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# EVALUATION OF ACID LIME (*CITRUS AURANTIFOLIA* SWINGLE) GENOTYPES DURING *HASTH BAHAR* FOR GROWTH, YIELD AND QUALITY ATTRIBUTES

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## ABSTRACT

An experiment was conducted during 2013-2015 to evaluate 39 cluster bearing acid lime (*Citrus aurantifolia* Swingle) genotypes during *hasth bahar* at Akola for growth, fruit set, yield and quality attributes. The tree growth parameters in respect of tree height (5.10 m) and tree volume (105.16 $m^3$) was found maximum in genotype 35-2; maximum number of flower/cluster (8.00) and fruit set percentage per cluster (64.58%) was observed in 15-1. The maximum juice content (50.15%) and minimum number of seeds per fruit (4.67) was recorded in 19-7 and 36-2 respectively, the maximum number of fruits per tree (760) in 25-3 and maximum fruit weight (58.24 g) as well as fruits yield per tree (37.73 kg/tree) was recorded highest 15-1. Similarly fruit quality in respect of fruit volume (54.27 $cm^3$), fruit diameter (3.79 cm), T.S.S (8.25 Brix), acidity percentage (8.66), ascorbic acid (32.8 mg/100ml) was also found superior in genotype 15-1. The correlation among the yield contributing characters viz., fruits per cluster, fruit set percent per cluster, fruit volume and number of fruits per tree was highly significant. On the basis of yield and yield contributing characters the genotypes *viz*., 20-5 and 15-1 were found promising for future improvement programme.

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## INTRODUCTION

Acid lime (*Citrus aurantifolia* Swingle), is the third most important species of citrus in India after mandarin and sweet orange. India is largest producer of acid lime in the world (Chadha, 2002). Fruits of acid lime possess great medicinal and nutritional value. It is a rich source of vitamin "C". Fruits being acidic in nature, they are largely used for garnishing and flavouring several vegetarian and non- vegetarian dishes. Besides its value-added products like pickle, juice, squash etc., lime peel oil, peel powder are also in great demand in soap and cosmetic industry.

The soil and climatic conditions of semi arid regions in Vidarbha offers suitable condition of acid lime under irrigated and rain-fed conditions as well. However, the production of acid lime fruits is not sufficient enough to meet the local demand and distant markets under *hasth bahar* (summer crop) fruits which fetches 6 to 8 times more price than *ambia bahar* and 3-4 times than *mrig bahar*. It is possible to bridge this gap by growing acid lime in Vidarbha region of Maharashtra where there are some stray trees with fairly good performance. To necessitate the successful genotype selection and acceptance by the consumers, directional selection for yield alone cannot be the criteria in crop like citrus; instead fruit qualities are equally an essential component of decisiveness to be accepted by the consumers.

Genetically superior, disease-free propagating material is the foundation stone for a successful scientific citrus cultivation. Bud mutations have occurred fairly often in the history of citriculture and instances of their commercial exploitation are well documented (Chakrawar and Rane 1997). The different genotypes do not perform equally well in all regions due to differences in variability, adaptability and micro climatic variation. Many studies have focused on the evaluation of acid lime varieties and genotypes under different regions of India during *ambia* and *mrig bahar* (Jature and Chakrawar, 1981; Ranpise, 1993; Srinivas *et al.,* 2006 and Kumar *et al.,* 2011). The genotypic character in respect of growth parameters, flowering, fruit development and maturity varies under each genotype and from *bahar* to *bahar* (Iqbal and Karacali, 2004; Mukhim *et al.*, 2015). However there is no reported work on selection of acid lime strains for *hasth bahar,* therefore an attempt is made to find out the suitability of some acid lime genotypes for fruit yield and quality attributes under semi arid conditions during *hasth bahar*.

## MATERIALS AND METHODS

The genetic material used for the study consisted of 15 years old plant selections from acid lime growing areas of Vidarbha and Western Maharashtra, and seedling selections of acid lime. Tree spacing was maintained at 6 m X 6 m. The soil was medium black clay with 48.42 % clay and pH 8.10. Genotypes were maintained under uniform cultural conditions at AICRP on Fruit (Citrus), Dr. P.D.K.V. Akola., India. Various tree characters, fruit yield and quality characters were recorded during *hasth bahar*. Tree height and canopy diameter were converted into tree spread and tree volume. Tree spread ($m^2$) was estimated using formula Tree spread

(N-S) × Tree spread (E-W))/2. The tree volume ($m^3$) is calculated using formula: [(tree spread × tree height) × 0.85] (Tripathi *et al.,* 2016). All fruit samples were assessed for fruit weight (g), equator and polar diameter of fruit (cm), fruit volume (ml), peel thickness (mm), number of segments, juice percentage [( juice weight (g)/ fruit weight (g)) x 100] and seed number per fruit for 2 years (2014 and 15) using standard procedures. Total soluble solids (°Brix), acidity (%) and ascorbic acid (mg/ 100 ml juice) were estimated using procedures described by Ranganna (1986). The data recorded for two years in respect of all the above parameters were pooled and average of two years data were subjected to statistical analysis and for interpretation of results. The analysis of the data was analyzed by one way classification method (Panse and Sukhatme, 1978).

## RESULTS AND DISCUSSION

### Growth, yield and yield contributing parameters

The maximum tree height (5.10 m) was recorded in 35-2 genotype followed by 34-2 (4.60 m). The maximum height of the tree might be due to the vigorous growth and genetic influence. This was in concurrence with the earlier findings of Srinivas *et al.* (2006). Similarly, tree spread and tree volume is an important character which contributes significantly on yield of tree as it supports primary branches as well as secondary branches essential for fruit bearing. In the present study, the highest tree spread (17.50 $m^2$) was recorded in genotype 35-2 followed by 33-4 (16.40 $m^2$) and tree volume was found maximum in genotype 35-2 (105.16 $m^3$) followed by 34-2 (83.47 $m^3$). The maximum leaf area (18.67 $cm^2$) was recorded

**Table 1: Performance of acid lime genotypes for tree growth and fruit yield attributes**

| Genotypes | Tree height (m) | Tree spread ($m^2$) | Tree Volume ($m^3$) | Leaf area ($cm^2$) | Total chlorophyll content (mg/100g) | Flowers per cluster | Fruit set per cluster | Fruit set (%) | Number of fruits /Tree | Fruit yield / Tree (Kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 18-2 | 3.50 | 11.00 | 45.36 | 18.67 | 1.15 | 7.00 | 1.67 | 23.80 | 408 | 20.62 |
| 18-6 | 4.00 | 10.40 | 49.02 | 17.40 | 1.08 | 7.17 | 2.00 | 27.91 | 547 | 24.53 |
| 19-7 | 4.20 | 11.60 | 57.40 | 18.33 | 1.22 | 6.67 | 2.33 | 35.00 | 580 | 30.51 |
| 19-9 | 3.30 | 12.10 | 47.05 | 17.43 | 1.11 | 6.83 | 2.67 | 39.02 | 610 | 29.19 |
| 20-1 | 4.50 | 11.80 | 62.57 | 17.43 | 1.14 | 7.00 | 2.50 | 35.71 | 595 | 29.12 |
| 20-4 | 4.20 | 12.20 | 60.37 | 17.33 | 1.33 | 7.33 | 2.17 | 29.55 | 480 | 22.00 |
| 21-5 | 4.50 | 12.50 | 66.28 | 18.47 | 1.22 | 6.83 | 2.50 | 36.59 | 510 | 21.14 |
| 21-8 | 3.50 | 10.00 | 41.24 | 16.97 | 1.16 | 7.17 | 1.83 | 25.58 | 360 | 19.36 |
| 22-4 | 3.20 | 8.50 | 32.05 | 18.00 | 1.16 | 6.83 | 2.17 | 31.71 | 595 | 32.42 |
| 22-10 | 4.50 | 13.20 | 69.99 | 17.97 | 1.20 | 7.00 | 2.50 | 35.71 | 640 | 33.18 |
| 23-2 | 4.00 | 13.00 | 61.27 | 17.97 | 1.12 | 6.83 | 2.50 | 36.59 | 525 | 24.16 |
| 23-10 | 3.50 | 11.50 | 47.42 | 17.57 | 1.24 | 6.67 | 2.50 | 37.50 | 575 | 27.52 |
| 24-5 | 4.20 | 13.10 | 64.83 | 18.20 | 1.03 | 6.67 | 2.67 | 40.00 | 615 | 30.57 |
| 24-10 | 4.50 | 11.40 | 60.44 | 18.03 | 1.20 | 7.33 | 2.83 | 38.63 | 714 | 33.51 |
| 25-3 | 4.00 | 12.50 | 58.91 | 18.23 | 1.06 | 7.33 | 2.83 | 38.64 | 760 | 29.35 |
| 25-10 | 3.70 | 11.80 | 51.44 | 18.43 | 1.03 | 6.83 | 2.33 | 34.15 | 615 | 23.50 |
| 26-1 | 3.20 | 11.00 | 41.47 | 17.47 | 1.01 | 6.67 | 1.83 | 27.50 | 428 | 19.50 |
| 26-3 | 4.30 | 10.90 | 55.22 | 17.87 | 1.21 | 7.33 | 2.33 | 31.82 | 590 | 28.50 |
| 27-1 | 4.50 | 10.50 | 55.67 | 17.27 | 1.08 | 7.33 | 2.17 | 29.54 | 610 | 26.45 |
| 28-2 | 4.40 | 9.50 | 59.62 | 17.60 | 1.24 | 7.00 | 2.50 | 35.71 | 604 | 31.54 |
| 28-4 | 3.20 | 11.50 | 35.44 | 18.30 | 1.13 | 6.50 | 1.50 | 23.08 | 380 | 17.05 |
| 29-1 | 3.10 | 9.40 | 37.62 | 17.53 | 0.94 | 6.50 | 1.83 | 28.20 | 395 | 18.57 |
| 29-2 | 3.20 | 10.30 | 40.34 | 17.53 | 1.02 | 7.00 | 3.33 | 47.62 | 712 | 35.78 |
| 30-1 | 3.30 | 10.70 | 46.27 | 17.60 | 1.00 | 7.33 | 2.00 | 27.27 | 701 | 29.02 |
| 30-2 | 3.50 | 11.90 | 53.20 | 18.17 | 1.14 | 6.67 | 1.50 | 22.50 | 414 | 15.25 |
| 31-1 | 2.90 | 12.90 | 30.41 | 17.17 | 0.89 | 6.50 | 1.83 | 28.20 | 687 | 25.20 |
| 31-3 | 3.30 | 8.90 | 50.94 | 16.86 | 1.09 | 7.00 | 2.83 | 40.48 | 694 | 26.28 |
| 32-3 | 4.20 | 13.10 | 74.72 | 16.97 | 1.07 | 6.83 | 2.50 | 36.59 | 463 | 21.00 |
| 33-3 | 4.00 | 14.90 | 70.22 | 17.83 | 1.12 | 6.67 | 1.50 | 22.50 | 301 | 13.76 |
| 33-4 | 4.10 | 16.40 | 79.23 | 17.70 | 0.97 | 7.17 | 1.83 | 25.58 | 427 | 18.07 |
| 34-1 | 4.50 | 13.30 | 70.52 | 17.57 | 1.08 | 7.00 | 2.67 | 38.09 | 557 | 22.25 |
| 34-2 | 4.60 | 15.40 | 83.47 | 18.30 | 0.94 | 7.00 | 2.17 | 30.95 | 412 | 24.16 |
| 35-1 | 4.00 | 13.20 | 62.21 | 17.60 | 0.89 | 7.00 | 2.50 | 35.71 | 648 | 28.25 |
| 35-2 | 5.10 | 17.50 | 105.16 | 16.53 | 1.12 | 7.00 | 2.17 | 30.95 | 405 | 18.64 |
| 36-2 | 4.40 | 12.70 | 65.84 | 18.27 | 1.13 | 7.33 | 1.67 | 22.72 | 381 | 20.68 |
| 36-5 | 4.20 | 14.10 | 69.78 | 18.30 | 1.11 | 6.17 | 1.67 | 27.03 | 451 | 20.90 |
| 15-1 | 4.20 | 13.70 | 67.80 | 18.57 | 1.20 | 8.00 | 5.17 | 64.58 | 647 | 37.73 |
| 11-2 | 4.30 | 14.90 | 75.49 | 18.47 | 1.13 | 7.83 | 4.33 | 55.32 | 607 | 33.68 |
| PDKV Seedless | 3.50 | 10.30 | 42.48 | 16.13 | 1.22 | 6.83 | 1.50 | 21.95 | 280 | 12.86 |
| Sum | 153.30 | 473.60 | 2248.76 | 692.04 | 43.18 | 272.16 | 91.33 | 1299.97 | 20923.00 | 975.80 |
| Avg. | 3.93 | 12.14 | 57.66 | 17.74 | 1.10 | 6.97 | 2.34 | 33.33 | 536.48 | 25.02 |
| Std.dev. | 0.54 | 1.98 | 15.42 | 0.58 | 0.10 | 0.35 | 0.72 | 8.85 | 125.05 | 6.25 |
| SE (m) ± | 0.08 | 0.31 | 2.47 | 0.09 | 0.02 | 0.05 | 0.12 | 1.41 | 20.02 | 1.00 |

**Table 2: Performance of acid lime genotypes for fruit quality attributes**

| Genotypes | Fruit weight (g) | Polar diameter (cm) | Equator diameter (cm) | Fruit volume (ml) | Peel thickness (mm) | Number of seeds per fruit | Number of segments | Juice percentage | T.S.S. (°Brix) | Ascorbic acid content (mg/100ml) | Acidity (%) | T.S.S. Acidity ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18-2 | 50.40 | 3.51 | 3.46 | 46.51 | 2.87 | 10.33 | 10.00 | 49.03 | 7.38 | 26.00 | 6.74 | 1.10 |
| 18-6 | 44.67 | 3.65 | 3.60 | 41.54 | 2.32 | 10.67 | 10.17 | 43.57 | 7.33 | 25.42 | 6.83 | 1.07 |
| 19-7 | 51.78 | 3.53 | 3.42 | 47.63 | 2.31 | 10.67 | 10.00 | 50.15 | 7.38 | 26.57 | 7.24 | 0.96 |
| 19-9 | 48.00 | 3.33 | 3.42 | 45.12 | 1.93 | 10.00 | 10.00 | 49.24 | 7.58 | 27.23 | 7.61 | 1.00 |
| 20-1 | 54.53 | 3.53 | 3.47 | 50.71 | 2.67 | 10.83 | 10.00 | 45.05 | 7.38 | 24.66 | 7.17 | 1.03 |
| 20-4 | 45.52 | 3.56 | 3.41 | 42.33 | 2.23 | 9.83 | 10.00 | 44.30 | 7.33 | 25.42 | 6.95 | 1.05 |
| 21-5 | 41.15 | 3.55 | 3.30 | 39.79 | 2.43 | 9.67 | 10.00 | 38.75 | 7.83 | 25.88 | 7.30 | 1.07 |
| 21-8 | 53.42 | 3.23 | 3.09 | 49.68 | 2.62 | 10.00 | 10.00 | 44.47 | 7.90 | 26.80 | 7.64 | 1.03 |
| 22-4 | 54.07 | 3.38 | 3.17 | 49.74 | 2.08 | 10.50 | 10.00 | 47.20 | 7.58 | 26.34 | 7.59 | 1.00 |
| 22-10 | 51.43 | 3.48 | 3.25 | 47.70 | 2.57 | 10.33 | 10.00 | 48.92 | 7.70 | 27.73 | 7.25 | 1.06 |
| 23-2 | 45.90 | 3.37 | 3.20 | 42.36 | 2.53 | 10.33 | 9.67 | 47.28 | 7.85 | 24.96 | 7.68 | 1.02 |
| 23-10 | 48.32 | 3.43 | 3.22 | 43.97 | 2.37 | 10.17 | 10.00 | 43.70 | 7.77 | 27.04 | 8.19 | 0.95 |
| 24-5 | 49.73 | 3.52 | 3.33 | 45.74 | 1.98 | 9.67 | 10.00 | 37.71 | 8.08 | 28.88 | 8.06 | 1.00 |
| 24-10 | 46.60 | 3.18 | 3.12 | 43.19 | 2.57 | 10.00 | 10.00 | 42.56 | 8.18 | 29.58 | 8.39 | 0.98 |
| 25-3 | 38.53 | 3.42 | 3.27 | 36.21 | 2.38 | 10.00 | 10.00 | 40.10 | 8.18 | 29.12 | 7.34 | 1.12 |
| 25-10 | 38.38 | 3.07 | 2.93 | 35.19 | 2.25 | 9.67 | 10.00 | 33.50 | 7.55 | 26.81 | 7.94 | 0.95 |
| 26-1 | 45.18 | 3.28 | 3.12 | 41.86 | 2.10 | 10.00 | 10.00 | 38.59 | 7.62 | 26.80 | 7.89 | 0.96 |
| 26-3 | 48.00 | 3.27 | 3.19 | 45.60 | 1.97 | 9.67 | 10.00 | 40.70 | 7.53 | 27.73 | 8.06 | 0.93 |
| 27-1 | 44.42 | 3.45 | 3.25 | 39.94 | 2.22 | 6.17 | 10.00 | 38.86 | 7.95 | 27.73 | 7.94 | 1.00 |
| 28-2 | 45.33 | 3.00 | 3.00 | 48.05 | 2.30 | 10.17 | 10.00 | 40.01 | 7.52 | 27.04 | 7.30 | 1.03 |
| 28-4 | 51.90 | 3.70 | 3.58 | 47.22 | 1.88 | 10.50 | 10.00 | 35.24 | 7.45 | 29.58 | 7.93 | 0.93 |
| 29-1 | 44.73 | 3.35 | 3.10 | 43.12 | 2.08 | 10.00 | 10.00 | 38.80 | 7.46 | 27.73 | 8.28 | 0.90 |
| 29-2 | 46.56 | 3.08 | 3.08 | 43.30 | 2.08 | 10.00 | 10.00 | 44.67 | 7.51 | 22.64 | 7.68 | 0.98 |
| 30-1 | 43.95 | 3.22 | 3.20 | 38.10 | 2.32 | 10.00 | 10.00 | 42.73 | 7.61 | 29.35 | 7.72 | 0.99 |
| 30-2 | 41.30 | 3.38 | 3.25 | 38.86 | 2.32 | 10.17 | 10.00 | 38.85 | 7.45 | 31.43 | 7.77 | 0.96 |
| 31-1 | 36.80 | 3.43 | 3.09 | 34.16 | 1.87 | 5.83 | 10.50 | 39.89 | 7.47 | 30.04 | 7.72 | 0.97 |
| 31-3 | 37.07 | 3.17 | 3.12 | 34.13 | 2.31 | 10.50 | 10.00 | 37.93 | 7.54 | 29.49 | 7.34 | 1.03 |
| 32-3 | 45.17 | 3.22 | 3.14 | 41.72 | 2.03 | 9.17 | 10.00 | 38.73 | 7.57 | 31.20 | 7.42 | 1.02 |
| 33-3 | 45.57 | 3.32 | 3.19 | 42.06 | 2.08 | 9.83 | 10.00 | 47.00 | 7.45 | 30.50 | 8.06 | 0.92 |
| 33-4 | 42.03 | 3.28 | 3.25 | 38.82 | 2.17 | 10.17 | 10.17 | 41.96 | 7.47 | 27.96 | 6.91 | 1.08 |
| 34-1 | 43.23 | 3.34 | 3.18 | 39.92 | 2.38 | 10.00 | 10.00 | 40.01 | 7.53 | 27.04 | 7.55 | 1.00 |
| 34-2 | 47.90 | 3.30 | 3.20 | 44.64 | 2.33 | 10.17 | 10.00 | 44.26 | 7.47 | 27.73 | 7.30 | 1.02 |
| 35-1 | 43.56 | 3.50 | 3.14 | 40.12 | 2.22 | 10.17 | 10.00 | 38.96 | 7.47 | 25.42 | 7.98 | 0.94 |
| 35-2 | 52.02 | 3.31 | 3.17 | 42.36 | 2.33 | 10.33 | 10.00 | 39.89 | 7.64 | 24.49 | 7.94 | 0.96 |
| 36-2 | 54.20 | 3.29 | 3.17 | 49.32 | 2.27 | 4.67 | 10.00 | 44.18 | 8.00 | 31.43 | 7.13 | 1.12 |
| 36-5 | 50.26 | 3.29 | 3.18 | 46.36 | 2.07 | 10.17 | 10.00 | 40.51 | 8.17 | 30.50 | 7.55 | 1.08 |
| 15-1 | 58.24 | 3.83 | 3.80 | 54.27 | 1.72 | 10.00 | 10.00 | 46.63 | 8.25 | 32.81 | 8.66 | 0.95 |
| 11-2 | 55.53 | 3.67 | 3.57 | 51.06 | 1.88 | 10.83 | 9.83 | 45.21 | 8.20 | 31.43 | 8.41 | 0.92 |
| PDKV Seedless | 46.22 | 3.18 | 3.08 | 42.28 | 1.68 | 1.50 | 10 | 44.02 | 7.89 | 30.04 | 7.42 | 1.10 |
| Sum | 1831.59 | 131.60 | 126.69 | 1694.68 | 86.72 | 372.69 | 390.34 | 1653.16 | 299.22 | 1088.55 | 297.88 | 38.54 |
| Avg. | 46.96 | 3.37 | 3.25 | 43.45 | 2.22 | 9.55 | 10.00 | 42.38 | 7.67 | 27.91 | 7.63 | 0.98 |
| Std.dev. | 5.21 | 0.18 | 0.18 | 4.79 | 0.26 | 1.84 | 0.10 | 4.03 | 0.27 | 2.31 | 0.45 | 0.13 |
| SE (m)± | 0.83 | 0.03 | 0.03 | 0.76 | 0.04 | 0.29 | 0.01 | 0.64 | 0.04 | 0.37 | 0.07 | 0.02 |

in 18-2, where total chlorophyll content (1.33 mg/100g) was recorded maximum in 20-4 genotype. The variation in chlorophyll content may be due to the age of tree, stage of reproduction and dormancy period.

Acid lime usually produces a large number of flowers over the year. The floral load depends on the cultivar, tree age and environmental conditions (Monselise, 1986). In acid lime fruits are clustered in most of the time. The maximum number of flowers per cluster and fruits set per cluster (8.00, 5.17) was recorded in genotype 15-1 followed by 11-2 (7.83, 4.33). Similarly, the maximum percent of fruit set per cluster (64.58%) was recorded in 15-1 genotype followed by 11-2 (55.32 %) which may be due to genetically potential of producing more pin type flower. The lower percentage of fruit setting might be due to self-incompatibility. Greater fruit set was observed in the leafy than in the leafless inflorescence, although the variation was not significant (Iqbal and Karacali, 2004).

The number of fruits per tree showed wide variance among the genotypes studied and was the highest in genotype 25-3 (760.00) followed by 24-10 (714.00) and 29-2 (712.00). The higher number of fruits per tree obtained may be due to more vegetative growth result to high rate of photosynthesis and helps in more number of fruits. These results were in concurrence with the earlier findings of Jature and Chakrawar (1981) who found significant variation in the fruit number which ranged from 600 to 2100 in the kagzi lime clones. Similarly, fruit yield per tree also varied widely among the genotypes studied. The genotype 15-1 recorded highest fruit

**Table 3: Estimates of phenotypic correlation coefficient (r) among characters**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | ‘15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.598$^{**}$ | 0.863$^{**}$ | 0.240 | 0.206 | 0.142 | 0.148 | 0.193 | 0.141 | 0.238 | 0.265 | 0.085 | 0.059 | 0.263 | -0.042 | -0.089 | 0.29 | -0.005 | 0.133 |
| 2 | | 1 | 0.918$^{**}$ | 0.197 | 0.182 | 0.032 | 0.056 | -0.04 | 0.017 | -0.04 | 0.013 | 0.23 | 0.001 | 0.125 | 0.168 | 0.004 | -0.122 | -0.192 | -0.142 |
| 3 | | | 1 | 0.243 | 0.219 | 0.087 | 0.103 | 0.082 | 0.081 | 0.098 | 0.137 | 0.184 | 0.028 | 0.208 | 0.075 | -0.033 | 0.061 | -0.126 | -0.023 |
| 4 | | | | 1 | 0.986$^{**}$ | 0.242 | 0.404$^{*}$ | 0.089 | 0.383$^{*}$ | 0.307 | -0.193 | 0.279 | 0.176 | 0.449$^{**}$ | 0.107 | 0.412$^{**}$ | 0.130 | 0.597$^{**}$ | 0.755$^{**}$ |
| 5 | | | | | 1 | 0.233 | 0.347$^{*}$ | 0.053 | 0.332$^{*}$ | 0.272 | -0.189 | 0.315 | 0.147 | 0.418$^{**}$ | 0.051 | 0.414$^{**}$ | 0.100 | 0.630$^{**}$ | 0.769$^{**}$ |
| 6 | | | | | | 1 | 0.374$^{*}$ | 0.039 | 0.391$^{*}$ | 0.301 | 0.136 | 0.388$^{*}$ | 0.118 | 0.225 | 0.190 | 0.094 | 0.063 | 0.15 | 0.284 |
| 7 | | | | | | | 1 | 0.368$^{*}$ | 0.973$^{**}$ | 0.471$^{**}$ | -0.109 | 0.274 | 0.364$^{*}$ | 0.088 | 0.139 | -0.02 | 0.278 | 0.042 | 0.232 |
| 8 | | | | | | | | 1 | 0.332$^{*}$ | 0.863$^{**}$ | -0.079 | -0.118 | 0.520$^{**}$ | 0.225 | 0.020 | 0.06 | 0.448$^{**}$ | -0.332$^{*}$ | 0.105 |
| 9 | | | | | | | | | 1 | 0.433$^{**}$ | -0.121 | 0.24 | 0.294 | 0.104 | 0.133 | 0.042 | 0.228 | 0.044 | 0.210 |
| 10 | | | | | | | | | | 1 | -0.045 | 0.15 | 0.533$^{**}$ | 0.251 | 0.056 | 0.117 | 0.459$^{**}$ | -0.173 | 0.322$^{*}$ |
| 11 | | | | | | | | | | | 1 | 0.363$^{*}$ | 0.195 | -0.157 | -0.458$^{**}$ | -0.432$^{**}$ | 0.155 | 0.059 | 0.005 |
| 12 | | | | | | | | | | | | 1 | 0.069 | -0.221 | -0.314 | 0.064 | 0.007 | 0.254 | 0.311 |
| 13 | | | | | | | | | | | | | 1 | -0.004 | -0.132 | -0.238 | 0.369$^{*}$ | -0.024 | 0.291 |
| 14 | | | | | | | | | | | | | | 1 | 0.463$^{**}$ | 0.430$^{**}$ | 0.173 | 0.187 | 0.283 |
| 15 | | | | | | | | | | | | | | | 1 | 0.321$^{*}$ | 0.004 | -0.109 | -0.108 |
| 16 | | | | | | | | | | | | | | | | 1 | -0.104 | 0.176 | 0.231 |
| 17 | | | | | | | | | | | | | | | | | 1 | -0.111 | 0.087 |
| 18 | | | | | | | | | | | | | | | | | | 1 | 0.854$^{**}$ |
| 19 | | | | | | | | | | | | | | | | | | | 1 |

| | | | |
|---|---|---|---|
| 1. Tree height | 2. Tree spread | 3. Tree volume | 4. Fruits per cluster |
| 5. Fruit set percent per cluster | 6. Leaf area | 7. Equator diameter | 8. Fruit weight |
| 9. Fruit size | 10.Fruit volume | 11. Peel thickness (mm) | 12. Number of seeds per fruit |
| 13.Juice per cent (%) | 14.Total soluble solids($^0$Brix) | 15. Ascorbic acid | 16. Acidity (%) |
| 17.Total chlorophyll content (mg/100gm) | 18. Number of fruit per tree | 19. Fruit yield per tree | |

yield (37.73 kg/tree) followed by 29-2 with 35.78 kg/tree. Yield being a polygenic and complex character, is determined by various vegetative and reproductive characters. This differential yielding ability is primarily ascribed to number of fruits retained per shoot and average fruit weight. This implies that the selection for more fruit number will automatically lead to higher yield. These results are in line with Jature and Chakrawar (1981) and Srinivas *et al.* (2006).

**Fruit growth and development**

Fruit growth and development is an important aspect in any fruit crop. This indicates the rate of fruit growth and decides the size of the fruit. Highly significant variation was observed among the different acid lime genotypes for fruit length, fruit diameter, average fruit weight and volume of fruit. The maximum fruit weight (58.24 g) was recorded in 15-1, followed by 11-2 (55.53 g), 20-1 (54.53 g) and 36-2 (54.20 g) during *hastha bahar*. The minimum fruit weight was recorded in 31-1 (36.80 g). It might be due to the more fruit diameter and juice content in these genotypes. Fruit weight is positively correlated with number of seeds (Table 3) and in the present study genotype 31-1 exhibited less number of seed. These results support the earlier findings made by Desai and Ranpise (1995).

The results of *hastha bahar* indicated that the genotype 15-1 and 29-2 recorded equator diameter and polar diameter of 3.83 cm, 3.80 cm and 3.67 cm, 3.57 cm respectively. The polar and equator diameter enlargement of fruit in terms of diameter which may be due to both cell elongation and cell division. Hulme (1970) reported cell division continued to take place during initial stages of fruit growth and at later stage, only cell elongation occurred. These results are in accordance with the earlier findings of Srinivas *et al.* (2006).

Less number of seeds per fruit is a desirable character in acid lime. The seedless fruit are generally smaller in fruit size (Chao, 2005). In the *hastha bahar* season, data showed that the average minimum numbers of seeds per fruits were recorded in the genotype PDKV Seedless genotype (1.50 seeds/ fruit) followed by 36-2 (4.67seeds /fruit) and 31-1 (5.83seeds/ fruit) during *hastha bahar*. The fruit development is linked to the development of the ovule; it is possible that a hormonal stimulus from the seeds regulates fruit growth. Pollen has been found to play a role in fruit size and generally larger fruit with more seeds are produced if more pollen is applied to the stigma of the flower (Ladaniya, 2008). Similarly, the genotype with large size fruit *i.e.* 15-1, 11-2 and 20-1 recorded 10.00, 10.83 and 10.83 seeds per fruit respectively. Similar results were reported by Desai and Ranpise (1995).

The maximum number of segments (10.50) was recorded in 31-1 while minimum in 23-2 (9.67). The genotypes PDKV seedless and 15-1 recorded minimum peel thickness i.e. 1.68 and 1.72 mm respectively. While maximum peel thickness was recorded in 18-2 (2.87 mm). It may be due to the development of fruit where in the stored food material from the non-edible part of fruit might have been translocated to the edible part (Khodade, 1987).

The results elucidated that the maximum juice per cent (50.15) was recorded in the genotype 19-7 followed by 19-9 (49.03) and 22-10 (48.92) whereas, minimum juice per cent in 25-10 (33.50). This could be due to the production of proportionately more juice in properly developed bigger sized fruits than the smaller. The juice content of fruit is highly positive correlated with fruit volume (Table 3).

**Quality characters**

The analysis showed that the maximum total soluble solid (8.25 $^0$Brix) was recorded in the genotype 15-1 followed by 11-2 (8.20 $^0$Brix) and 25-3 (8.18 $^0$Brix). The increase in TSS might be due to conversion of starch and their insoluble carbohydrate into soluble form of sugar which is responsible for increasing the TSS content (Hulme, 1970). The highest ascorbic acid (32.81mg/100 ml) was recorded in 15-1 followed by 11-2, 36-2 and 30-2 genotypes each with 31.43 mg/100 ml. The increase in ascorbic acid was associated with rapid increase in total sugar as the fruit synthesizes ascorbic acid from hexose sugar precursors (Mapson, 1970). These results are in conformity with the earlier findings of Srinivas *et al*. (2006), Mukhim *et al*. (2005).

The analysis results of summer seasons showed that the maximum titrable acidity (8.66 %) was recorded in the 15-1 followed by 11-2 (8.41 %) and 24-10 (8.39 %). The acidity increases during development reaching levels below optimal for enzymatic activity. Prior to reaching vacuolar acid levels that can sustain physiological rates of acid hydrolysis, imported sucrose must be catabolised to support growth and development in lemon (Echeverria, 1990). These results are in conformity with the earlier findings of Jature and Chakrawar (1981). The TSS to acid ratio is an important determination of the eating quality of citrus fruit and is used to determine the fruit's maturity (Van Rensburg, 1985). The maximum TSS acid ratio (1.12) was reported in 36-2 and 25-3. Immature fruit have low TSS content and a high acid, as the fruit mature the TSS increase and the acid level drops, bringing about an increase in the ratio (Van Rensburg, 1985).

**Correlation**

An estimate of association of various characters is a useful aid for effective selections from the population. In present study, correlations were worked out for different characters for interest. It was observed that the number of fruits per cluster, fruit set per cluster and number of fruits per tree had association with other characters mostly in desirable direction. It had significant positive correlation with fruit set percent per cluster, equator diameter of fruit, fruit size, total soluble solids, acidity, number of fruits per tree, and fruit yield per tree.

It was observed that the tree height, had association with other characters mostly in desirable direction (Table 3). It had positively and significantly correlated with tree spread and tree volume which were helpful. Whereas, negatively and non-significantly correlation with ascorbic acid, acidity and number of fruits per tree. Tree spread was positively and significantly correlated with tree volume and tree spread. Whereas the average number of fruits per cluster were positively and significantly correlated with fruit set percent per cluster, equator diameter, fruit size, total soluble solids, acidity, number of fruits per tree and fruit yield per tree.

The important attribute, Fruit weight was positively and significantly correlated with equator diameter, fruit size, fruit volume and juice percentage. While non significant correlation with the tree height, tree volume, number of fruits per cluster, fruit set percent per cluster, leaf area, number of seeds per fruit, total soluble solids, ascorbic acid, chlorophyll content, number of fruits per tree and fruit yield per tree . Peel thickness was positively and significantly correlated with number of seeds per fruit. It had negative and significant correlation with ascorbic acid and acidity. Juice percentage was positively and significantly correlated with equator diameter, fruit weight, fruit volume and chlorophyll content. Whereas negative and non significant correlation with total soluble solids, ascorbic acid, acidity and fruit yield per tree. But the total soluble solids revealed positive association with number of fruits per cluster, fruit set percent per cluster, ascorbic acid and acidity.

Ascorbic acid was positively and significantly correlated with total soluble solids and acidity (Table 3). Similar finding was also reported by Patel *et al*. (2015) in guava. But Acidity content was positively and significantly correlated with the number of fruits per cluster, fruit set percent per cluster, total soluble solids and ascorbic acid content.

The number of fruits per tree was positively and significantly correlated with fruits per cluster, fruit set percent per cluster and fruit yield per tree. The Fruit yield per tree was positively and significantly correlated with fruits per cluster, fruit set percent per cluster and fruit volume. Similar results were obtained by Patel *et al*. (2015) in guava. Whereas the non-significantly correlated with tree height, leaf area, equator diameter, fruit weight, fruit size, peel thickness, number of seeds per fruits, juice percent, total soluble solids, acidity and chlorophyll content. Somewhat similar nature of character association in acid lime was also observed by Chakrawar and Jature (1980) and Ranpise (1993).

From these findings, it is evident that there exists a significant variability among acid lime collections. These can be utilized for commercial cultivation while other genotypes which are superior in one or other traits may be utilized in breeding programmes. The genotypes 20-5 and 15-1 showed promising results for fruit yield and quality attributes.

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