Research Article

Comparative Studies of Exotic Papaya Cultivars under Sub-Tropical Conditions

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Abstract | The current changing climatic scenario cause attraction towards introduction of exotic crops. Among those crops Papaya can be adapted to agro-climatic conditions of Faisalabad, Punjab. Papaya is one of the commercial fruit crops grown throughout the world. The experiment was designed to study the adaptability of two commercial papaya cvs. viz., Red lady and Calena during the year 2019-2021. The parameters studied were plant height, canopy area, stem girth, leaf length, number of flowers, number of fruit set, number of fruits matured, average yield and fruit quality (TSS, TA, vitamin C, sugars, Total phenolic contents and antioxidants. Results showed that the vegetative growth, yield and quality of Red lady is better than Calena and it is well adapted for cultivation under climatic conditions of Punjab.

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1. Introduction

Papaya (*Carica papaya* L.) belongs to family Caricaceae. It is herbaceous semi-wood perennial plant of great commercial importance (Salinas *et al.*, 2020). It is believed to be originated from tropical America and commercially grown in tropical and subtropical regions. It grows best where mean temperature sustains between a range of 28-38^{0}C (Kaur and Kaur, 2017), and is able to produce the fruit throughout the year (Paul and Duarte, 2011). Papaya is a basket full of nutrients comprised of carotene which is a precursor of vitamin A, vitamin C, carbohydrates, protein, and minerals like iron, Phosphorus and calcium. It contains papain which is protolytic enzyme that helps digestion. Due to papain, papaya is used as a bleaching agent and meat tenderizer (Kumar *et al.*, 2021). Papaya is identified as nutraceutical plant because of its medicinal properties as it cures constipation, lowers the level of cholesterol, treatment for dengue fever, and rich source of antioxidants that strengthen the immune system. It is used as a fresh fruit, shakes, jams, jellies, pies, ice cream and in dried form. Due to its

multipurpose uses, it occupies major contribution in cosmetic industry. It is the third most traded fruit of tropics excluding bananas (Vincent *et al*., 2019) and important fruit of India, Malaysia, Sri Lanka, Hawaii, South Africa, Myanmar and Queens Land in terms of production. India leads in papaya production followed by Dominican Republic, Brazil, Mexico and Indonesia (FAOStat, 2021). Its production area is increasing due to various reasons such as its wide adaptability to various ecological zones, early fruiting, year round bearing and high economic returns (Patel *et al*., 2020).

In Pakistan, the total area under papaya cultivation was 1678 ha along with production of 8635 tonnes (FAOStat, 2021-22). Papaya cultivation was gaining importance among local farmers because of high economic returns and better nutritional value. In Pakistan papaya is mostly cultivated in districts of Sindh i.e., Malir and Thatta. Mostly two varieties are cultivated in these areas known as Malir (Desi) and Bangali. Malir is an open pollinated variety. Cultivation of Red lady (the imported variety) had gained popularity due to its wide adaptability (Anonymous, 2018). As the agro-ecological zones are changing due to changing climate scenario, fruit crops are changing their regimes. Tropical fruits like papaya are now successfully grown in subtropical areas. For this reason, new varieties are being introduced to make them commercially important.

Changing climatic conditions makes it dire need of time to introduce new crops that can be well adjusted to our agro-climatic conditions. Among the new crops introduced those varieties must be selected that can become of commercial importance. Therefore, the current experiment was designed to select and acclimatize papaya varieties that can thrive well under subtropical condition of Punjab. Evaluation of variety on the basis of its performance (quality and yield) can open up new market for local consumption.

2. Materials and Methods

This experiment was conducted in the research area of Horticultural Research Institute, Ayub Agricultural Research Institute, Faisalabad (Elevation 189 m, Latitude 31.42° N, Longitude 73.09 ° E) during the year 2019-2021. This experiment comprised of comparison of two papaya cultivars *viz.*, Red lady and Calena. The height of seedlings at time of transplantation were 15-23 cm. The seedlings were transplanted in experimental area during second week of April, 2019 on raised beds (approximately 69 cm above ground). The spacing of plants was 183 x 183 cm. Regular cultural practices included irrigation after one-week interval in summer and fortnightly in winter. All plants were subjected to similar fertilizer, insecticide and fungicide applications (Kumar *et al*., 2010). Young plants were covered with fronds of date palm to protect them from sever heat in summer whereas in winter they were covered with polythene sheet. Essential plant protection measures were taken against insects/ pests attack during the growing phase. During this study period, prevailing climatic data of precipitation, maximum and minimum temperature for the year 2020 and 2021 was collected from the meteorological observatory of Ayub Agricultural Research Institute and given in Table 1. Plant height, stem girth and canopy area was measured with the help of measuring tape of one-year-old plant and expressed in cm and m^2, respectively (Nasir *et al*., 2018). Plant height and stem girth were measured at 23 cm height from the ground. Leaf size (cm^2) was calculated by measuring the leaf length and width in cm and multiplying them respectively (Nasir *et al*., 2018). Papaya started to bear flower after 6 months of transplantation. As the plants started flowering, number of flowers, number of fruit set at walnut size stage, and number of mature fruit were counted at different phenological stages during the whole study period. Papaya fruit reached to horticultural maturity stage in 180-250 days. Papaya was harvested at color break stage. Fruits of commercial grade were

Table 1: Meteorological data for the Year of 2020 and 2021.

Month	2020			2021		
	Temp. °C		Avg. rain-fall (mm)	Temp. °C		Avg. rain-fall (mm)
	Max.	Mini.		Max.	Mini.	
January	17.3	5.5	50.8	17.3	5.5	56.5
February	23.8	8.7	24.8	25.9	9.8	--
March	24.5	13.9	135.0	30.4	15.3	37.8
April	33.1	18.8	20.6	34.5	18.4	15.4
May	37.5	23.1	19.9	38.6	24.0	11.2
June	39	25.8	69.8	39.0	25.6	14.2
July	38.3	27.6	130.6	37.3	26.9	241.6
August	36.5	28.1	134.6	37.7	26.8	5.0
September	37.1	25.3	9.9	35.2	25.5	29.8
October	35.0	17.0	--	33.7	19.1	0.3
November	26.3	10.2	0.8	28.3	11.0	--
December	21.0	6.5	2.3	22.1	5.9	Traces

counted at the time of harvest (Patel *et al.*, 2020). Fruit was washed gently with tap water, dried and packed for uniform ripening by using ethylene sachet. After ripening, different physical and biochemical parameters were recorded. For average fruit weight, weight of three fruits was measured individually in gram (g) with the help of weighing balance (SF-400A, China) and then average was calculated. Average fruit yield per plant was calculated by multiplying the total number of fruits harvested with average fruit weight in Kg. Fruit size (cm^2) was noted by measuring fruit length and fruit width with Vernier's calipers and multiplying the length and width of respective fruits. Reading for Total soluble solids (TSS) was taken in ^{0}Brix from digital Refractometer (Atago, Japan). For the determination of acidity (%), 10 mL juice was taken in conical flask of 100 mL and volume was made upto 50 mL with distilled water. This solution was titrated against NaOH of 0.1 N using phenolphthalein as an indicator till pink color achieved and TA was determined in percentage. Vitamin C (ascorbic acid) was determined through protocol adopted by Ruck (1969) where 10 mL of aliquot was taken in a conical flask of 100 mL and its volume was made up to the mark with 0.4% oxalic acid. 5 mL aliquot was taken in a beaker from conical flask of 100 mL and titrated against freshly prepared dye (2,6-dichlorophenol indophenol) till light pink color achieved as an end point.

Folin-Ciocalteu method was adopted to determine the total phenolic contents of papaya where gallic acid was used as a standard. Phenolic contents were measured as gallic acid equivelant (GAE mg/g) of the lyophilized samples (Satisha *et al.*, 2008). Total antioxidant was calculated by the method illustrated by Ullah *et al.* (2013). Absorbance was noted at 517 nm and antioxidants were documented in terms of DPPH scavenging activity. % DPPH inhibition was calculated and expressed as %.

2.1 Statistical design

The experiment was laid out under randomized completer block design (RCBD). Single treatment was taken as an experimental unit replicated 4 times. The Pearson correlation ($P \leq 0.05$) and box plot design were used to express the correlation among various parameters (Steel *et al.*, 1997).

3. Results and Discussion

The statistical analysis showed significant differences in the quality characters of both papaya varieties being cultivated under similar agro-climatic conditions. It was observed that the maximum leaf size was observed in variety 'Red Lady' (1095 $inch^2$) whereas, Calena showed smaller leaf size (777.6 $inch^2$) (Table 2). Significant difference in plant height, stem girth and canopy volume was recorded in both papaya cultivars. Maximum plant height (86.37 inch), stem girth (13.89 inch) and canopy area (4.84 ft^2) were recorded in cultivar Red Lady (Table 2). Box plot (Figure 2) give us a clear view that the performance of Red Lady is far better compared to Calena in agro-ecological zone of the region. Pearson correlation ($P \leq 0.05$) exhibited that leaf size is directly positively correlated to the plant height and canopy area (Figure 1). Plant height also showed significant positive correlation ($P \leq 0.05$) to the canopy area (Figure 1). It showed that increase in leaf area improved plant height and canopy area in papaya plants irrespective of the variety grown. The better vegetative growth in red lady may be due to the fact that it is better adapted to the climatic condition of the region.

Table 2: Vegetative growth of Red Lady and Calena under subtropical conditions.

Variety	Leaf size ($inch^2$)	Plant height (inch)	Stem girth (inch)	Canopy area (ft^2)
Red Lady	1095a	86.37a	13.89a	4.84 a
Calena	777.6b	74.74b	13.20b	4.32 b
LSD (P≤ 0.05)	67.07	1.16	0.5	0.22

Table 3: Reproductive growth of papaya cultivars under subtropical conditions.

Variety	No. of flowers	Number of fruit set	Number of fruit matured	Average yield (kg)
Red Lady	86.42 a	79.25 a	73.08 a	71.75 a
Calena	72.83 b	70.91 b	61.25 b	55.12 b
LSD (P ≤ 0.05)	4.52	4.91	3.28	8.76

The results depicted significant difference in the reproductive growth of both papaya cultivars (Table 3). Red lady showed better growth as compared to Calena in the agro-climatic condition of the region. It was observed that maximum number of flowers (86.42), number of fruits set (79.25), number of fruit matured (73.08) and average yield (71.75 kg) was observed in Red Lady (Table 3). While Calena showed less number of flowers (72.83), buds (70.91), fruits (61.25) and yield (55.12) (Table 2). The box plot illustrates that in Red lady the number of flowers, the number of fruit set, number of fruit matured and

yield falls in a range of 54-125, 48-112, 45-107, 29-134kg, respectively (Figure 2). The performance of Calena was low compared to Red Lady as depicted in Box plot (Figure 2). Pearson correlation ($P \leq 0.05$) analysis showed that leaf size is directly positively correlated to number of fruits matured and yield of plants (Figure 1). Plant height is positively correlated to number of fruits matured and yield of plants (Figure 1). Similarly, canopy area is also positively correlated to the average yield and number of fruits (Figure 1). It revealed that the vegetative growth is directly proportional to the reproductive growth. The increase in vegetative growth improves the yield of papaya irrespective of the cultivar.

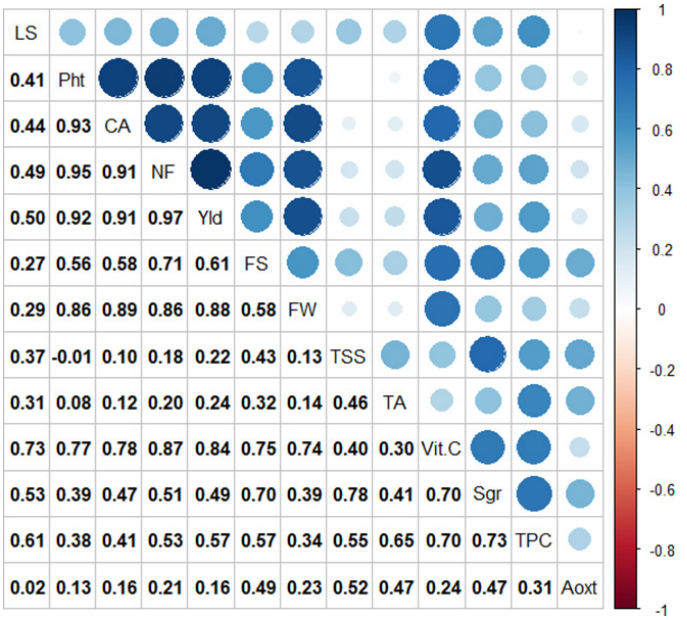

Figure 1: Pearson correlation analysis (P≤0.05) of relationship between different growth and phsico-chemical parameters of papaya cultivars being grown under sub-tropical climatic conditions.

*LS = leaf size, Pht = plant height, CA = canopy area, NF = Number of fruits, Yld = yield, FS = Fruit size, FW = Fruit weight, TSS = Total soluble solids, TA= Titrateable acidity, Vit. C = vitamin C, Sgr = sugar, TPC = Total phenolic contents, Aoxt = antioxidants.

Fruit quality characteristics of both papaya cultivars showed significant variation among them (Table 4). Box plot also gave us a clear view about the better performance of 'Red lady' under agro-climatic condition of the local region (Figure 2). Maximum fruit size (300 cm^2) was observed in Calena variety (Table 4). The range of fruit size of Calena varies from 161-532 cm^2, while, in Red lady the range was between 155-500 cm^2 (Figure 2). High fruit weight (922 g) was recorded in Red Lady (Table 3). Fruit weight range for Red lady falls in between 597-1260 g; whereas, the range for Calena falls in between 517-1050 g (Figure 2). Similarly, higher TSS (10.85 ^{0}Brix) was calculated in Red lady variety (Table 4). The TSS falls in a range of 9-12.4 in case of Red Lady, whereas, in Calena the range falls in between 8.9-11.2 (Figure 2). The plot TA does not show any significant differences among both cultivars (Table 4). Maximum vitamin C (32.38 mg/100 g) and sugars (15.37%) were observed in Red Lady cultivar (Table 4). In Red lady the vitamin C falls in range 28.6-36 mg/100 g and in Calena the range is 27.6-33.4 mg/100g (Figure 2). The total sugars fall in between 14.8-16.2% and in Calena the range is between 14.3-15.9 (Figure 2). Highest TPC were noted in Red Lady i.e., 166.4 mg GAE/100 g (Table 4).

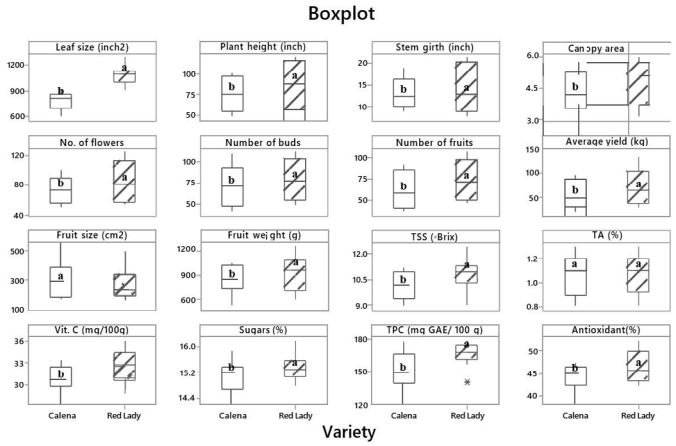

Figure 2: Box plot analysis to compare the performance of two papaya cultivars grown under similar agro-climatic conditions.

The range for TPC in Red Lady was 140-178 mg GAE/100 g; in case of Calena the range fall between 123.4-177 mg GAE/100 g (Figure 2). Similarly, maximum antioxidant (46.62%) were noted in

Table 4: Physico-chemical analysis of papaya fruits grown under subtropical conditions.

Variety	Fruitsize (cm^2)	Fruit weight (g)	TSS (Brix)	TA (%)	Vit. C (mg/100g)	Sugars (%)	TPC (mg GAE/100 g)	Antioxidant (%)
Red Lady	268 b	922 a	10.85 a	1.07	32.38 a	15.37 a	166.42 a	46.62a
Calena	300 a	848 b	10.08 b	1.06	30.67 b	15.10 b	150.5 b	44.05 b
LSD (P≤0.05)	27.93	49.37	0.22	NS	0.41	0.24	3.45	1.14

Red Lady; while minimum antioxidant (44.02%) was observed in Calena (Table 4). The TPC falls in range between 42.1-52.2% in Red Lady and in Calena it falls in range for 38.7-47.3% (Figure 2).

Pearson correlation ($P \leq 0.05$) analysis exhibited that fruit TSS is significantly affected by fruit size. The increase in fruit size was directly proportional to fruit TSS (Figure 1). Vitamin C was significantly positively correlated to the leaf size, plant height, canopy area, number of flowers, yield, fruit size, fruit weight and TSS (Figure 1). The total sugars in papaya fruits was positively correlated to the plant leaf size, canopy area, number of flowers, yield, fruit size, fruit weight, TSS, TA and vitamin C (Figure 1). The TPC of papaya fruits was positively significantly correlated to the leaf size, yield, fruit size, TSS, TA, vitamin C and sugars (Figure 1). The antioxidants of papaya fruits were significantly positively correlated to the TSS and total sugars (Figure 1).

Conclusion

Under the changing climatic scenario, introduction of new crops is dire need of time. The agro-climatic conditions of Punjab are favorable for cultivation of different fruit crops. That opens the window for local and exotic fruit crops. Papaya is an economical crop that has potential of high economic returns. The adaptability studies of different papaya cultivars showed that Red lady is best suitable to the agro-climatic conditions of Punjab. The Red lady has higher yield, best suited to local climatic conditions, showed better vegetative growth and fruit quality.

Acknowledgement

This experiment was carried out at Horticultural Research Institute, Faisalabad.

Novelty Statement

Papaya is new emerging crop in Pakistan (Punjab) because of its economical and nutritional importance and its adaptability study is the need of time. Therefore, the present study was planned to evaluate the performance of exotic papaya cultivars in Punjab.

Author's Contribution

Maryam Nasir and Nida Mahreen designed the experiment and write paper Muhammad Maaz Aziz and Malik Mohsin Abbas assisted in proof reading of paper, Akbar Hayat Saggu helped in biochemical analysis. Afzal Ansari assisted and provided guidance regarding conduction of trial. M. Amna Jamil Kanwal and Hira Faiz helped in statistical analysis.

Conflict of interest

The authors have declared no conflict of interest.

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