce bigger seeds, have more branches, its management is often challenging in terms of harvesting, spraying and its tendency to lodging and shading unless wide spacing is used.

Primary and secondary branches of pigeon pea cultivars have been associated with yield attributes. The mean and range of primary branches of pigeon pea cultivars in this experiment are in agreement with the values reported by Egbe and Vange (2008) and Remanandan (1990). In their research, the above authors reported the number of primary branches on pigeon pea cultivars in the range of 11.6 to 23.06, with a mean value of 17.2 (Egbe and Vange, 2008; Remanandan, 1990). In contrast to the beneficial aspects of additional water application to the vegetative growth of pigeon pea, cultivars ICEAP 00911 and MZ 2/9 responded negatively to water application during the crop season,

and the primary branches were 14.7 and 11.7 branches for the above cultivars, respectively (Table 4). It should also be emphasized that farming practices that rely on rain-fed conditions for rural sustainable management practices for early crop season will also provide economic

benefit to farmers. Positive and significant correlations of pigeon pea branches with plant height have also been reported (Vijayalakshmi et al., 2013). Both primary and secondary branches were also shown to increase seed weight and number of seeds per pod at both locations during the crop

season. This indicates that under favorable conditions, high number of branches may lead to increased seed weight and seed per pod. Similar results have also been reported by other authors (Bharathi and Saxena, 2013; Saleem et al., 2005).

The period from planting to flower development and plant maturity have been of considerable importance to pigeon pea yield (Table 5). We observed earliness in the flowering of pigeon pea cultivars in this research. The earliness in flowering of medium maturity pigeon pea cultivars at Kambi ya Mawe has been reported by Manyasa et al. (2009), when evaluating some pigeon pea germplasm from Uganda. In this study, we observed significant interactions between locations and cultivars of pigeon pea. This is in agreement with previous studies, which showed that cultivars of pigeon pea and chickpea differed in flower development and plant maturity across locations (Makelo et al., 2013). The increases (delay) in the number of days from planting to flowering and plant maturity for field plots subjected to additional water applications has also been reported previously (Felix, 2009). Deshmukh and Mate

Table 5. Flower development and maturity in pigeon pea genotypes grown at Kiboko and Kambi ya Mawe locations in eastern Kenya during the crop season in 2012–13.

Cultivar	Time to 50% flowering (d) ^z		Time to 75% maturity (d) ^z	
	Kambi ya Mawe	Kiboko	Kambi ya Mawe	Kiboko
ICP 7035B	82.0	109.7	103.0	137.0
ICEAP 00068	88.3	113.	108.7	140.0
ICEAP 00850	90.7	119.0	111.0	141.0
ICEAP 00554	87.3	119.3	112.7	146.7
ICEAP 00557	87.7	114.3	105.7	144.0
ICEAP 00540	85.0	109.0	104.7	142.7
KAT 60/8	78.0	103.3	102.0	138.0
MTHAWAJUNI	80.0	107.3	107.0	130.0
MZ 2/9	81.0	119.0	105.0	146.7
ICEAP 00911	84.0	108.0	103.3	135.3
ICEAP 00902	96.0	115.7	110.7	142.7
KIONZA ^v	180.7	216.7	215.3	252.7
Means	93.39	121.19	115.76	149.73
LSD(0.05) ^x	7.78	17.26	19.81	28.45

^zWhen 50% of flowers were developed and 75% of plant maturity was achieved.

^vLocal control cultivar.

^xTukey's least significant difference at $P < 0.05$.

Table 6. Correlation coefficients for plant growth characteristics and some yield parameters of vegetable pigeon pea cultivars at two locations (Kambi ya Mawe and Kiboko) in eastern Kenya during 2012–13 cropping season.

Location	Time to 50% flowering ^z	Time to 75% maturity ^z	Grain wt ^y	Grain yield ^x	Plant ht	Pods + grain	Pod length	Pods/plant	Pod width	Primary branches
Kambi ya Mawe										
Time to 75% maturity	0.98**	—								
Grain weight	-0.03 NS	-0.25 NS	—							
Plant ht	0.89**	0.88**	-0.12 NS	0.52*	—					
Pod + grain	-0.17 NS	-0.37 NS	0.97**	0.97**	-0.05 NS	—				
Pod length	0.61**	0.64**	-0.10 NS	-0.10 NS	0.71**	0.07 NS	—			
Pods/plant	0.17 NS	0.18 NS	0.35 NS	-0.03 NS	0.12 NS	0.32 NS	-0.03 NS	—		
Pod width	0.41*	0.43*	0.15 NS	0.17 NS	0.40*	0.24 NS	0.55*	0.11 NS	—	
Primary branches	0.26 NS	0.23 NS	-0.01 NS	0.20 NS	0.14 NS	0.05 NS	-0.07 NS	0.25 NS	-0.02 NS	—
Kiboko										
Time to 75% maturity	0.88**	—								
Grain weight	-0.17 NS	-0.17 NS	—							
Plant height	0.87**	0.84**	-0.14 NS	0.02 NS	—					
Pod + grain	-0.11 NS	-0.12 NS	0.92**	0.88**	-0.06 NS	—				
Pod length	0.43**	0.40 NS	-0.14 NS	-0.19 NS	0.49*	0.21 NS	—			
Pods/plant	-0.06 NS	-0.05 NS	0.32 NS	0.18 NS	-0.02 NS	0.29 NS	-0.14 NS	—		
Pod width	0.56*	0.56*	0.28 NS	-0.04 NS	0.32 NS	0.31 NS	0.25 NS	0.22 NS	—	
Primary branches	0.66*	0.65*	-0.26 NS	-0.05 NS	0.65**	-0.26 NS	0.17 NS	-0.06 NS	0.13 NS	—

^zDays from crop planting when 50% of flowers were developed and 75% of plant maturity were achieved.

^yRefers to weight of 100 seeds per cultivar in each replicate.

^xPigeon pea at harvest (t·ha⁻¹) from replicated plots.

*, **Significance at $P < 0.05$ and $P < 0.01$, respectively; NS, nonsignificant ($P > 0.05$).

Table 7. Mean pod length and width of pigeon pea cultivars evaluated at Kiboko and Kambi ya Mawe locations in eastern Kenya in 2011–12 and 2012–13 cropping years.

Cultivar	Kambi ya Mawe		Kiboko	
	Crop season	Ratoon season	Crop season	Ratoon season
	Pod length (cm) ^z	Pod length (cm) ^y	Pod length (cm)	Pod length (cm)
ICP 7035B	7.3	7.9	7.9	7.7
ICEAP 00068	8.4	8.9	8.4	9.4
ICEAP 00850	7.2	8.5	8.0	8.0
ICEAP 00554	7.4	6.9	8.0	8.2
ICEAP 00557	8.0	5.3	8.0	8.7
ICEAP 00540	7.4	8.4	8.5	8.7
KAT 60/8	7.0	7.4	7.7	7.7
MTHAWAJUNI	7.8	8.2	8.0	8.2
MZ 2/9	7.4	7.7	8.2	8.2
ICEAP 00911	7.0	7.0	7.5	7.7
ICEAP 00902	6.6	7.5	7.4	7.9
KIONZA ^a	9.3	— ^w	8.8	—
Means	7.6	7.6	8.0	8.2
LSD _(0.05) ^v	0.89	1.90	0.95	0.92
Cultivar	Kambi ya Mawe		Kiboko	
	Crop season	Ratoon season	Crop season	Ratoon season
	Pod width (cm)	Pod width (cm)	Pod width (cm)	Pod width (cm)
ICP 7035B	1.2	1.2	1.3	1.2
ICEAP 00068	1.3	1.3	1.3	1.4
ICEAP 00850	1.1	1.1	1.2	1.2
ICEAP 00554	1.2	1.2	1.2	1.3
ICEAP 00557	1.2	0.7	1.1	1.3
ICEAP 00540	1.3	1.1	1.2	1.3
KAT 60/8	1.1	1.1	1.2	1.2
MTHAWAJUNI	1.3	1.3	1.3	1.4
MZ 2/9	1.3	1.3	1.4	1.4
ICEAP 00911	1.1	1.1	1.2	1.2
ICEAP 00902	1.1	1.1	1.2	1.3
KIONZA	1.4	—	1.5	—
Means	1.2	1.1	1.3	1.3
LSD _(0.05)	0.17	0.36	0.15	0.12

^zCrop period during which regular cultivation of plants occurred; 1 cm = 0.3937 inch.

^yRatoon season refers to period in which pod parameters were quantified from crop regrowth of previously planted pigeon pea.

^aLocal pigeon pea cultivar (control) grown in the region.

^wNo growth was observed.

^vTukey's least significant difference at $P < 0.05$.

(2013) reported that days to flower development were reduced by 5–6 d due to moisture stress conditions, whereas plant maturity was delayed by 10–14 d when pigeon pea crops were irrigated. In this study, the cultivars that flowered early such as KAT 60/8 also matured early at both locations. The differences in flower maturity among some cultivars and between seasons indicate that the duration to flower and maturity is not only influenced by the cultivar alone, but also by the environment and their interactions. In our research, the mean days to flowering was within the range observed by Remanandan (1990), which were 55 to 237 d among 10,670 accessions evaluated in India, as well as the range

recorded for pigeon pea cultivars in Kenya (Mergeai et al., 2001; Silim and Omanga 2001). Egbe and Vange (2008) studied the relationship between duration to flower development and plant maturity in pigeon pea and observed that duration to flowering and maturity are very highly and positively correlated. This observation was noted by Upadhyaya et al. (2006) who indicated that days to maturity could be predicted from days to flowering of cultivars. Other studies by Sreelakshmi et al. (2010), Sodavadiya et al. (2009), and Vijayalakshmi et al. (2013) on pigeon pea have reported significant positive correlations between duration to flower development and plant maturity and plant

height, pod length and width, as well as primary and secondary branches of the plants.

In vegetable cowpea (*Vigna unguiculata*), pod length and width are important yield components, as they are known to influence the pod weight and the grain yield (Nwofia, 2012). All cultivars used in this study had pod length in excess of 5.5 cm, making them suitable for utilization as vegetable pigeon pea (Table 7). Similarly, cultivar selection for vegetable pigeon pea is often based on pod length. In breeding for vegetable pigeon pea, long pod size is one of the most important plant characteristics of vegetable pigeon pea that is considered. It has been reported that cultivars, which had mean pod length in excess of 5.5 cm is often considered for selection (Faris et al., 1987; Saxena and Sharma, 1990; Saxena et al., 2010a, 2010b).

We conclude that ambient temperatures affected the growth and development of vegetable pigeon pea cultivars, with the greatest effect recorded at flowering phase. Increases in ambient temperatures during vegetative phase accelerated plant maturity, plant height, and pod length and width at the above experimental locations. Increased mean temperatures during the flowering phase led to reduction in the number of days to flowering and maturity. It appears that additional water application at Kiboko location may have resulted in reduced temperatures at this location. In this research, cultivars that took longer to flower and mature had lower yield of vegetable pigeon pea. Late maturing cultivars had average days to flowering of 122 d. On the cultivars MZ 2/9, ICEAP 00911, ICEAP 00068, ICEAP 00902, Mthawajuni, ICEAP 00554, and KAT 60/8, the average plant growth values were good, indicating early maturity since the flower development and plant maturity duration were less than 50% that of the KIONZA, the control cultivar. 'ICEAP 00557' and 'ICP 7035B' also performed well when supplemental water application were made to field plots.

Literature cited

Bharathi, M. and K.B. Saxena. 2013. Character association between seed yield and component traits among CMS-based pigeon pea hybrids. *Electronic J. Plant Breeding* 4:1086–1089.

- Deshmukh, D.V. and S.N. Mate. 2013. Evaluation of pigeon pea genotypes for morpho-physiological traits related to drought tolerance. *World J. Agr. Sci.* 9:17–23.
- Egbe, O.M. and T. Vange. 2008. Yield and agronomic characteristics of 30 pigeon pea genotypes at Otobi in southern Guinea Savanna of Nigeria. *Life Sci. J.* 5:70–80.
- Faris, D.G., K.B. Saxena, S. Mazumdar, and U. Singh. 1987. Vegetable pigeon pea: A Promising Crop for India. Res. Inst. Semi-Arid Tropics (ICRISAT), Patancheru, India.
- Felix, A.I. 2009. Influence of supplementary irrigation and organic manure application on micronutrient density and yield of five common bean genotypes. MS Thesis, Univ. Nairobi, Nairobi, Kenya.
- Gomez, K.N. and A.A. Gomez. 1984. Statistical procedures for agricultural research. 2nd ed. Wiley, New York, NY.
- International Board for Plant Genetic Resources and International Crops Research Institute for the Semi Arid Tropics. 1993. Descriptors for pigeon pea [*Cajanus cajan* (L.) Millsp.]. Intl. Board Plant Genet. Resources (IBPGR), Rome, Italy and Intl. Crops Res. Inst. Semi-Arid Tropics (ICRISAT), Patancheru, India.
- Khourgami, A., E. Maghooli, M. Rafiee, and Z. Bitarafan. 2012. Lentil response to supplementary irrigation and plant density under dry farming condition. *Intl. J. Sci. Advanced Technol.* 2:51–55.
- Kimani, P.M. 1991. Pigeon pea research in Kenya: An overview. Proc 1st Eastern and Southern Africa Regional Legumes (Pigeon pea) Workshop, Nairobi, Kenya, 25–27 June 1990. p. 108–117.
- Lannucci, A., M.R. Terribile, and P. Martiniello. 2007. Effects of temperature and photoperiod on flowering time of forage legumes in a Mediterranean environment. *Field Crops Res.* 106:156–162.
- Makelo, M.N., R. Melis, and S. Githiri. 2013. Stability of cytoplasmic male-genetic sterility in pigeon pea (*Cajanus cajan* (L.) Millsp.) under different environmental conditions in Kenya. *Intl. J. Agr. Policy Res.* 1:11–18.
- Manyasa, E.O., S.N. Silim, and J.L. Christiansen. 2009. Variability patterns in Ugandan pigeon pea landraces. *J. Semi-Arid Trop. Agr. Res.* 7:1–9.
- Manzer, H.S., M.Y. Al-Khaishany, M.A. Al-Qutami, M.H. Al-Whaibi, A. Grover, H.M. Ali, M.S. Al-Wahibi, and N.A. Bukhari. 2015. Response of different genotypes of faba bean plant to drought stress. *Intl. J. Mol. Sci.* 16:10214–10227.
- Mergeai, G., P.M. Kimani, A. Mwangombe, F. Olubayo, C. Smith, P. Audi, J. Baudoin, and A. Le-Roi. 2001. Survey of pigeon pea production systems, utilization and marketing in semi-arid lands of Kenya. *Bio-technol. Agron. Soc. Environ.* 5:145–153.
- Nganyi, W.E.A. 2009. Pigeon pea response to phosphorus fertilizer, temperature and soil moisture regimes during the growing season at Katumani and Kambi ya Mawe in Machakos and Makueni districts of Kenya. MS Thesis, Univ. Nairobi, Nairobi, Kenya.
- Nwofia, G.E. 2012. Yield and yield components in vegetable cowpea on an ultisol. *Afr. J. Agr. Res.* 7:4097–4103.
- Okoko, O., S. Obaga, and B. Okeyo. 2002. Introduction of improved pigeon pea genotypes in the marginal areas of Lake Victoria region of south west Kenya, p. 299–301. In: J.G. Mureithi, G.K.K. Gachene, F.N. Muyekho, M. Onyango, L. Mose, and O. Magenyia (eds.). Participatory technology development for soil management by small holders in Kenya. Kenya Agr. Res. Inst., Nairobi, Kenya.
- Omanga, P. and J.B.W. Matala. 1987. Grain legumes production in Kenya. Research on grain legumes in eastern and central Africa. Summary Proc. Consultative Group Mtg. for Eastern and Central African Regional Research on Grain Legumes, 8–10 Dec. 1986, Addis Ababa, Ethiopia.
- Ott, R.L. 1993. An introduction to statistical methods and data analysis. Duxbury Press, Belmont, CA.
- Prasad, P.V.V., K.J. Boote, and L.H. Allen. 2003. Effect of elevated temperature and carbon dioxide on seed set and yields of kidney bean (*Phaseolus vulgaris* L.). *Glob. Change Biol.* 8:710–721.
- Reddy, L.J. 1990. Pigeon pea: Morphology, p. 47–86. In: Y.L. Nene, S.D. Hall, and V.K. Sheila (eds.). The pigeon pea. CAB International, Wallingford, UK.
- Remanandan, P. 1990. Pigeon pea: Genetic resources, p. 89–97. In: Y.L. Nene, S.D. Hall, and V.K. Sheila (eds.). The pigeon pea. CAB International, Wallingford, UK.
- Saleem, M., A. Zafar, M. Ahsan, and M. Aslam. 2005. Interrelationships and variability studies for grain yield and its various components in chick pea (*Cicer arietinum* L.). *J. Agr. Soc. Sci.* 1:266–269.
- Saxena, K.B., R.V. Kumar, and C.L.L. Gowda. 2010b. Vegetable pigeon pea—A review. *J. Food Legumes* 23:91–98.
- Saxena, K., R. Kumar, and R. Sultana. 2010a. Quality nutrition through pigeon pea—A review. *Health* 2:1335–1344.
- Saxena, K.B. and D. Sharma. 1990. Pigeon pea genetics, p. 137–157. In: Y.L. Nene, S.D. Hall, and V.K. Sheila (eds.). The pigeon pea. CAB International, Wallingford, UK.
- Shiferaw, B.A., T.A. Kebede, and L. You. 2008. Technology adoption under seed access constraints and the economic impacts of improved pigeon pea varieties in Tanzania. *Agr. Econ.* 39:309–323.
- Silim, S.N. 2001. Strategies and experiences in pigeon pea genotype development for eastern and southern Africa, p. 13–20. In: S.N. Silim, G. Mergeai, and P.M. Kimani (eds.). Status and potential of pigeon pea in eastern and southern Africa. Proc. Reg. Wkshp., 12–15 Sept. 2000, Nairobi, Kenya and Intl. Crops Res. Instit. Semi-Arid Tropics, Patancheru, India.
- Silim, S.N., R. Coe, P.A. Omanga, and E.T. Gwata. 2006. The response of pigeon pea genotypes of different duration types to variation in temperature and photoperiod under field conditions in Kenya. *J. Food Agr. Environ.* 4:209–214.
- Silim, S.N., E.T. Gwata, R. Coeb, and P.A. Omanga. 2007. Response of pigeon pea genotypes of different maturity duration to temperature and photoperiod in Kenya. *African Crop Sci. J.* 15:73–81.
- Silim, S.N. and P.A. Omanga. 2001. The response of short-duration pigeon pea to variation in temperature under field conditions in Kenya. *Field Crops Res.* 72:97–108.
- Sodavadiya, P.R., M.S. Pithia, J.J. Savaliya, A.G. Pansuriya, and V.P. Korat. 2009. Studies on characters association and path analysis for seed yield and its components in pigeon pea (*Cajanus cajan* (L.) Millsp.). *Legume Res.* 32:203–205.
- Sreelakshmi, C.H., C.V.K. Sameer, and D. Shivani. 2010. Genetic analysis of yield and its component traits in drought tolerant genotypes of pigeon pea (*Cajanus cajan* L. Millspaugh). *Electronic J. Plant Breeding* 1:148–149.
- Udansi, O., E.V. Ikpeme, A.A. Markson, E.A.B. Edu, E.J. Umana, and I.S. Urua. 2010. Selection of soybean genotypes using morphological markers. *Intl. J. Current Res.* 7:5–8.
- Upadhyaya, H.D., L.J. Reddy, C.L.L. Gowda, K.N. Reddy, and S. Singh. 2006. Development of a mini core subset for enhanced and diversified utilization of pigeon pea germplasm resources. *Crop Sci.* 46:2127–2132.
- Vijayalakshmi, P., C.H. Anuradha, D. Pavankumar, A. Sreelaxmi, and G. Anuradha. 2013. Path coefficient and correlation response for yield attributes in pigeon pea (*Cajanus cajan* L.). *Intl. J. Sci. Res. Publ.* 3:1–6.
- Wang, J., Y.T. Gan, F. Clarke, and C.L. McDonald. 2006. Response of chick pea yield to high temperature stress during reproductive development. *Crop Sci.* 46:2171–2178.