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Evaluation of litchi (*Litchi chinenesis* Sonn.) genotypes for fruit quality attributes

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Abstract
The study on characterization of physico-chemical attributes of litchi genotypes and its correlation study were conducted for two years to evaluate litchi cultivars for fruit quality attributes such as TSS, total sugars, reducing sugar, titratable acidity and ascorbic acid. The maximum TSS was found in genotype IC-0615610 and lowest in IC-0615589, ascorbic acid was found maximum in genotype IC0615613 and lowest in IC-0615595. Total sugar was recorded maximum in genotype Coll. 35 and minimum in IC-0615586 while maximum reducing sugar was found in genotype IC-0615601 and lowest in IC-0615589. The maximum titratable acidity was found in genotype IC-0615585 and lowest in IC-0615601. The maximum TSS/acidity ratio was recorded in genotype IC-0615602 while lowest was observed in Coll. 39. TSS was significantly and positive correlated with reducing sugar (0.382) while titratable acidity was significantly and negatively correlated with reducing sugar (-0.397) and TSS/acidity ratio (-0.954). Total sugar was significantly and positive correlated with reducing sugar (0.703) and reducing sugar was significantly and positive correlated with TSS/acidity ratio.

Keywords: Litchi, genotype, characterization, physico-chemical quality

1. Introduction
The litchi (*Litchi chinensis* Sonn.), a popular member of the family Sapindaceae is an evergreen subtropical tree. It belongs to the group called 'drupe' characterized by thin and generally pink-red colour pericarp, the edible part aril that is dull white, juicy and covers the single brown-black seed. It is highly specific to climatic requirements particularly chilling shock for successful flowering and fruiting and this is the reason of its restricted cultivation in few countries and limited states in India and fluctuation in temperature significantly affect fruit retention (Lal *et al*., 2017) [13]. Litchi makes significant contribution to the lives and economic health of millions of people in India particularly in Bihar followed and West Bengal. In Bihar this crop is the livelihood for millions of people as it provides both onfarm and off-farm employment. The litchi fruit is a good source of food, nutrition and has good medicinal value.
It is known for its sweet value and juicy flesh and attractive bright red pericarp. Apart from being consumed freshly, litchi fruit is also processed into juice, canned litchi and dried fruits. Litchi juice is enriched with sugar, minerals, vitamin, and various antioxidants and widely appreciated flavor, and thus it is able to compete in the market of fruit juices (Wu *et al*., 2007 [26]; Zeng *et al*., 2008 [27]; Saxena *et al*., 2011) [18]. Therefore, popularity is increasing day by day and litchi is spreading in non-tradition area of the country. There is an utmost need to make Indian litchi globally competitive since it is highly export oriented in nature and has great potential to earn foreign exchange in the international market. The poor qualities of fruits do not allow sustaining in national and international market. The Indian litchi have narrow genetic base which restrict the choices by the consumers. Thus, there is a need to widen diversity to select the cultivars/clones, and characterize and evaluate them for their best quality. The aims of this study were: (1) to determine quality of different genotypes of litchi; (2) to compare the genotype differences of quality; and (3) to investigate the correlations among quality attribute.

2. Materials and Methods
Thirty litchi germplasm of thirteen years old planted in Active National Germplasm Site at ICAR-NRC on Litchi, Muzaffarpur with uniform vigour and size were selected for the investigation for two year (2017 and 2018). These trees were given uniform cultural practices and three tree of each germplasm were considered for recording the observations.

The experiment was conducted in RBD with three replications.

2.1: Litchi genotypes collected from different sources

Source of collection	Litchi accessions
Sabour, Bhagalpur Bihar	IC-0615585, IC-0615586, IC-0615587, IC-0615588, IC-0615589, IC-0615590, IC-0615591
Pantanagar, Udham Singh Nagar (UK)	IC-0615592, IC-0615593, IC-0615594
Palandu, Ranchi (JH)	IC-0615595, IC-0615596, IC-0615597, IC-0615599, Coll. 39, IC-0615600, IC-0615601, IC-0615602
Gurdaspur, Punjab	IC-0615603, IC-0615604, IC-0615605, IC-0615606
Mohanpur, Nadia, (WB)	IC-0615608, Coll. 38
Muzaffarpur, Bihar	IC-0615610, IC-0615611, IC-0615613, Coll. 35
Surguja (CG)	Coll. 36
Bhubaneswar, Odisa	Coll. 37

2.2. Total Soluble Solid (^{0}Brix)

Total soluble solids in the fruits were recorded at room temperature using digital refractometer and were expressed in terms of ^{0}Brix. Five fruits per replication were taken from each treatment for taking the average value.

2.3 Vitamin-C (mg/100g)

Ascorbic acid content was estimated by the visual titration as described by Freed (1966) [4].Twenty two mg of Sodium bicarbonate and 25 mg of 2,6dichlorophenolindophenols were added to 100 ml distil water and mix thoroughly. This reagent was kept in an amber colour bottle and stored in freeze and used within a week of its preparation.

$$\text{Ascorbic acid (mg/100gm)} = \frac{\text{Volume made up} \times \text{Dye factor} \times \text{Titre value} \times 100}{\text{Aliquot of extract taken for estimation x Volume of sample taken for estimation}}$$

2.4 Total sugar (%)

Total sugar content of litchi pulp was determined calorimetrically by the anthrone method (Jayaraman, 1981) [9].

Reagents

The following reagents were used for determination of total sugar:

(a) Anthrone reagent: the reagent was prepared by dissolving 2 g of anthrone in one litre of concentrated H_2SO_4,

(b) Standard glucose solution: a standard solution of glucose was prepared by dissolving 10 mg of glucose in 100 mL of distilled water.

Extraction of Sugar from litchi pulp: Four gram of litchi flesh was cut into small pieces and immediately plunged into boiling ethyl alcohol and was allowed to boil for 5 to 10 minutes (5 to 10mL of alcohol was used per gram of pulp).

The extract was cooled and crushed thoroughly in a mortar with pestle. Then the extract was filtered through two layers of muslin cloths and the ground tissue was re extracted for three minutes in hot 80% alcohol, using 2 to 3 mL of alcohol per gram of tissue. The second extraction ensured complete removal of alcohol soluble substances. The extract was cooled and passed through two layers of muslin cloth. Both of the extracts were filtered through Whatmann no. 41 filter paper. The volume of the extract was evaporated to about 25% (1/4) of the volume over a steam bath and cooled. This reduced volume of the extract was transferred to a 100 mL volumetric flask and it was made up to the mark with distilled water.

Procedure: Aliquot of 1 mL of pulp extract was pipette into test tubes and 4 mL of the anthrone reagent was added to each of this solution and mixed well. Glass marbles were placed on top of each test tube to prevent loss of water through evaporation. Then the tubes were placed in a boiling water bath for 10 minutes and then cooled. A reagent blank was prepared by taking 1 mL of water and 4 mL of anthrone reagent in a tube and treated similarly. The absorbance of blue green solution was measured at 680 nm in a colorimeter. A standard curve of glucose was prepared and the amount of total sugar present in the extract was calculated from the standard curve of glucose. Finally, the percentage of total sugar was determined by using the following formula:

$$\text{Total sugar (g/100 g of mango)} = \frac{Quantity\ of\ sugar\ obtained}{Weight\ of\ Sample} \times 100$$

2.5 Acidity (%)

Ten ml of juice was taken and volume made up 100 ml with distilled water. Then 10 ml of this solution was taken for the purpose of titration with 0.1 N NaOH as per method described by Ranganna (1979) [16] using phenolphthalein as indicator. Titratable acidity of litchi fruits was calculated by using the following:

$$\text{Titratable acidity (\%)} = \frac{\text{Titre x Normality of alkali x equiv. wt. of acid x 1000}}{\text{Volume of Sample taken x weight or Volume of sample}}$$

2.6 Reducing sugar

The reducing sugar of litchi pulp was determined by Dinitrosalicylic acid method (Miller, 1972) [14].

Reagents

The following reagents were used for determination of total sugar:

Dinitrosalicylic acid: Dissolved by stirring one gram of DNS, 200 mg crystalline phenol and 50 mg sodium sulphate in 100 ml 1% NaOH.

40 % Rochelle salt Solution

Procedure

100 mg of sample was weighed and extracted sugar with 80 % Ethanol twice (5 ml each time). Supernatant was collected and evaporated by keeping it on water bath at 80 ^{0}C. Sugar was dissolved by adding 10 ml of distilled water. The 0.3 ml of extract was taken in test tube and volume made up to 3 ml with distilled water and added 3 ml of DNS reagent. The content was heated in a water bath for five minutes and added 1 ml of Rochelle salt. Read the absorbance at 510 nm when solution was cool. The standard glucose was made to prepare graph and calculated the amount of reducing sugar.

2.7 TSS/acidity ratio

It was calculated by dividing the total soluble solids with titratable acidity.

3. Results and Discussion

The TSS content recorded in genotype IC-0615610 (19.98 °Brix) was significantly higher than other genotypes and lowest TSS was recorded in genotype IC-0615589 (17.04 °Brix) followed by IC-0615605 (17.19 °Brix) and IC-0615587 (17.52 °Brix). The variation in TSS was also reported by (Waseem *et al*., 2002 [25], Islam *et al*., 2003 [7], Haq and Rab, 2012) [6].

Table 1: Quality attributes of different litchi genotypes

Genotypes	TSS (°Brix)	Vit-C (mg/100 g)	Titratable acidity (%)	Total Sugar (%)	Reducing Sugar (%)	TSS/Acidity ratio
IC-0615585	19.49	24.66	0.55	11.67	9.55	35.44
IC-0615586	17.75	41.06	0.53	10.05	8.12	33.49
IC-0615587	17.52	30.23	0.37	10.12	8.60	47.35
IC-0615588	17.64	28.80	0.35	10.64	8.27	50.40
IC-0615589	17.04	24.58	0.33	10.13	7.69	51.64
IC-0615590	17.90	17.32	0.38	11.08	9.75	47.11
IC-0615591	18.50	22.28	0.51	11.05	9.22	36.27
IC-0615592	18.08	24.67	0.42	12.58	8.04	43.05
IC-0615593	19.78	33.13	0.43	10.60	9.14	46.00
IC-0615594	18.15	20.57	0.33	12.77	10.58	55.00
IC-0615595	17.55	14.62	0.38	10.55	8.05	46.18
IC-0615596	19.94	40.50	0.43	10.46	9.05	46.37
IC-0615597	18.25	16.78	0.24	12.44	10.23	76.04
IC-0615598	17.65	30.62	0.54	10.80	8.08	32.69
IC-0615599	19.74	25.23	0.55	11.80	9.42	35.89
IC-0615600	18.04	24.62	0.25	12.03	10.40	72.16
C-0615601	18.55	25.67	0.23	12.25	10.78	80.65
IC-0615602	19.78	43.58	0.24	11.76	9.51	82.42
IC-0615603	19.38	24.33	0.42	12.05	10.30	46.14
IC-0615604	19.78	39.66	0.43	10.53	9.16	46.00
IC-0615605	17.19	26.15	0.51	10.85	8.13	33.71
IC-0615606	18.68	31.41	0.26	11.83	10.35	71.85
IC-0615608	18.57	24.18	0.27	11.05	9.95	68.78
IC-0615610	19.98	24.50	0.52	13.01	10.32	38.42
IC-0615611	19.23	30.55	0.51	10.88	9.30	37.71
IC-0615613	19.22	47.50	0.38	11.39	8.43	50.58
Coll. 35	17.98	22.62	0.28	13.54	10.56	64.21
Coll. 36	19.22	20.63	0.29	11.10	9.38	66.28
Coll. 37	18.65	19.73	0.28	11.05	9.03	66.61
Coll. 38	18.88	20.88	0.31	11.44	9.00	60.90
SEm ±	0.080	0.376	0.007	0.376	0.172	0.430
CD at 5%	0.228	1.066	0.021	1.067	0.489	1.222

The maximum content of ascorbic acid was found in genotypes IC-0615613 (47.50 mg/100 g) followed by IC-0615602 (43.58 mg/100 g) and IC-0615586 (41.06 mg/100 g) whereas, minimum in IC-0615595 (14.62 mg/100 g) followed by IC-0615597 (16.78 mg/100 g) and IC-0615590 (17.32 mg/100 g). Singh *et al.* (2010) [20] recorded highest ascorbic acid in cv. Rose scented (41.29 mg/100 g) and lowest in cv. Kasba (19.94 mg/100 g). The differences in ascorbic acid might be due to genetic effect of the variety. Similar varietal differences have been observed by Tripathi *et al*., (1987) [23] and Jain *et al.*, (1988) [8].

The total sugar contents of different genotypes were spread over wide ranges of 10.05-13.54%. The data regarding the total sugars revealed the highest total sugars in genotype Coll. 35 (13.54%) succeeded by IC-0615610 (13.01%) and IC-0615594 (12.77%) whereas, lowest in genotype IC-0615586 (10.05%) followed by IC-0615587 (10.12%) and IC-0615589 (10.13 %). Sucrose, fructose and glucose are found to be the major sugars in litchi (Jiang *et al*., 2006) [10]. The total sugar content of litchi fruit vary between different cultivar types (Wang *et al*., 2006) [24]. The wide variations in total sugar content in pulp were also seen by Singh and Singh, 1995[21]; Jiang *et al*., 2006 [10], Haq and Rab, 2012 [6]). Differences in sugar content might be due to maximum conversation of starch into sugar which might be related to inherent varietal character. The present results were in confirmation of Tripathi *et al.* (1987) [23], Ghosh *et al.* (1988) [5] and Jain *et al.* (1988) [8]. It seems like genotype Coll. 35 is a good sugar accumulator than the rest of the genotypes under this study.

The reducing sugar contents of litchi fruits varied significantly among different cultivars with the highest reducing sugars (10.58%), recorded in genotype IC-0615601 succeeded by IC-0615594 (10.58%) and Coll. 35 (10.56%) while lowest in genotype IC-0615589 (7.69%) followed by IC-0615592 (8.04%) and IC-061595 (8.05%). The litchi cultivars have been shown to have considerable variations have been observed in reducing sugars content of different litchi cultivars (Waseem *et al*., 2002) [25] but generally represent more than 70% of the total sugars in the aril (Jiang *et al*., 2006) [10].

The maximum titratable acidity i.e. 0.55 per cent in both the genotypes IC-0615585 and IC- 0615599 followed by 0.54 per cent in IC-0615598 and 0.53 per cent in IC-0615586 whereas, minimum in genotype IC-0615601 (0.23 %) followed by 0.24 per cent in both the genotypes IC-0615602 and IC-0615597. The highest TSS/acidity ratio of the fruit was observed in genotype IC-0615602 (84.42) followed by IC-0615601 (80.65) and IC-0615597 (70.04) whereas, lowest TSS/acidity ratio was found in genotype IC-0615598 (32.69) which was found *at par* with IC-0615586 (33.49) and IC-0615605 (33.71). Singh *et al.* (2010) [20] recorded maximum acidity in cultivar Dehradun (0.41) followed by cv. Kasba (0.40) and

minimum was recorded in cultivar Late Bedana (0.27). China recorded highest with TSS and Acid ratio (71.18) followed by Purabi (70.57) while the lowest was recorded for cultivar Kasba (50.76). These differences might be due to their inherent characters. The role of pyruvic acid in the process of respiration might be manifested and expressed in the form of titratable acidity. These differences in TSS and Acid ratio in different cultivars were due to different levels of TSS and acid in different cultivars.

Correlation coefficient

Among the chemical characters TSS significantly and positive correlated with reducing sugar (0.382) while titratable acidity was significantly and negatively correlated with reducing sugar (-0.397) and TSS/acidity ratio (-0.954). Total sugar was significantly and positive correlated with reducing sugar (0.703) and reducing sugar was significantly and positive correlated with TSS/acidity ratio.

Table 2: Correlation coefficient for quality traits in 30 litchi genotypes

	TSS	Vit-C	Titratable acidity	Total Sugar	Reducing Sugar	TSS/Acidity ratio
TSS	1	.360	.152	.196	.382*	.035
Vit-C		1	.184	-.310	-.250	-.107
Titratable acidity			1	-.265	-.397*	-.954**
Total Sugar				1	.703**	.351
Reducing Sugar					1	.523**
TSS/Acidity ratio						1

*****Correlation was significant at P = 0.01. ******Correlation was significant at P=0.5.

The study on guava shown that TSS was positive correlated with reducing sugar (Lal and Das 2017) [12]. Similarly total solublesolids and total sugar was positively correlated with reducing sugar shown by Agrawal (2010) [1] in guava, Tripathi and Gangwar (1971) [22] in guava, Chakrawar and Solanki (1981) [2] in ber, Singh *et al*. (1985) [19] in mango, Kurmi (1992) [11] and Pandey *et al.* (1997) [15] in guava. The ascorbic acid was significantly and positively correlated with TSS (0.764) and negatively correlated with total sugars (-0.924) in mango. Similarly, acidity was significantly and negatively correlated with TSS (-0.785) and with ascorbic acid (-0.765). TSS:acid ratio significantly and positively correlated with TSS (0.817) and negatively correlated with ascorbic acid (-0.825) and with acidity (-0.772). These findings are in close agreement with the findings of Chakrawar and Jathure (1980) [3] in lime, Saha (2004) [17] in lemon.

4. Conclusion

It has been stated that genotype IC-0615610 possessed highest TSS and genotype IC0615613 had maximum ascorbic acid content. Total sugar was recorded maximum in Coll. 35 while maximum reducing sugar and lowest acidity was found in IC-0615601 The maximum TSS/acidity ratio was recorded in IC-0615602 while lowest was observed in Coll. 39. TSS was significantly and positive correlated with reducing sugar while titratable acidity was significantly and negatively correlated with reducing sugar and TSS/acidity ratio. Total sugar was significantly and positive correlated with reducing sugar and reducing sugar was significantly and positive correlated with TSS/acidity ratio. TSS/acidity around 40 is the best indicator of ripening of fruit in litchi.

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