

*Full Length Research Paper*

# **Agronomic performance of new Jkuat papaya in different agro-ecological zones of Kenya**

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Papaya is one of the most important fruits crops of Kenya. However, in the recent past, papaya productivity and quality have been limited by lack of high quality seeds. Most producers depend on farmer selected and imported seeds for propagation. However, this is not satisfactory since few farmers can afford imported seeds due to their high price. On the other hand, most of the farmer selected seeds give rise to trees with inferior fruit quality and are susceptible to diseases. The above mentioned challenges necessitated the development of new Jomo Kenyatta University of Agriculture and Technology (JKUAT) papaya lines with superior qualities to help boost fruit production. So far, the new JKUAT papaya has been evaluated only at JKUAT main campus in Kiambu County. This study evaluated the performance of newly developed JKUAT papaya lines (Line 1, 5, 6 and 7) in different agro-ecological zones of Kenya. The study sites were JKUAT (upper midlands zone), Nkubu (upper highlands zone), KALRO Mwea (upper midlands zone) and Mitunguu irrigation scheme (upper highlands zone). The results on morphological, fruiting and biochemical quality showed significant differences. The total number of fruits varied significantly where line 1 had the lowest number (84 fruits) in JKUAT and the highest number was recorded in line 5 (134 fruits) in KALRO Mwea. The fruit weight varied significantly and ranged from 1.2 kg in line 5 in JKUAT to 2 kg in line 7 in KALRO Mwea. The total soluble solids (TSS) varied significantly from 8.3% in line 7 in KALRO Mwea to 13.7% in line 5 from Nkubu. The results revealed that new lines had good productivity and they should be commercialized in Kenya. However, there is a need to determine the performance of the newly developed papaya lines under heat and water stress conditions.

**Key words:** Agro-ecological zones, fruit quality, fruit yield, morphology, papaya lines.

## **INTRODUCTION**

Fruit production represents an important part of the agricultural industry and it contributes to income generation, food and nutritional security (FAOSTAT, 2018). The major fruits grown in Kenya are banana, mangoes, avocado, papaya, pineapples, oranges and

passion fruit. Papaya (*Carica papaya* L.) is highly valued for its nutritional and health benefits since it is extremely rich in vitamins A and C (Pinnamaneni, 2017). Papaya has medicinal properties and is a good source of antioxidants, phytonutrients and flavonoids that prevent

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cells from undergoing free radical damage (Samreen and Prakash, 2015). Papaya does well in the tropical and sub-tropical regions across the world (Krikorian, 1989). Among the countries that produce papaya in large volumes are India, Brazil, Indonesia, Nigeria, and Mexico. In Africa, Nigeria is the leading producer followed by Democratic Republic of Congo. Kenya is ranked number fifteen in terms of acreage and volume of production (HCDA, 2018). There are many papaya cultivars grown across the world that were developed from conventional breeding programmes and selection by growers. The commonly grown varieties are Solo sunrise, Solo sunset, Mountain, Guinea gold, Betty and Sunny bank (Mitra et al., 2019). The major producing areas in Kenya are coastal and Eastern regions, while western and some parts of Nyanza produce smaller quantities (Rimberia and Wamocho, 2014). Production of papaya depends largely on farmers selected seeds while a few commercial growers use imported seeds. The main challenges in papaya production are poor adaptation and infestation by diseases leading to low yield and poor quality. It is estimated that 30-50% of the production never reaches the final consumer due to poor quality. Acceptability of fruits depends on the consumers' preference which is influenced by appearance, shape, weight, and colour (Saran et al., 2015). The major producing countries invest heavily on hybrid seeds to achieve high quality and yield. Another challenge is that there is genetic erosion of desired characteristics from time to time due to the open pollinated nature of papaya which decreases varietal purity from one generation to the other. Moreover, imported papaya seeds are very expensive for ordinary farmers, while farmer-selected seeds are inferior in quality. In an attempt to minimize on the afore-mentioned challenges, a team of breeders at JKUAT developed new JKUAT papaya lines with superior fruit quality, dwarf stature and resistant to viral infections. These lines were evaluated at JKUAT and showed superior morphological and fruit quality characteristics (Nishimwe et al., 2019). However, they have not been evaluated in other agro-ecological zones of Kenya. The objective of the study was to evaluate the agronomic performance of newly developed JKUAT papaya lines in four sites located in two different agro-ecological zones of Kenya.

## **MATERIALS AND METHODS**

This study was carried out from April 2018 to October 2019 using four new JKUAT papaya lines; line 1, 5, 6 and 7 and solo sunrise variety as a control.

### **Location of experiment**

The study was conducted in four different locations namely, KALRO Mwea, JKUAT, Nkubu and Mitunguu irrigation scheme that lie in two different agro-ecological zones (Upper Midlands and Upper Highlands). The regions on the Upper Midlands are KALRO Mwea

in Kirinyaga County and lies at Latitude of 0.6939°S, Longitude of 37.377°E, at an elevation of 1159 m above sea level. Its average annual temperature is about 21.5°C and receives an average annual rainfall of about 807 mm. The second site is JKUAT in Kiambu County that lies at a latitude of 1.0891°S, Longitude of 37.0105°E, at an elevation of 1416 m above sea level. Its average annual temperature is about 19.6°C and receives an annual rainfall of about 799 mm. The third site was Mitunguu irrigation scheme in Meru County in the Upper Highlands at a latitude 0.1089°S and longitude 37.7849°E at an elevation of 1020 m above the sea level. Its average annual temperature is about 21.6°C and receives an average annual rainfall of about 1080 mm. The fourth site was Nkubu in Meru County at latitude 0.04626 N, longitudes of 37.65587 and at an altitude of 1388 m above the mean sea level. Its average annual temperature is about 18.8°C and receives an annual rainfall of about 1687 mm.

### **Experimental details**

All seedlings of the five genotypes were raised at JKUAT and when they reached about 30 cm in height, they were transplanted in different sites in holes of 60 cm deep and 60 cm wide at inter and intra row spacing of 3.0 m. The experiment was laid out in Randomized Complete Block Design (RCBD) and replicated three times. In each replication, there were 35 plants whereby every treatment comprised of seven plants which were spaced at 3 m apart. Five plants in each treatment in every replication were randomly selected for data collection (Tables 1 and 2).

### **Data collection**

#### **Morphological characteristics**

Data on morphological characteristics were collected every 30 days from the time of planting to the time of fruit harvesting. The data collected included plant height, leaf length, width, internode length and height at first flower emergence. The plant height was measured as the distance from the ground surface to the shoot apex. Height at first flower emergence was the distance from the ground surface to the node that differentiated the first flower. Internode length of each tree was the mean length of five randomly selected internodes from 20 cm above the ground. The leaf blade length and width represented the mean values from maximum lengths and widths of five randomly selected leaves per tree. Plant population was determined by counting the plants in each block.

#### **Fruit yield**

The fruits that were used for yield assessments and analysis were about 4-5 months old (mature green to ripe stages). Data for total number of fruits, fruit weight, fruit diameter, and fruit length and flesh thickness were collected. Fruit yield of each line was determined by counting and weighing all the fruits that were formed after the commencement of flowering. Fruit weight was the mean weight of ten fruits randomly selected from each tree. Longitudinal sections of the ten fruits were made and then fruit lengths determined as the mean length (pole to pole) of the fruits using a veneer calliper. Flesh thickness was estimated by mean thickness of the top, middle and bottom portions of the ten sectioned fruits using a veneer calliper.

#### **Statistical analysis**

The data on plant morphological features, yield and fruit quality

**Table 1.** Rainfall data for the experimental sites from May 2018 to September 2019.

Month	2018				2019			
	Mwea	Juja	Nkubu	Mitunguu	Mwea	Juja	Nkubu	Mitunguu
January					51	39	48.3	37.7
February					56	39	40.8	31.2
March					132	101	58.7	67
April					372	188	109	96
May	86	110	186	104	306	102	68.4	55
June	27	7	16	8	58	22	132	116.4
July	12	2	21	4	47	11	48.4	36.1
August	15	5	24	8	53	12	69.9	47
September	9	15	24	17	40	14	60.9	60
October	79	57	285	135				
November	201	148	393	273				
December	74	75	148	114				

**Table 2.** Mineral composition of soil from the experimental sites.

Location	Nitrogen (%)	Phosphorus (mg/kg)	Potassium (me/100g)	pH	EC(Ms/cm)
KALRO Mwea	0.51	165.5	8.32	6.82	0.079
JKUAT	0.28	121	8.91	6.0	0.190
Nkubu	0.39	119	5.90	5.7	0.195
Mitunguu	0.47	129	8.22	6.3	0.102

were subjected to GenStat software program, seventeenth edition to assess the analysis of variance (ANOVA) between the lines. Means comparison was done using one way analysis of variance for the different treatments. Treatment means was separated by Tukey's Honestly Significant Difference (HSD) test ( $p=0.05$ ). Each value of the mean and standard error in the tables represented three replicates of each treatment.

## RESULTS

### Plant height of papaya plants in each of the four locations in two different agro ecological zones of Kenya

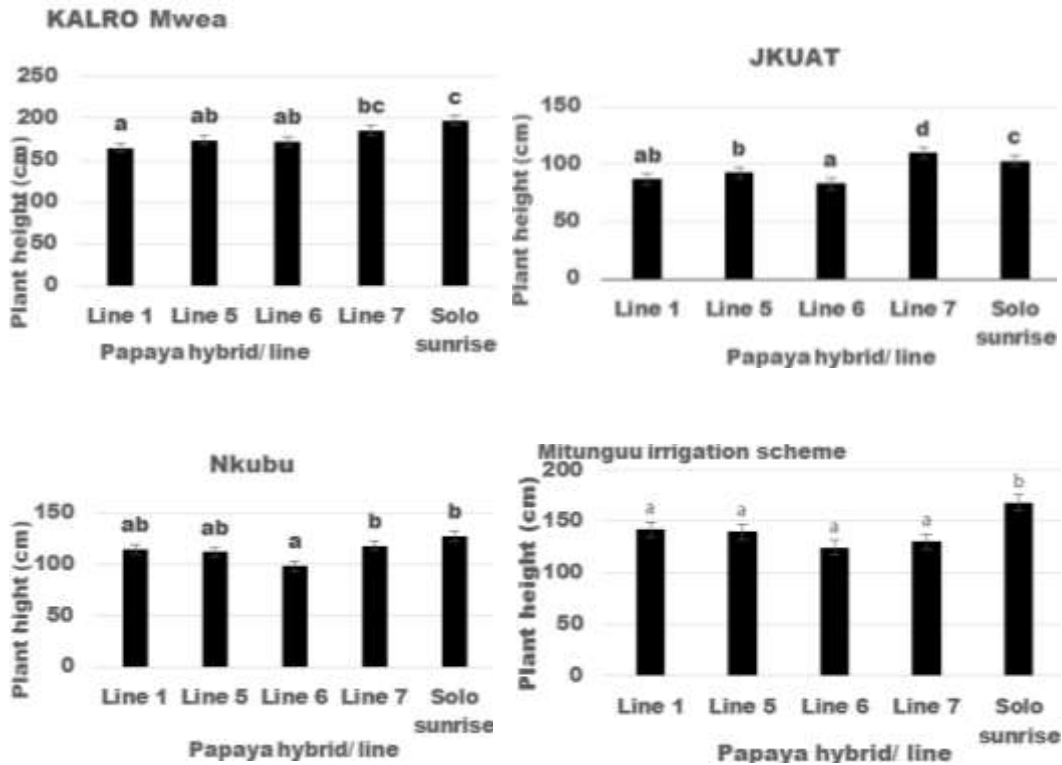
The morphological characteristics of papaya lines varied significantly (Figure 1) among the papaya lines and Sunrise solo in plant height, internode length and height at first flower emergence. Solo sunrise recorded the highest plant height in three zones, KALRO Mwea (197.3 cm), Mitunguu irrigation scheme (167.8 cm) and Nkubu (128.0 cm), while line 7 recorded the highest height of 109.7 cm at JKUAT. The least heights were recorded in line 6 in the three zones, Mitunguu irrigation scheme (124.0 cm), Nkubu (99.0 cm) and JKUAT (83.0 cm) while at KALRO Mwea, line 1 recorded the least height of 165.0 cm (Figure 1).

### Internode length of papaya lines from the four locations

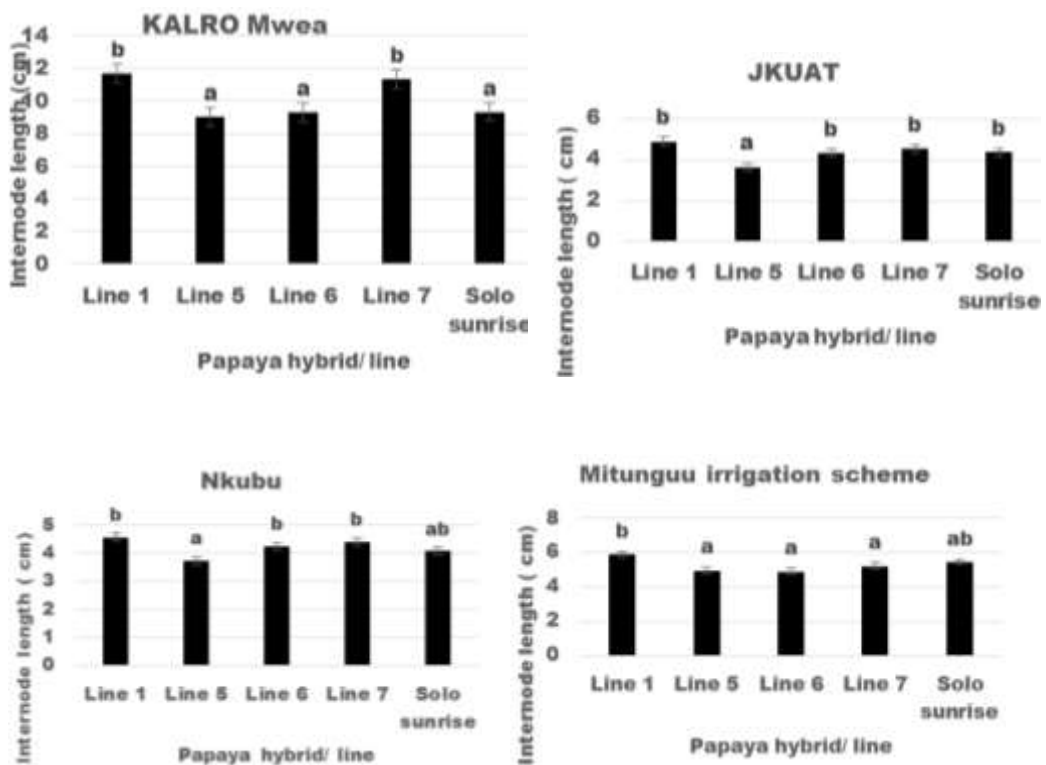
There were significance differences ( $p=0.05$ ) in internode length where line 1 recorded the highest value in all the zones, KALRO Mwea (11.7 cm), Mitunguu irrigation scheme (5.9 cm), JKUAT (4.9 cm) and Nkubu (4.6 cm). Line 5 recorded the least internode length in JKUAT (3.6 cm), Nkubu (3.7 cm) and KALRO Mwea (9.0 cm) respectively while in Mitunguu irrigation scheme, line 7 recorded the least (4.9 cm) (Figure 2).

### The height at first flower emergence of the new papaya plants from different agro ecological zones of Kenya

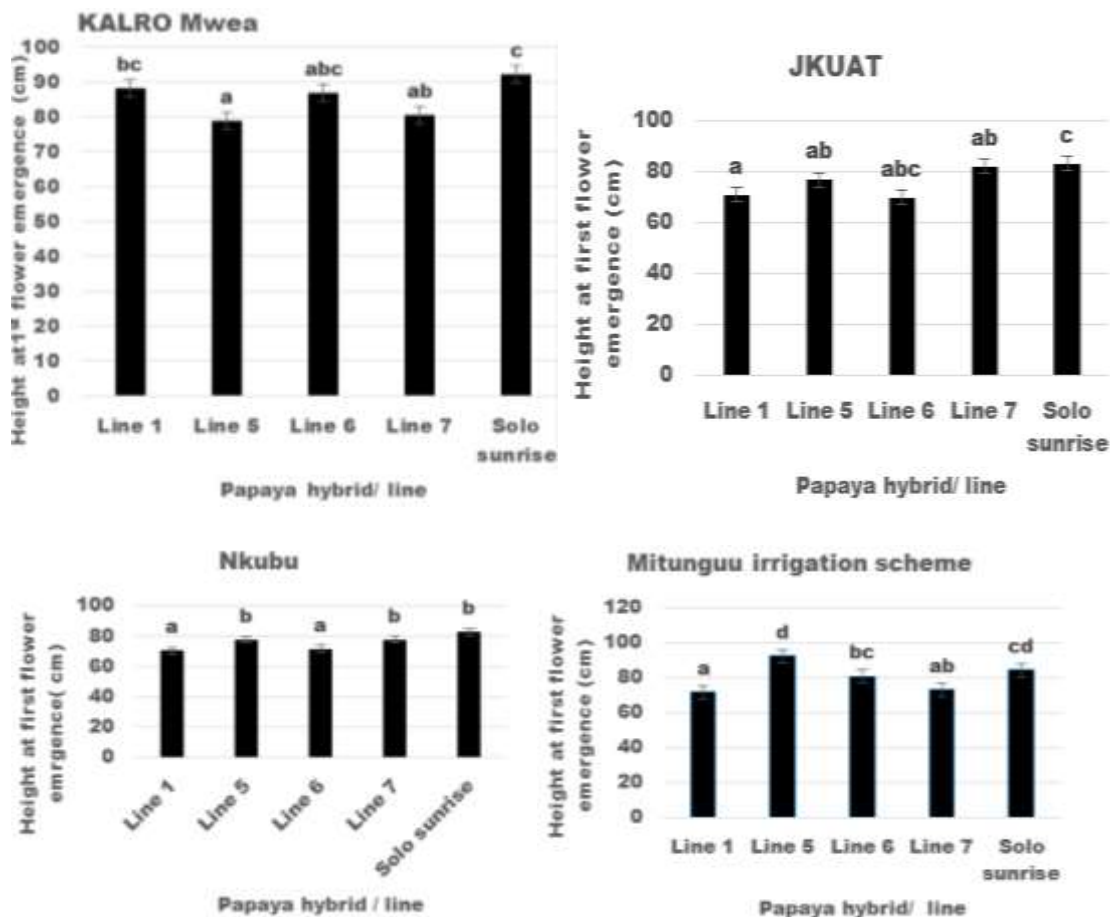
There were significance differences in the height of papaya plants at first flower emergence. Solo sunrise recorded the highest height at first flower emergence in the 3 locations, KALRO Mwea (92.3 cm), JKUAT (83.3 cm) and Nkubu (83.0 cm) while line 5 recorded the highest height at first flower emergence in Mitunguu irrigation scheme (92.5 cm). Line 1 recorded the least height at first flower emergence in Nkubu and Mitunguu irrigation scheme at 70.7 and 72.0 cm respectively. Line



**Figure 1.** The height of the new papaya lines from 4 locations in different agro ecological zones of Kenya 80 days after transplanting ( $p=0.05$ ).



**Figure 2.** The internode length of the new papaya lines from the four locations in different agro ecological zones of Kenya 80 days after transplanting ( $p=0.05$ ).



**Figure 3.** The height at first flower emergence of the new papaya lines from the four locations in different agro ecological zones of Kenya.

5 recorded the least height at first flower emergence in KALRO Mwea (79.0 cm) and JKUAT (69.9 cm.) (Figure 3).

#### **The length of time (days) from planting to 50% flowering of the new papaya lines in different agro-ecological zones of Kenya**

There were no significant differences among the papaya lines with respect to the time taken to first flower emergence. In KALRO Mwea, it ranged between 64 days to 68 days, JKUAT (76-82 days), Nkubu (71-77 days) and Mitunguu irrigation scheme (64-69 days). Similarly time taken to first fruit ripening did not vary significantly and they took between 220 days (7.3 months) to 232 (7.7 months) days after the emergence of the first flower. In KALRO Mwea, it ranged between 214-220 days, JKUAT (236-241 days), Nkubu (227-233 days) and Mitunguu irrigation scheme.

The data are expressed as means and standard error of differences of means. The means followed by the

same letters in the same column are not significantly different at  $p=0.05$ . The time taken to 50% flowering showed significant differences ( $p=0.05$ ) among the papaya lines and the solo sunrise. Line 6 took the longest time to 50% flowering in all four zones under the study, JKUAT (150 days), Nkubu (143.7 days), Mitunguu irrigation scheme (130.3 days) and KALRO Mwea (129.7 days). The least number of days to 50% flowering was recorded by line 7 in three zones, KALRO Mwea (119.7 days), Mitunguu irrigation scheme (121 days) and Nkubu (133 days). Line 5 recorded least number of days in JKUAT (139.7 days) (Table 3).

#### **Yield of the new papaya lines in each of four locations in different agro ecological zones of Kenya**

The yield of the fruits varied significantly (Table 4) among the papaya lines. The total number of fruits ranged from a minimum of 84 in line 1 in JKUAT to a maximum of 134 in line 5 in KALRO Mwea. Line 5 had the highest number of fruits in all the four zones, KALRO Mwea (134 fruits),

**Table 3.** The length of time (in days) from planting to 50% flowering of the new papaya lines in different agro-ecological zones of Kenya.

Papaya lines	KALRO Mwea	JKUAT	Nkubu	Mitunguu irrigation scheme
Line 1	128.3±1 <sup>c</sup>	148.3± 1 <sup>c</sup>	141.3±1 <sup>bc</sup>	129±2 <sup>bc</sup>
Line 5	120±1 <sup>a</sup>	139.7± 1 <sup>a</sup>	133±1 <sup>a</sup>	121.7±1 <sup>a</sup>
Line 6	129.7±2 <sup>c</sup>	150±1 <sup>c</sup>	143.7±1 <sup>c</sup>	130.3±1 <sup>c</sup>
Line 7	119.7±2 <sup>a</sup>	141±2 <sup>a</sup>	133±1 <sup>a</sup>	121±2 <sup>a</sup>
Solo sunrise	126±2 <sup>b</sup>	145.7±1 <sup>b</sup>	137.3±2 <sup>b</sup>	127±2 <sup>b</sup>

**Table 4.** Yield of the new papaya lines in different agro-ecological zones of Kenya.

Location	Papaya line	No. Fruits per tree	Weight (kg) per fruit	Fruit yield (tons ha <sup>-1</sup> )
KALRO Mwea	Line 1	103.7±6 <sup>a</sup>	1.9± 0.1 <sup>ab</sup>	184.8 ±28 <sup>a</sup>
	Line 5	134.3±5 <sup>c</sup>	1.6± 0.1 <sup>a</sup>	210.3±28 <sup>a</sup>
	Line 6	128±5 <sup>bc</sup>	1.7± 0.2 <sup>a</sup>	207.6±29 <sup>a</sup>
	Line 7	106.3±6 <sup>ab</sup>	2± 0.1 <sup>b</sup>	204.6±27 <sup>a</sup>
	Solo sunrise	113.7±6 <sup>abc</sup>	1.8± 0.2 <sup>ab</sup>	195.8±29 <sup>a</sup>
JKUAT	Line 1	84±3 <sup>a</sup>	1.7± 0.2 <sup>bc</sup>	132.4±17 <sup>a</sup>
	Line 5	117.3±4 <sup>d</sup>	1.2± 0.1 <sup>a</sup>	131.0±19 <sup>a</sup>
	Line 6	108.3±4 <sup>c</sup>	1.4± 0.2 <sup>ab</sup>	147.7±18 <sup>a</sup>
	Line 7	85.7±4 <sup>ab</sup>	1.8± 0.2 <sup>c</sup>	149.3±18 <sup>a</sup>
	Solo sunrise	94±3 <sup>b</sup>	1.5± 0.1 <sup>abc</sup>	135.9±17 <sup>a</sup>
Nkubu	Line 1	97.3±4 <sup>a</sup>	1.7± 0.1 <sup>b</sup>	163.1±29 <sup>a</sup>
	Line 5	127.7±4 <sup>d</sup>	1.4± 0.1 <sup>a</sup>	177.3±29 <sup>a</sup>
	Line 6	115±5 <sup>bc</sup>	1.6± 0.1 <sup>ab</sup>	183.2±27 <sup>a</sup>
	Line 7	105±4 <sup>ab</sup>	1.8± 0.2 <sup>b</sup>	182.1±26 <sup>a</sup>
	Solo sunrise	118±5 <sup>cd</sup>	1.6± 0.1 <sup>ab</sup>	182.1±28 <sup>a</sup>
Mitunguu	Line 1	98.5±4 <sup>a</sup>	18.3±0.3 <sup>b</sup>	171.6±21 <sup>a</sup>
	Line 5	126.8±4 <sup>c</sup>	16.5±0.3 <sup>a</sup>	162.4±23 <sup>a</sup>
	Line 6	121.2±4 <sup>c</sup>	16.7±0.3 <sup>a</sup>	171.7±23 <sup>a</sup>
	Line 7	102.3±4 <sup>ab</sup>	16.6±0.3 <sup>a</sup>	198.1±21 <sup>a</sup>
	Solo sunrise	115±4 <sup>bc</sup>	17.1±0.3 <sup>a</sup>	183.7±19 <sup>a</sup>

The data are expressed as means and standard error of differences of means. The means followed by the same letters in the same column are not significantly different at  $p=0.05$ .

Nkubu (127 fruits), Mitunguu irrigation scheme (126 fruits) and JKUAT (117 fruits). Line 1 recorded the least number of fruits in all the zones under study, JKUAT (84 fruits), Nkubu (97 fruits), Mitunguu irrigation scheme (99 fruits) and KALRO Mwea (104 fruits). The weight per fruit varied significantly (Table 3) and ranged from 1.2 kg in line 5 in JKUAT to 2 kg in line 7 in KALRO Mwea. The highest fruit weight was recorded by line 7 in three zones; KALRO Mwea (2.0 kg), JKUAT and Nkubu (1.8 kg) each while in Mitunguu irrigation scheme, line 1 recorded the highest weight (1.8 kg). The least average fruit weight was recorded by line 5 in all the four zones, JKUAT (1.2

kg), Nkubu and Mitunguu (1.4 kg) each and KALRO Mwea (1.6 kg).

#### Fruit size and quality characteristics of the new papaya lines in different agro-ecological zones of Kenya

The size of flesh varied significantly ( $p=0.05$ ) among the lines in all the zones. Line 7 recorded the highest in all the four zones, KALRO Mwea and Nkubu (1.9 cm) each and JKUAT and Mitunguu irrigation scheme (1.8 cm)

each. The least flesh size was recorded by line 5 in all the zones; Mitunguu irrigation scheme (1.4 cm), JKUAT and KALRO Mwea (1.5 cm) each while Nkubu (1.6 cm). There was observed significance differences ( $p=0.05$ ) in fruit length among the papaya lines. Line 1 recorded the highest fruit length in all the zones; KALRO Mwea (19.1 cm), Nkubu (18.6 cm), Mitunguu irrigation scheme (18.3 cm) and JKUAT (17.8 cm). The least fruit length was recorded by line 7 (14.5 cm) in Nkubu, line 5 recorded the least in both JKUAT and Mitunguu irrigation scheme (16 cm and 16.5 cm) respectively while in KALRO Mwea, line 6 recorded the least fruit length (17.4 cm). The fruit diameter varied significantly where line 7 recorded the highest diameter in all the four zones; KALRO Mwea (13.9 cm), Mitunguu irrigation scheme (13.3 cm), JKUAT (12.8 cm) and Nkubu (11.6 cm). Line 6 recorded the least diameter in Mitunguu irrigation scheme (7.7 cm), line 1 recorded the least diameter in KALRO Mwea and JKUAT (9.7 cm and 8.8 cm) respectively while solo sunrise had the least diameter in Nkubu (9.8 cm). There were significance differences ( $p=0.05$ ) in the total soluble solids among the papaya lines in all the zones. Line 5 recorded the highest total soluble solids in Mitunguu irrigation scheme, Nkubu and JKUAT (14%, 13.7% and 11.7%) respectively while line 1 recorded highest content in KALRO Mwea with 11.67%. However, line 7 recorded the least total soluble solids KALRO Mwea (8.3%) and JKUAT (9.0%) while in Nkubu and Mitunguu irrigation scheme line 6 had the least total soluble solids (9.67% and 10.7%) respectively (Table 4).

## DISCUSSION

From the findings of this study, the significant variations that were observed in the plant growth and development in the different five papaya lines studied is due to various attributes that affects performance of a given plant. The plants growth and development is influenced by genetic makeup as well as factors that come from immediate surrounding environment (Bindu, 2018). The work agrees by the work previously done by Sudaric et al. (2006) who reported significance differences in plant morphological characteristics in other plants due to different genetic and prevailing environmental conditions. This is related to our study where all the four zones recorded different data on average rainfall and temperature. The differences noted on different morphological features in different ecological zones could be due to availability of different moisture content at the time when the study was carried out as shown by other studies in other plants (Ramalingam et al, 2011). There were significance differences observed on height at first flower emergence among the papaya lines. Some papaya lines flowered at lower heights compared to others for example line 5 (79cm) in Mwea, line 6 (70 cm) in JKUAT, line 1 (70.7 cm) in Nkubu and line 1 (72 cm) in Mitunguu. These lines had a more pronounced

dwarfing compared to the other lines that flowered at a much higher height (Lim and Siti 2007). From this study, it was noted that the rate of growth from transplanting to first flower emergence and to the first fruit ripening did not show significance differences among the papaya lines and the control which means that genotype-environment ( $G^*E$ ) interactions and their intranslational implication was zero. However, there was significance difference on the time taken from the first flower to 50% flowering. The process occurred earlier in some lines than others in the different agro ecological zones under study. These variations may be attributed to the plants inherited characteristics and the genetic capability (Khan et al, 2013). Additionally, different plant traits contributes to different techniques of acclimatization to the growing area and also the ability of seedling to withstand stress and disturbances during the transplanting stage (Kaur and Kaur, 2017). Literature indicates that early flowering is one of the adaptation mechanisms in plants in times of harsh environmental conditions especially at the start of reproductive stage. From this study all the papaya lines in JKUAT flowered at lower height compared to other zones. This may be attributed to low amount of mean rainfall (55.7 mm) and higher temperatures in JKUAT as compared to other zones during the study period.

The Fruit weight/plant(tons  $ha^{-1}$ ) among the papaya lines and solo sunrise varied significantly (Table 3) and ranged from 131.0 tons in line 5 in JKUAT to 210.3 tons in line 7 in KALRO Mwea. The significant differences in fruit yield among the papaya lines as found in this study agrees with similar findings were reported by Nkansah et al (2011) who reported significant differences in pepper lines. This disparity can be attributed to the differences in the genetic makeup of the papaya lines and the solo sunrise. This is true since all the new papaya lines originated from different parents. There are other additional factors related to prevailing environmental conditions that might have caused variation of yield of the new papaya lines in the two agro ecological zones. The variations exhibited in yield attributes such as number of fruit, weight, diameter and flesh size among the papaya lines is due to various physiological phenomenon such as photosynthetic efficiency among the lines (Long et al, 2006), different rates of translocation of the photosynthates from the source sink together with the photo respiration that took place in the plant body (Aliyev, 2012). From the study, we postulate that line 5 (KALRO Mwea), line 7 (JKUAT), line 6 (Nkubu) and line 7 (Mitunguu irrigation scheme) had the best physiological phenomenon that resulted to better yield. These factors are also affected by different genetic constitution of different lines which are key and directly responsible for expression of genetic characters under a particular set of environment (Bhandari et al, 2017). The total soluble solids varied significantly among the papaya lines which was also reported by Nishimwe et al. (2018). This is attributed to high photosynthetic efficiency and fast rate

of diversion of sugars from source (leaf) to sink (fruit) which is different among the lines. From the study, this was best exhibited by line 5 that recorded the highest total soluble solids in Mitunguu irrigation scheme, Nkubu and JKUAT (14%, 13.7% and 11.7%) respectively and line 1 in KALRO Mwea with 11.67%. The papaya fruits also showed significance differences in diameter, length and shape. This happened since during fruit growth, the size of the fruit increases which is determined by the cultivar and cell elongation during anthesis and post-anthesis whereas the fruit shape is influenced by cell division that take place at the pre-anthesis stage. The fruit characteristics such as size, flesh thickness, total soluble solids, length and diameter, are important for both the producers and consumers.

## Conclusion

Among the papaya lines, line 7 stands out in terms of size and flesh thickness while line 5 performed better and had the highest total soluble sugars in three different agro ecological zones. Additionally, all the zones had different soil nutrient levels and this may have attributed to the significance differences in both morphological and quality characteristics among the papaya lines. Soil fertility has a direct impact on crop yield and quality (Singh et al., 2010). This study revealed that the newly developed JKUAT papaya lines had adapted well to prevailing conditions in different agro ecological zones in Kenya. They showed high productivity with good quality fruits. Therefore, Kenyan farmers can rely more on the new papaya lines and avoid using the farmer selected seeds which have inferior qualities. These lines could be recommended for cultivation by farmers in the test locations and other areas with similar environmental conditions. Further, more research is needed to evaluate the performance of the newly developed papaya lines under heat and water stress conditions.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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