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Assessment of variability in fruit, yield and biochemical characters of acid lime (*Citrus aurantifolia* Swingle) germplasm

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Abstract
The present variability studies for fruit, yield and biochemical characters in acid lime (*Citrus aurantifolia* Swingle) were laid out at out at the All India Coordinated Research Project on Fruits, Dr.Y.S.R. Horticultural University, Citrus Research Station, Tirupati during 2020-21 and 2021-22. The experiment was conducted in Randomized Block Design (RBD) with three replications comprising forty genotypes to study variability in fruit, yield and biochemical characters. Significant variation among the genotypes was observed for fruit, yield and biochemical characters. Fruit diameter and fruit length was recorded highest in TAL/94-14 (54.87 mm and 54.95 mm respectively). With respect to number of segments per fruit, highest number of segments was recorded in BKS-4(12.33). The juice percent was highest in TAL/94-14 (54.95 mm) followed by selection-8 (54.44 mm). The Fruit weight was highest in TAL/94-14 (56.4 g). Highest fruit number and fruit yield/tree was recorded in Petlur Pulusu nimma i.e., (5358.67 and 232.72 kg/tree respectively). The Fruit rind thickness was highest in TAL/94-14 (1.66 mm). Highest total soluble solids were observed in TAL/94-13 (10.33 °Brix) and RHRL-122 (10.33 °Brix). Highest acidity percentage was recorded in KL-12 (8.04%). The ascorbic acid content was highest in Punjab lime (58.93 mg 100 ml^{-1}).

Keywords: Acid lime, fruit yield, ascorbic acid, acidity, fruit weight, fruit number

1. Introduction
Citrus fruits are gaining commercial importance and popularity around the world due to their nutritional value as well as possibility to be eaten fresh. Acid lime (*Citrus aurantifolia* Swingle) is a commercial citrus fruit crop cultivated in India with diploid chromosome number 2n=2x=18. After mandarin and sweet orange, acid lime is one of the most vital tropical citrus fruits. It is believed to have originated in South Eastern China and India.

Acid lime belongs to the Citrus genus and the Rutaceae family, but its taxonomic classification is complicated. The compatibility of Citrus species with related genera is the primary cause of this complexity, which creates confusion about the actual number of Citrus species. Many scientists proposed various botanical classifications, but the taxonomic systems proposed by Swingle and Reece (with 16 species) and Tanaka (with 162 species) were widely accepted (Swingle and Reece, 1967) [25]. Acid lime also known as Kagzi lime (Nimboo), has gained more popularity, as it can be used to make pickles and seasonal cuisine in India and other zones of the world. Acid lime is a bushy shrub covered with small sharp spines. Fruit consists of 83.88 percent moisture, 9.96 percent carbohydrate, 1.0 percent protein, 90 mg/100 ml calcium, 20 mg/100 ml phosphorus, 0.3 mg/100 ml iron and 62.90 mg/100 ml vitamin C (Waghaye *et al*. 2019) [27]. Morphological characterization helps towards effective conservation and maintenance of existing genetic diversity. Variability among different genotypes can be assessed with the help of morphological and molecular characterization and variable genotypes can be incorporated in commercial hybrid programmes to develop the desired variety with high yield.

2. Materials and Methods
The present investigation entitled "Assessment of variability in quantitative tree, leaf, floral and yield attributing characters of acid lime" was carried out during 2020-2021 and 2021-2022 at AICRP on fruits, Citrus Research Station, Tirupati, Dr. YSR Horticultural University, and Andhra Pradesh.

The experiment was conducted in Randomized Block Design (RBD) with 3 replications with forty genotypes. Age of the plants was 12 years and spacing of the plants was 6 x 6 m. Experimental material for the current investigation consists of 40 acid lime genotypes (Table.1) which are maintained at the Citrus Research Station, Tirupati.

The shape of fruit base was visually observed in five mature and recorded as necked, convex, truncate, concave, collared or collared with neck. Shape of fruit apex was observed in five mature fruits from each selected tree and recorded as mammiform, acute, rounded, truncate and depressed. Fruit surface texture of Fruits is recorded by visualization as smooth, rough, Pappilate, pitted, bumpy or grooved. The albedo colour of five fruits from each replication was visually evaluated and classified as greenish, white, yellow, pink, orange, and reddish. Pulp flesh colour was examined visually and noted as a mention in a citrus descriptor by IPGRI, Italy (Anon 1999) for five fruits in each replication and classified as white, green, yellow, orange, pink, light red, orange red, red, and purple.

The diameter of five randomly selected completely developed fruits from each replication was measured using a Vernier's callipers from the centre of the fruit, and the mean diameter was computed.

For measuring fruit length, five fruits were chosen at random from each replication, and their lengths were measured using a Vernier's callipers, and the mean length was recorded.

Five fruits were taken from each replication, and the segment count for each fruit was recorded. The average number of segments was determined.

The content of juice was recorded in percentage of juice present in endocarp of five fruits per replication in relation to fruit weight and the average was stated in per cent.

At harvesting time, five fruits from each replication were picked and the average fruit weight in grams was recorded using a digital analytical balance. The fruit number per tree was calculated by counting the fruits on each tree and the average was recorded. The total number of fruits per tree was multiplied by the average fruit weight per tree to compute total fruit yield.

Fruit rind thickness was measured with a Vernier's callipers and measurements were made at several locations on the rind of a sliced fruit, and an average was calculated.

Table 1: List of genotypes used for the study

S. No	Name of the clone	14.	Selection-7	28.	RHRL-124
1.	Tirupati acid lime/94-4	15.	Selection-8	29.	RHRL-159
2.	Tirupati acid lime/94-5	16.	Selection-16	30.	KL-12
3.	Tirupati acid lime/94-7	17.	Selection-17	31.	BKS-4
4.	Tirupati acid lime/94-8	18.	Selection-18	32.	Nalgonda
5.	Tirupati acid lime/94-9	19.	Selection-20	33.	Periakulam-1
6.	Tirupati acid lime/94-11	20.	Selection-21	34.	Balaji
7.	Tirupati acid lime/94-13	21.	Selection-25	35.	Petlur Pulusunimma
8.	Tirupati acid lime/94-14	22.	Selection-27	36.	Vikram
9.	Tirupati acid lime/94-17	23.	Selection-30	37.	Pramalini
10.	Tirupati acid lime/95-1	24.	Selection-32	38.	Punjab lime
11.	Tirupati acid lime/95-2	25.	Selection-33	39.	Akola lime
12.	Tirupati acid lime/95-3	26.	Sai-sharbati	40.	Local kagzi lime
13.	Selection-3	27.	RHRL-122		

The TSS of the fruits was measured using digital hand refractometer and the average was presented in °Brix.

In a volumetric flask, 10 ml of fruit juice was taken and 100 ml of distilled water was added. The contents were filtered using Whatman No. 1 filter paper, and a 10 ml aliquot was added in a 250-milliliter conical flask for titration against 0.1N NaOH with phenolphthalein as an indicator. The aliquot's change to a pale pink colour that lasted 15 seconds was regarded the end point, and the titratable acidity was expressed in percent citric acid (Ranganna, 1986).

Factor for acidity = 1 ml of 0.1 N NaOH = 0.0064 g of citric acid

$$\text{Acidity} = \frac{\text{Titre value x Normality of NaOH x 0.0064 x 100}}{\text{Volume of aliquot taken}}$$

Ranganna's method for estimating ascorbic acid was followed (1986). Ten milliliters of freshly extracted fruit juice was combined with 3% metaphosphoric acid, and the quantity was made up to 50 ml with 3% metaphosphoric acid. The contents were filtered using Whatman No.1 filter paper, and 10 ml of the metaphosphoric acid extract was titrated against standard 2, 6 dichlorophenol indophenol dye until pink end point achieved.

$$\text{Ascorbic acid} = \frac{\text{Titre value x Dye factor x Volume made up}}{\text{Volume taken x Weight of the sample}} \times 100$$

3. Results and Discussion

3.1 Fruit Characters

Fruit shape was recorded according to the citrus descriptors. Among all the forty acid lime genotypes studied, thirty five (87.5%) genotypes have spheroid shape and the remaining five genotypes (12.5%) were observed with ellipsoid shape. Similar results were found by Jaskani *et al*. (2006) [9] in bitter sweet orange and yuma citrange where the fruit shape was ellipsoid than pyriform and round. Dorji & Yapwattanaphum (2011) [6] also found considerable difference in fruit shape among the genotypes of mandarin. Singh *et al*. (2016) [22] also noticed spheroid, ellipsoid and obloid type of fruits, revealing considerable variations among mandarin genotypes.

The shape of fruit base was visually observed and recorded according to citrus descriptors. There was a considerable variation in shape of the fruit base among the genotypes studied, truncate fruit base was recorded in twenty seven (67.5%) genotypes and convex fruit base was recorded in thirteen (32.5%) genotypes among forty acid lime genotypes in the study. Singh *et al*. (2016) [22] also observed concave collared, collared with neck and convex shape of fruit base in mandarin genotypes.

There was a considerable variation in shape of the fruit apex among the genotypes studied, rounded fruit apex was recorded in twenty eight (70%) genotypes and mammiform fruit apex was recorded in twelve (30%) genotypes among forty acid lime genotypes in the study.

Similar results were observed from the findings of Malik *et al*. (2012) where, rounded to truncate shaped fruit apex was reported among the different varieties of sweet orange. Dorji and Yapwattanaphum (2011) [6] and Singh *et al.* (2016) [22] also observed fruit apex shape variations in mandarin.

There was a considerable variation in fruit surface texture among the genotypes, thirty six (90%) genotypes recorded smooth fruit texture and four (10%) genotypes recorded rough fruit texture. Smooth fruit surface was observed from the findings of Santos *et al*. (2003) in all the genotypes of mandarin and Singh *et al*. (2016) [22] was reported no variations in fruit surface texture among mandarin genotypes studied.

Among the forty acid lime genotypes studied no variation was present and all (100%) genotypes recorded with white albedo colour. Albedo colour was white in most of the strains except Noreo and Texas, in a study done by Harjeet *et al*. (2010) [7] among rangpur lime (*Citrus limonia* osbeck.) strains.

Fruit pulp colour among the genotypes studied showed little variation and revealed yellow pulp colour in the fruits of thirty (75%) genotypes and green pulp colour was recorded in ten (25%) genotypes.

Pulp colour also varied in study conducted by Harjeet *et al*. 2010 [7] among rangpur lime (*Citrus limonia* Osbeck.) Strains from orange to white in different strains studied. Santos *et al*. (2003) reported presence of orange pulp colour in the mandarin genotypes studied and no variations was reported.

The difference in fruit rind thickness (table 2) was found to be significant for the forty acid lime genotypes studied from a range of 0.92 mm to 1.66 mm and the mean fruit rind thickness of the genotypes recorded was 1.16 mm (table 4.13). The Fruit rind thickness was highest in TAL/94-14 (1.66 mm) followed by TAL/94-5 (1.45 mm), RHRL-124 (1.43 mm), RHRL-122 (1.43 mm) and TAL/94-11(1.43 mm) which were on par to one another and the lowest fruit rind thickness was recorded in Selection-33 (0.92 mm).

Thin rind is a desirable character in Kagzi lime for crop improvement. Thin rind may be due to the migration of food material from non-edible part of the fruit to the edible part during fruit development phase. The rind thickness declines when the juice content increases during the course of the development of the fruit and a thick rind are desirable for pickle purposes.

Results were similar to the work of Tirthakar *et al*. (2004) [26], recorded maximum rind in cv. Borgaon (1.30 mm) and minimum in cv. Maispur (1.10 mm), Srinivas *et al*. (2006) [23] identified rind thickness in Kagzi lime ranged from (1.00 to 3.00 mm). Singh *et al*. (2009) observed rind thickness ranged from (0.14 to 0.85 cm) in hill lemon. These are also supported by Deshmukh *et al*. (2015) [3] in acid lime, and Madhavi and Babu, (2003), where maximum rind thickness was recorded in cv. Jaffa (6.75 mm), followed by Blood Red Malta (6.70 mm), and minimum in cv. Valencia (6.31 mm).

The difference in fruit diameter (table 2) was found to be significant for the forty genotypes studied from a range of 32.66 mm to 54.87 mm and the mean fruit diameter of the genotypes 40.24 The fruit diameter was highest in TAL/94-14 (54.87 mm) followed by Selection-8 (53.27 mm), Local kagzi lime (52.19 mm), RHRL-49 (48 mm) the lowest fruit diameter was recorded in TAL/94-8 (32.66 mm) followed by TAL/94-9 (32.86 mm).

Enlargement of fruit in terms of diameter may be due to cell elongation and cell division. Cell division continues to take place during the initial stages of fruit growth and cell elongation occurs at later stage. These findings are identical to Tirthakar *et al*. (2004) [26] observed a fruit diameter of 5.10 cm in cv. Donagargaon, followed by Kanheri (4.75 cm), Maispur (4.13 cm) in acid lime. Similarly, Kumar *et al*. (2011) [13], observed the largest fruit diameter in the acid lime cultivar Tenali (5.86 cm). Jawandha *et al*. (2012) [10] noted that Barmasi lemon under Punjab conditions had a fruit diameter ranging from (4.04 to 6.60 cm).

Deshmukh *et al*. (2015) [3] observed that PDKV lime (3.99 cm) recorded a significantly maximum diameter of fruit followed by Sai Sharbati (3.80 cm) whereas a minimum diameter was observed in Chakradhar (3.40 cm) and Mahanthesh *et al*. (2016) recorded the fruit diameter (3.79 cm) of acid lime genotype 15-1.

The difference in fruit length (table 2) was found to be significant for the forty genotypes studied from a range of 33.79 mm to 54.95 mm and the mean fruit length of the genotypes 40.99 mm. The fruit length was highest in TAL/94-14 (54.95 mm) followed by Selection-8 (54.44 mm), local kagzi lime (50.26 mm), RHRL-159(48.88 mm) the lowest fruit length was recorded in TAL/94-8 (33.79 mm) followed by TAL/94-9(34.23 mm).

These conclusions are in accordance with Srinivas *et al*. (2006) [23] found that the largest polar diameter was (5.50 cm) in kagzi lime. Kumar *et al*. (2011) [13] noted the highest fruit length in Vikram (5.78 cm) during the second season and in the first season for the acid lime cultivar Tenali (6.02 cm). Jawandha *et al*. (2012) [10] observed fruit lengths ranging from 4.08 to 6.80 cm in Baramasi lemon. Yadlod *et al*. (2018) [28] noticed the maximum fruit length in acid lime strain LTR11 (4.95 cm).

Number of segments per fruit (table 2) among the genotypes studied differed significantly, ranging from 10.00 to 12.33 and the mean number of segments was found to be 10.81 (table 4.13). The number of segments was highest in BKS-4 (12.33) followed by KL-12 (12.00) and TAL/94-5 (12.67). TAL/94-11(12.67), TAL/94-14(12.67) and TAL/95-1(12.67) were on par to one another. The lowest value for number of segments (10) was recorded in TAL/94-4 and four other genotypes, Selection-8, Selection-20, Selection-30 and Selection-32. Considerable variations were noticed in number of segments in fruit and it might be due to differences in the size of the fruits (Diwan *et al*. 2014). Soh Bitara fuits showed more number of segments in a study by Govind and Singh (2002) in 15 citrus species and 8 hybrids.

Srinivas *et al*. (2006) [23] observed the number of segments ranged from (9.00 to 12.67) in Kagzi lime and Kamalesh *et al*. (2014) in sweet orange. The results were also supportive with the findings of Shaaban *et al*. (2006) and Santos *et al*. (2003) in mandarin.

The difference in juice percent (table 2) was found to be significant for the forty genotypes studied from a range of 42.81% to 55.94% and the mean juice percent of the genotypes was 48.34%. The juice percent was highest in Petlur Pulusunimma (54.94 %) followed by TAL/94-11 (55.23 %), Selection-20 (53.79 %) and the lowest juice

percent was recorded in TAL/94-13 (42.81 %) followed by Selection-33 (44.46 %).

These observations are in line with Desai *et al*. (1994) who found that juice per cent in Kagzi lime ranged from 33.00% to 66.66%. Shinde *et al*. (2004) [20] recorded the maximum juice content in cv. Pramalini (57.72%). Srinivas *et al*. (2006) [23] observed maximum juice content ranged from 32.80 to 62.04% in seedling strains of acid lime.

Singh *et al*. (2009) [21] observed juice content in hill lemon ranged from 33.40 to 59.60%. Shrestha *et al*. (2012) [24] noted the maximum juice content in the Terai accession of acid lime (44.10%), lowest in mid hills accession (36.80%). Mahantesh *et al*. (2015) [15] noted the highest juice content in Chakradhar (49.57%), Pramalini (48.20%), and PDKV lime (46.63%).

The difference in fruit weight (table 2) was found to be significant for the forty genotypes studied from a range of 33.9 g to 56.4 g and the mean fruit weight of the genotypes recorded was 44.1g. The Fruit weight recorded was highest in TAL/94-14 (56.4 g) followed by PKM-1 (53.6g), BKS-4 (51.8g) which were on par to one another and the lowest fruit weight was recorded in TAL/94-9 (33.9 g) followed by TAL/94-13 (34.5 g).

The fruit weight is a dependent character that influences the yield through fruit characters like fruit volume, polar and equator diameter, peel thickness, number of seeds, juice weight, and juice volume.

Results obtained were similar to the work of Sonkar *et al*. (2004) [19] on acid lime where highest fruit weight (33.44g) was recorded in Schaub Rough lemon. Similarly, Kumar *et al*. (2011) [13] reported that the maximum fruit weight (45.53 to 47.33 g) in acid lime cultivar Vikram followed by PKM-1 (44.70 - 42.53 g) during both seasons. Mahantesh *et al*. (2015) [15] identified that the cultivar PDKV lime had the highest fruit weight.

3.2 Yield characters

The difference in number of fruits per tree was found to be significant for the forty genotypes studied from a range of 1992.00 to 5358.67 and the mean fruit number of 2614.87 (Table 3). The fruit number recorded was highest in Petlur Pulusunimma (5358.67) followed by Balaji (4005.33), RHRL-49 (3160.67), Vikram (2989.33), Selection-21 (2861.33) which were on par to one another and the lowest fruit number was recorded in TAL/94-9 (1922.00) followed by TAL/94-11 (2066.67).

The primary factor affecting yield is the number of fruits per plant, which has a direct impact on its weight in Hasta bahar (58.24 g). Also, Dinesh *et al*. (2018) [5] identified the PDKV Bahar lime with the maximum fruit weight (54.31 g).

The difference in number of fruits per tree was found to be significant for the forty More vegetative development leads to a faster rate of photosynthesis and aids in the production of more fruits, may be the reason for significant difference among different acid lime clones for difference in number of fruits per tree.

Results were in line with prior research by Josan and Kaur (2006) [11] who recorded the maximum number of fruits in the Cleopatra Mandarin (2334 fruits/tree) followed by cv. Fewtrells Early (1064 fruits/tree) of Mandarin cultivars.

Srinivas *et al*. (2006) [23] noticed the fruits ranged from 250.00 -2350.00 in Kagzi lime. Kumar *et al*. (2011) [13] noticed the highest number of fruits in Vikram (384.85 to 406.35) under Tamil Nadu conditions, Mahantesh *et al*. (2015) [15] observed the maximum number of fruits per tree (760.00) in genotype 25-3 of acid lime.

The difference in total yield per tree (table 3) was found to be significant for the forty genotypes studied from a range of 67.34 kg/tree to 232.72 kg/tree and the mean yield of 114.21 kg/tree (Table 3). The fruit yield/tree recorded was highest in Petlur Pulusunimma (232.72 kg/tree) followed by Balaji (162.29 kg/tree), PKM-1 (145.75 kg/tree), Local kagzi lime(136.29 kg/tree).

Table 2: Variation in fruit physical characters among acid lime clones

Clones	Fruit rind thickness (mm)	Fruit diameter (mm)	Fruit length(mm)	Fruit weight(g)	Number of segments per fruit	juice%
TAL/94-4	1.25	37.00	37.50	34.70	10.00	48.08
TAL/94-5	1.45	38.33	39.17	45.30	11.67	46.01
TAL/94-7	1.15	40.55	41.34	38.10	10.33	46.73
TAL/94-8	1.24	32.66	33.79	41.70	10.33	46.72
TAL/94-9	1.38	32.86	34.23	33.90	11.33	49.80
TAL/94-11	1.42	36.32	37.56	38.70	11.67	55.23
TAL/94-13	1.19	45.09	46.01	34.50	10.33	42.81
TAL/94-14	1.66	54.87	54.95	56.40	11.67	47.15
TAL/94-17	1.22	39.31	40.50	43.80	10.33	46.28
TAL/95-1	0.94	36.79	35.73	36.70	11.67	46.55
TAL/95-2	1.21	42.18	43.13	40.20	10.67	49.64
TAL/95-3	0.94	41.44	41.97	39.80	10.33	48.31
SEL-3	0.95	34.63	36.88	41.40	11.33	47.24
SEL-7	1.01	38.80	40.14	43.60	10.33	47.42
SEL-8	0.94	53.27	54.44	43.80	10.00	48.64
SEL-16	1.34	33.74	35.46	43.50	11.33	48.10
SEL-17	1.10	37.62	37.00	47.30	11.66	45.96
SEL-18	1.21	38.06	38.07	46.40	10.66	46.51
SEL-20	1.03	38.85	39.55	43.70	10.00	53.79
SEL-21	0.96	38.34	39.01	47.00	10.33	46.92
SEL-25	0.95	35.07	35.70	39.00	10.66	49.67
SEL-27	0.95	39.26	39.56	45.20	10.66	45.95
SEL-30	1.13	43.85	45.52	44.70	10.00	48.67
SEL-32	1.27	42.09	43.76	46.20	10.00	44.77
SEL-33	0.92	36.18	37.18	50.50	10.66	44.46

RHRL-49	1.21	48.00	48.34	41.20	11.33	50.94
RHRL-122	1.42	41.00	42.01	46.90	10.33	53.20
RHRL-124	1.43	37.13	38.14	48.00	10.33	52.36
RHRL-159	1.22	47.88	48.88	46.80	11.66	53.02
KL-12	0.96	41.47	42.48	46.00	12.00	48.44
BKS-4	1.18	39.45	40.45	51.80	12.33	45.66
Nalgonda	1.37	40.55	41.22	47.40	10.33	47.24
PKM-1	0.96	37.60	39.27	53.60	10.66	46.60
Balaji	1.20	39.44	40.11	44.50	10.33	45.54
Petlur Pulusunimma	0.95	41.56	40.89	43.40	11.66	55.94
Vikram	1.15	34.35	34.68	42.90	10.66	49.87
Pramalini	1.02	36.05	37.39	39.70	10.33	48.57
Punjab lime	1.25	43.84	44.18	47.70	11.33	49.79
Akola Lime	1.02	42.16	43.16	47.10	11.00	50.50
Local kagzi lime	1.12	52.19	50.26	51.00	10.33	44.79
SE m±	0.04	1.2	1.21	1.58	0.33	1.41
CD @ 5 %	0.13	3.38	3.41	4.46	0.95	3.98

and BKS-4 (130.85 kg/tree), Selection-33 (130.80 kg/tree), RHRL-124 (130.27 fruits/tree) which were on par to one another and the lowest fruit yield/tree was recorded in TAL/94-9 (67.34 kg/tree) followed by TAL/95-1 (76.29 kg/tree).

The difference in total yield per hectare (table 3) was found to be significant for the forty genotypes studied from a range of 18.65 t/ha to 64.46 t/ha and the mean fruit yield of 31.93t/ha (Table 3). The fruit yield (t/ha) recorded was highest in Petlur Pulusunimma (64.46 t/ha) followed by Balaji (44.95t/ha), TAL/94-14 (40.82 t/ha), PKM-1(40.37 t/ha) and the lowest fruit yield (t/ha) was recorded in TAL/94-9 (18.65t/ha) followed by TAL/95-1 (21.13t/ha).

Yield is a dynamic and polygenic trait that is influenced by a number of vegetative and reproductive characteristics. The average weight of fruit and percentage of fruits retained per shoot is primarily responsible for the difference in yielding capacity. Results found in this experiment were similar to that of Srinivas *et al*. (2006) [23] showed fruit yield ranged from (21.43 to 101.25 kg) in seedling strains of Kagzi lime. Amar Bahadur *et al*. (2018) [2] noticed that the acid lime genotype NRCP-49 recorded the highest fruit yield ranged (50.09 kg/plant) under Terai conditions. Dinesh *et al*. (2018) [5] recorded a maximum yield in PDKV Bahar (Clone-2) (34.54 t/ha). Magno *et al*. (2015) reported that, with regard to fruit yield per plant, selection number '5059'gave highest fruit yield (153kg/tree). Dinesh *et al*. (2018) [5] reported that PDKV Bahar (Clone-2) was superior over other clones and check variety and recorded significantly maximum yield (124.92 kg/plant and 34.54 t/ha).

3.3 Biochemical Characters

Among forty genotypes studied, significant and highest total soluble solids(TSS) were observed in TAL/94-13 (10.33 °Brix) and RHRL-122 (10.33 °Brix) followed by Sel-7 (9.67 °Brix), Sel-8 (9.66 °Brix) and Sel-3 (9.66 °Brix) which were on par with each other. Whereas the least TSS was recorded in TAL 94/8 (7.33°Brix) followed by PKM-1 (8 °Brix). (table 3)

The increase in TSS might be due to the conversion of starch and their insoluble carbohydrate into a soluble form of sugar which is responsible for increasing the TSS content (Hulme, 1970). In citrus fruits, starch does not accumulate (Selvaraj and Edward, 2000) [18]. The increase in TSS content is mainly due to an increase in total sugars (Randhawa *et al*., 1964) [17].

These findings are consistent with those made earlier of Shinde *et al*. (2004) [20] in acid lime, Singh *et al*. (2009) [21] in hill lemon. Kumar *et al*. (2011) [13] observed that the highest TSS was recorded in Vikram (7.45 °Brix). Mahantesh *et al*. (2015) [15] observed highest TSS in PDKV lime (8.25 °Brix), followed by Sai Sharbati (8.20 °Brix).

Abhilash *et al*. (2017) [1] observed that the 'KLS-23' strain recorded the highest total soluble solids (7.56 °Brix) in the Vijayapura district.

The difference in acidity (table 3) was found to be significant for the forty genotypes studied from a range 5.25% to 8.04% and the mean acidity of 6.91%. Among forty genotypes studied, significant and highest acidity was observed in KL-12(8.04%) followed by Punjab lime (7.65 %), BKS-4 (7.57%) and Sel-8 (7.44%) which were on par with each other. Whereas the least acidity percentage was recorded in Local (5.25%) followed by RHRL-124 (5.63%).

During development, the acidity rises to levels that are below optimum for enzyme activity. To maintain growth and development in lemon, extracellular sucrose must be catabolized prior to reaching vacuolar p^H of 2.5. At this stage, the sucrose breakdown is occurred by hydrolysis (Ed. Echeverria, 1990). These conclusions agree with the prior findings of Shinde *et al*. (2004) [20] in Kagzi lime, the acidity range was high in cv. Kanheri No.46 (11.93%) acid lime (Tirthakar *et al*., 2004) [26]. However, results were are also in line with Srinivas *et al*. (2006) [23] in Kagzi lime, Singh *et al*. (2009) [21] in Hill lemon, Mahantesh *et al*. (2015) [15] in PDKV lime, Mahantesh *et al*. (2016) [16] in the 15-1 genotype of acid lime, Abhilash *et al*. (2017) [1] in 'KLS-23' strain of Kagzi lime and Dinesh *et al*. (2018) [5] in PDKV Bahar (Clone-2).

The difference in ascorbic acid (table 3) content among the genotypes studied was found to be significant, ranged from 44.19 to 58.93 mg 100 ml^{-1} with the mean of 51.46 mg 100 ml^{-1} The ascorbic acid content was highest in Punjab lime (58.93 mg 100 ml^{-1}), which was on par with Local (58.74 mg 100 ml^{-1} and Petluru Pulusunimma (58 mg 100 ml^{-1}) the lowest was recorded in Pramalini (48.14 mg 100 ml^{-1}), which was on par with three other genotypes.

These findings are similar to Srinivas *et al*. (2006) [23] who found that ascorbic acid range from 33.30 to 39.70 mg/ 100 ml juice in Kagzi lime. Deshmukh *et al*. (2015) [3] found maximum ascorbic acid in PDKV lime (30.33 mg/100 g) followed by Pramalini (29.13 mg/100 g). The lowest ascorbic acid content was recorded in Mangali Pattu (27.17 mg/100 g). Mahantesh *et al*. (2016) [16] noted ascorbic acid content of 32.80 mg/ 100 ml juice in the 15-1 genotype of acid lime. The

KLS-23 strain of Kagzi lime was recorded at 31.65 mg/ 100 ml juice of ascorbic acid (Abhilash *et al*., 2017) [1].

Conclusion

In perusal of data with respect to fruit characters, significant variation among the genotypes was observed for fruit, yield and biochemical characters. Thirty five (87.5%) genotypes have spheroid shape. Fruit diameter and fruit length was recorded highest in TAL/94-14 (54.87 mm and 54.95 mm respectively). With respect to number of segments per fruit, highest number of segments was recorded in BKS-4(12.33). The juice percent was highest in TAL/94-14 (54.95 mm) followed by selection-8 (54.44 mm). The Fruit weight was highest in TAL/94-14 (56.4 g). Highest fruit number and fruit yield/tree was recorded in Petlur Pulusunimma i.e., (5358.67) and (232.72 kg/tree) respectively. The Fruit rind thickness was highest in TAL/94-14 (1.66 mm). Highest total soluble solids were observed in TAL/94-13 (10.33 °Brix) and RHRL-122 (10.33 °Brix). Highest acidity percentage was recorded in KL-12 (8.04%). The ascorbic acid content was highest in Punjab lime (58.93 mg 100 ml-1).

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Conflict of Interest. None.

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