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# Comparative seasonal influence of *Kuliana lime* for fruit and yield parameters under Bhubaneswar condition

**S. MISHRA AND D. K. DASH**

*Department of Fruit Science and Horticulture Technology,*
*College of Agriculture, OUAT, BBSR-03, India*

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## ABSTRACT

*Kuliana lime is an elite cultivar of Odisha. This research was conducted at Orissa University of Agriculture and Technology during 2016–17 to study the physiological and biometrical observations on fruit and yield attributes. The best season for yield has determined on the idea of seasonal performances as inter-seasonal variation has tremendous effect for yield. Spring season produced the best effect for fruit weight (32.11 g), specific gravity (1.30 g.cc$^{-1}$), fruit set (91.6 per cent), fruit retention (25.18 per cent), fruit per plant (132.80), yield plant$^{-1}$ (4.24 kg) and less duration for fruit maturity (113.44). Rainy season performs better with respect to fruit size (length and diameter was 4.68 cm and 4.39 cm respectively) and fruit volume (29.68 cc). Our results illustrated that the climactic condition was optimum during the spring season in fruit and yield attributes hence suggested to take up bahar treatment to induce the spring season flowering for better yield.*

***Keywords****:* Acid lime, fruit size, fruit set, fruit retention, kuliana lime, seed weight, yield

Citrus (*Citrus* sp.) is the world's leading tree-fruit crop comprising of many tree species and the third most important fruit crop in India. It occupies a place of considerable importance in the fruit economy of our nation. Acid lime (*Citrus aurantifolia* Swingle) was originated in India and spread other tropical and subtropical countries (Salunkhe and Desai, 1984). The important citrus producing countries are Brazil, Spain, USA, Israel, Morocco, China, Mexico, Russia, India, Canada and South Africa. In India, it is cultivated in 1.055 Mha area with a production of 12.746 MT, among which lemon and lime contribute about 0.255 Mha in area, 2.523 MT on production. The major producing states are Maharastra, Andhra Pradesh, Punjab, Odisha *etc*., (NHB, 2017). Odisha accounts for 9.37 per cent and ranked 4$^{th}$ to the national production of citrus fruits. Mayurbhanj, Keonjhar, Koraput, Ganjam, Gajapati and Dhenkanal are the major lime growing areas in Odisha. The area and production of lime and lemon is 27.97 thousand ha and 261.50 thousand tonne respectively in Odisha (Ministry of Agriculture and Farmer Welfare, 2017). Kuliana lime is a local elite land race of Mayurbhanj district of Odisha, where it is extensively grown as the hot summer and cool winter climate of the area is highly suitable for its cultivation (Mishra, 2017 and Mishra *et al*., 2018). This local elite acid lime land race is traditionally grown in village Kuliana. It is widely popular in the state for its size and juice content (Mishra and Dash, 2018a). Since the lime plant features a wide adaptability to soil and climate, it's necessary to enhance this fruit crop through planned breeding. Hence as a prerequisite, it is essential to study the effective season on yield attributes of this variety which might provides the useful information regarding the potential of the crop in utilizing for further crop improvement.

## MATERIALS AND METHODS

This experiment was conducted on 4 years old air layered acid lime cultivar Kuliana lime, planted at a spacing of 4 × 4m at Horticultural Research Station, Department of Fruit Science and Horticultural Technology, College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, India, for three seasons (rainy, winter and spring) during May 2016 to March 2017. The duration of rainy season (RS) was from July-2016 to September-2016, the winter season (WS) from October-2016 to December-2016 and that of the spring season (SS) was from January-2016 to March-2017 in Bhubaneswar condition. The experimental site is under 18$^{th}$ agro climatic region of the country (Eastern Coastal Plain) and termed as sub humid. The climate of which is warm, humid with distinct summer, rainy and winter seasons. The present experiment was conducted in "Random Effect Model under Proc Mixed through Statistical Analysis System (SAS) software" with three seasons as treatments each replicated ten times.

The maximum equatorial diameter and polar diameter of fruit was measured with vernier caliper and described as length (cm) and diameter (cm). Fruit volume (ml) was measured by using the water displacement method. Weight of fruit (g) was recorded by electrical balance. The specific gravity (g/cc) of fruit was calculated by dividing fruit weight with volume. Seed number and weight (g) were determined by counting and

*Email : subhrajyoti.ss235@gmail.com*

electronic balance respectively. The rind thickness (mm) of fruit was measured by vernier calliper. After extracting the juice and seed from fruit the remaining part of the fruit was weighed on an electronic balance and the value obtained was assigned as the pulp or rag weight (g). Fifty freshly opened hermaphrodite flowers were tagged randomly in each plant. After seven day, the numbers of fruit set was recorded and converted to percentage. The numbers of fruit which reach maturity were recorded and fruit retention percentage was calculated. Fruits of each tree in every season were counted at each harvesting and presented as number of fruit/ tree. Soon after fruit set ten fruits of each replication were tagged and the average time taken for maturity was determined. At each picking, the weight of the harvested fruits from each tree was recorded separately and yield per tree (kg) was calculated.

## RESULTS AND DISCUSSION

### Fruit size and volume

Among the three seasons RS was significantly superior on average length of the fruit (Table 1) followed by SS and WS. An average increase of 0.24 cm fruit length has been observed in RS season over the WS (P= 0.04) and the impact of SS in increasing fruit length was at par with the RS. Similar observation has reported for fruit diameter in which WS was at par with that of the SS. RS shows an increase in fruit diameter of 0.26 cm (P= 0.0027) and 0.25 cm (P= 0.0034) over WS and SS respectively. RS recorded maximum mean fruit volume which is statistically superior to other two seasons. The impact of RS for increasing the fruit volume over WS was significant (P= 0.0012) and an increase of 8.76 cc has been recorded. RS and SS over the WS have similar influence in increasing the fruit volume of Kuliana lime (Table 1). Maximum fruit size and volume of the RS was might be due to the availability of abundant soil moisture, which helps the cells to maintain in turgid condition. Higher osmotic potential of the cell in that season helps in growth and enlargement of the fruit. Relatively less fruit size was recorded in SS, might be attributed to the higher fruit retention in plant resulting in competition among the developing fruits for a limited supply of metabolites as fruit size was inversely related to crop load. The results are similar to the observations of Cooper *et al*. (1963), Guardiola (1997), Gaikwad (2003) and Tirthakar *et al.* (2004).

### Fruit weight

Fruit weight of SS was statistically superior over RS and WS. An average of 12.71 g increase in fruit weight has been observed in SS over WS (P<0.0001) and 9.55 g increase in RS over WS (P=0007). The impact of SS in increasing fruit length is at par with the RS (Table 1). Hence both the SS and RS have significant influence on increasing the fruit weight over the WS, however the Influence of SS was superior. The maximum fruit weight of the SS might be attributed to the efficient production of photosynthate as the SS foliage has maximum quantity of chlorophyll (Mishra and Dash, 2018a). The climatic condition during the fruit maturity in this season was moderate to optimum which might reserve most of the produced dry matter for fruit development (Tomer and Singh, 1988; Sema and Sanyal, 2002 and Xie *et al*., 2012).

### Fruit specific gravity

Maximum fruit specific gravity was obtained in the SS which is statistically superior over RS and WS. The increase in average specific gravity of fruit of SS over WS (0.37 g $cc^{-1}$) and RS (0.33 g $cc^{-1}$) and were significant at P <0.0001 each (Table 1). The effect of RS over WS was at par in increasing the specific gravity of the fruit. Maximum fruit specific gravity of SS might be the result of increased fruit weight and reduced fruit volume during this season.

### Number and weight of seeds $fruit^{-1}$

SS recorded the highest number of seed/ fruit which was statistically superior over other two seasons. The number of seeds/ fruit in WS was at par with RS (Table 2). SS recorded an increase of 3.86 and 3.82 in average number of seeds over the RS and WS respectively (P <0.0001 each). The SS and WS have similar influence in increasing the average seed weight per fruit of Kuliana lime. Maximum weight of seeds/ fruit was observed in WS which was statistically superior over SS and RS. SS and WS recorded an average increase of 0.165 g and 0.20 g seed weight over the RS at P= 0.0005 and P < 0.0001 respectively. SS recorded maximum number of seed may be due to higher pollination activity as the viable pollen in this season is more (Mishra and Dash, 2018b). We observed positively significant relation between number and weight seed/ fruit (Siddappa, 1952). Bearing and nutrient status of the plant has tremendous effect on number and weight of seed. The total days taken for fruit maturity (Table 3) was more during WS, might hasten seed growth resulting in maximum seed weight (Paudyal and Shrestha, 2004).

### Number of segments and weight of rag per fruit

WS recorded the maximum number of segments $fruit^{-1}$ which was at par with SS while RS recorded the lowest (Table 2). All the three season have similar influence on segment numbers in fruit. Hence this parameter was not affected by a particular season (Loussert, 1992 and Vand and Abdullah, 2012). The SS

**Table 1: Influence of season on length, diameter, volume, weight and specific gravity of fruit in Kuliana lime**

| Season | Plant | Length of fruit (cm) | Diameter of fruit (cm) | Volume of fruit (cc) | Weight of fruit (g) | Fruit Specific gravity (g $cc^{-1}$) |
|---|---|---|---|---|---|---|
| Rainy | 1 | 5.1 | 4.7 | 39.97 | 38.5 | 0.96 |
| | 2 | 3.76 | 3.96 | 20.6 | 15.6 | 0.76 |
| | 3 | 5.23 | 4.9 | 37.1 | 39.5 | 1.06 |
| | 4 | 5.03 | 4.86 | 41.26 | 35.9 | 0.87 |
| | 5 | 4.73 | 4.33 | 23 | 24.8 | 1.07 |
| | 6 | 4.83 | 4.29 | 30.85 | 31.78 | 1.03 |
| | 7 | 4.53 | 4.17 | 29.86 | 29.27 | 0.98 |
| | 8 | 4.49 | 4.21 | 21.7 | 22.13 | 1.02 |
| | 9 | 4.63 | 4.3 | 30 | 30 | 1 |
| | 10 | 4.45 | 4.2 | 22.5 | 22.05 | 0.98 |
| | **Mean** | **4.68** | **4.39** | **29.68** | **28.95** | **0.97** |
| Winter | 1 | 4.37 | 4.14 | 22.2 | 20.42 | 0.92 |
| | 2 | 4.59 | 4.14 | 20.1 | 17.08 | 0.85 |
| | 3 | 4.42 | 4.14 | 19.7 | 17.73 | 0.9 |
| | 4 | 4.37 | 4.22 | 23.4 | 22.99 | 0.98 |
| | 5 | 4.49 | 3.97 | 17.9 | 13.25 | 0.74 |
| | 6 | 4.53 | 4.26 | 31.4 | 28.57 | 0.91 |
| | 7 | 4.56 | 4.13 | 17.6 | 15.33 | 0.87 |
| | 8 | 4.32 | 4.1 | 15.2 | 14.17 | 0.93 |
| | 9 | 4.3 | 4.13 | 17.25 | 20.71 | 1.2 |
| | 10 | 4.39 | 4.09 | 24.46 | 23.73 | 0.97 |
| | **Mean** | **4.43** | **4.13** | **20.92** | **19.40** | **0.93** |
| Spring | 1 | 4.67 | 4.1 | 23.3 | 28.96 | 1.25 |
| | 2 | 4.56 | 4.02 | 21.5 | 30.1 | 1.4 |
| | 3 | 4.74 | 4.22 | 27.1 | 32.54 | 1.2 |
| | 4 | 4.76 | 4.38 | 22.8 | 32.1 | 1.4 |
| | 5 | 4.86 | 4.12 | 29.2 | 37.94 | 1.3 |
| | 6 | 4.79 | 4.26 | 33 | 37.66 | 1.14 |
| | 7 | 4.5 | 4.04 | 20.6 | 28.8 | 1.39 |
| | 8 | 4.48 | 4.04 | 24.8 | 32.72 | 1.3 |
| | 9 | 4.69 | 4.24 | 22.2 | 29.4 | 1.32 |
| | 10 | 4.59 | 3.98 | 24 | 30.86 | 1.28 |
| | **Mean** | **4.66** | **4.14** | **24.85** | **32.11** | **1.30** |
| **SE (±) Season** | | **0.08227** | **0.06395** | **1.7964** | **1.7817** | **0.3167** |
| **SEd (±) of LSM** | | **0.1127** | **0.07484** | **2.2798** | **2.344** | **0.04479** |
| Pr >\|t\| | Rainy spring | NS | 0.0034 | NS | NS | < 0.0001 |
| | Rainy winter | 0.0441 | 0.0027 | 0.0012 | 0.0007 | NS |
| | Spring winter | NS | NS | NS | <0.0001 | <0.0001 |

recorded the maximum rag weight per fruit followed by RS and WS (Table 2). The SS have a positive influence in increasing the average rag weight of the fruit over the WS (8.18 g) at P <0.0001 and RS (5.30 g) at P= 0.0015. The maximum weight of rag of SS flowering might be a result of more fruit weight but somewhat decreased fruit juice content during this season.

**Fruit set and retention**

Significantly higher fruit set was recorded during SS which was significantly superior over WS and the lowest was recorded during RS (Table 3). An average reduction in fruit set of 3.55 and 0.45 per cent has been observed in RS over SS (P<0.0001) and WS (P=0.0004) respectively, whereas the SS recorded an increase of 1.36

**Table 2: Influence of season on number of seed it, seed weight/ fruit, number of segments and rag weight in *Kuliana* lime**

| Season | Plant | Number of seed per fruit | Weight of seed per fruit (g) | Number of segment per fruit | Weight of rag per fruit (g) |
|---|---|---|---|---|---|
| Rainy | 1 | 5.2 | 0.5 | 11 | 18.22 |
| | 2 | 3.9 | 0.19 | 10.6 | 7.05 |
| | 3 | 4.7 | 0.4 | 10 | 17.2 |
| | 4 | 5 | 0.3 | 9.8 | 7.4 |
| | 5 | 6.3 | 0.3 | 10 | 10.2 |
| | 6 | 7.1 | 0.5 | 10 | 13.27 |
| | 7 | 7.2 | 0.32 | 10.2 | 14.94 |
| | 8 | 5.6 | 0.49 | 10.6 | 11.52 |
| | 9 | 4.5 | 0.35 | 10.8 | 12.6 |
| | 10 | 3.9 | 0.2 | 10.2 | 9.8 |
| | **Mean** | **5.34** | **0.36** | **10.61** | **12.22** |
| Winter | 1 | 5.6 | 0.51 | 10.4 | 10.18 |
| | 2 | 4.9 | 0.63 | 10.8 | 7.36 |
| | 3 | 4.3 | 0.46 | 11 | 8.07 |
| | 4 | 5.7 | 0.62 | 10.6 | 12.41 |
| | 5 | 5.2 | 0.59 | 11 | 4.64 |
| | 6 | 4.3 | 0.56 | 10.8 | 13.25 |
| | 7 | 5.9 | 0.48 | 10.8 | 6.8 |
| | 8 | 6.7 | 0.5 | 10.6 | 6.76 |
| | 9 | 6.2 | 0.6 | 10.2 | 11.43 |
| | 10 | 5.05 | 0.58 | 11 | 12.48 |
| | **Mean** | **5.38** | **0.55** | **10.72** | **9.34** |
| Spring | 1 | 8.2 | 0.47 | 9.8 | 11.74 |
| | 2 | 8.6 | 0.48 | 10.8 | 18.75 |
| | 3 | 10.6 | 0.61 | 10.8 | 17.585 |
| | 4 | 8.2 | 0.47 | 11 | 20.75 |
| | 5 | 8.6 | 0.44 | 10.8 | 19.16 |
| | 6 | 7.2 | 0.42 | 10.6 | 19.3 |
| | 7 | 9 | 0.53 | 10.4 | 15.08 |
| | 8 | 11.2 | 0.56 | 10.6 | 19.05 |
| | 9 | 9.6 | 0.59 | 10.6 | 16.96 |
| | 10 | 10.8 | 0.63 | 11 | 16.82 |
| | **Mean** | **9.20** | **0.52** | **10.64** | **17.52** |
| **SE (±) Season** | | **0.3545** | **0.02749** | **0.1091** | **1.001** |
| **SEd (±) of LSM** | | **0.5013** | **0.03888** | **0.1543** | **1.4156** |
| Pr >\|t\| | Rainy spring | < 0.0001 | 0.0005 | NS | < 0.0001 |
| | Rainy winter | NS | < 0.0001 | NS | NS |
| | Spring winter | < 0.0001 | NS | NS | 0.0001 |

(NS = Not Significant)

per cent in the mean fruit set over WS (P<0.0001) in Kuliana lime. The highest fruit retention was recorded during SS followed by RS and WS (Table 3). The increase in fruit retention percentage of the SS was significantly superior over the WS (0.48 per cent) at P=0.0001 and RS (0.19 per cent) at P=0.0033. No significant variations in the same character have been noticed in the RS over WS. Higher fruit set and retention in Kuliana lime during the SS might be due to the optimum environmental condition as well as the efficient production and uses of photosynthate during the flowering periods (Cooper *et al*., 1963). Low fruit set in

**Table 3: Influence of season on fruit set, fruit retention, fruit per plant, yield and days to maturity in the Kuliana lime**

| Season | Plant | Fruit set (%) | Fruit retention (%) | Number of fruit per plant | Yield per plant (kg) | Days to maturity |
|---|---|---|---|---|---|---|
| Rainy | 1 | 80.21(63.58) | 22.34 (28.19) | 93 | 3.58 | 109.3 |
| | 2 | 80.96 (64.13) | 18.46 (25.41) | 117 | 1.825 | 115.7 |
| | 3 | 75.4 (60.27) | 17.49 (24.72) | 87 | 3.44 | 117.6 |
| | 4 | 72.5 (58.37) | 18.23 (25.27) | 64 | 2.29 | 109.4 |
| | 5 | 85.36 (67.51) | 22.92 (28.59) | 109 | 2.7 | 113.8 |
| | 6 | 78.39 (62.3) | 18.25 (32.08) | 109 | 3.46 | 111.2 |
| | 7 | 78.92 (62.66) | 19.7 (26.35) | 83 | 2.43 | 115.2 |
| | 8 | 77.98 (62.02) | 20.56 (26.95) | 105 | 2.32 | 117 |
| | 9 | 79.5 (63.08) | 24.21 (29.47) | 103 | 3.09 | 113.6 |
| | 10 | 75.28 (60.19) | 22.04 (27.99) | 122 | 2.69 | 118.8 |
| | **Mean** | **78.46(62.411)** | **21.3(27.502)** | **99.20** | **2.7825** | **114.16** |
| Winter | 1 | 85.62 (64.32) | 18.4 (25.4) | 107 | 2.18 | 119.4 |
| | 2 | 81.23 (63.76) | 17.26 (24.55) | 104 | 1.77 | 123.4 |
| | 3 | 80.47 (62.94) | 23.22 (28.8) | 111 | 1.97 | 125.4 |
| | 4 | 79.3 (67.13) | 19.73 (26.36) | 101 | 2.32 | 120.4 |
| | 5 | 84.9 (68.66) | 21.47 (27.61) | 116 | 1.54 | 124.2 |
| | 6 | 86.76 (63.55) | 18.93 (25.79) | 79 | 2.26 | 118.6 |
| | 7 | 80.17 (69.25) | 19.9 (26.49) | 101 | 1.55 | 121.4 |
| | 8 | 87.45 (68.87) | 22 (27.97) | 106 | 1.5 | 121.8 |
| | 9 | 87 (68.28) | 18.7 (25.62) | 88 | 1.82 | 123 |
| | 10 | 86.3 (73) | 17.7 (24.88) | 103 | 2.44 | 123.4 |
| | **Mean** | **84.1(66.447)** | **19.69(26.347)** | **101.60** | **1.935** | **122.10** |
| Spring | 1 | 91.46 (68.69) | 25.34 (30.22) | 137 | 3.97 | 109.4 |
| | 2 | 94.32 (66.74) | 21.37 (27.43) | 129 | 3.88 | 112.3 |
| | 3 | 86.79 (75.17) | 27.8 (31.82) | 148 | 4.81 | 118.7 |
| | 4 | 84.4 (73.58) | 24.3 (29.53) | 151 | 4.85 | 110.9 |
| | 5 | 93.45 (73.18) | 26.4 (30.92) | 125 | 4.74 | 109 |
| | 6 | 92.01 (75.46) | 24.62 (29.74) | 123 | 4.63 | 113 |
| | 7 | 91.63 (72.77) | 22.79 (28.51) | 138 | 3.97 | 115.8 |
| | 8 | 93.7 (77.91) | 28.43 (32.21) | 121 | 3.96 | 118.4 |
| | 9 | 91.23 (72.77) | 24.67 (29.77) | 132 | 3.88 | 113 |
| | 10 | 95.61 (77.91) | 24.96 (29.96) | 124 | 3.83 | 113.9 |
| | **Mean** | **91.6 (73.272)** | **25.18(30.011)** | **132.80** | **4.252** | **113.44** |
| **SE (±) Season** | | **0.8944** | **0.5481** | **4.2206** | **0.1489** | **0.9528** |
| **SEd (±) of LSM** | | **0.9267** | **0.7409** | **5.9688** | **0.1821** | **0.889** |
| Pr >\|t\| | Rainy spring | <0.0001 | 0.0033 | <0.0001 | <0.0001 | NS |
| | Rainy winter | 0.0004 | NS | NS | 0.0002 | <0.0001 |
| | Spring winter | <0.0001 | 0.0001 | 0.0001 | <0.0001 | <0.0001 |

(*Figures in parenthesis denotes Arc Sine value; NS= Not Significant*)

rainy season might be attributed to the higher temperature during the time of bloom (May-June). The results are in line with Reuther (1980), Rohidas and Chakrawar (1982), Taniguchi (1983), Liu *et al*. (1992) and Araujo *et al*. (1999). Young and newly set fruit let dry up and shedding of fruit at different stage occurred due to high temperature. Low humidity during the winter months promoted transpiration and loss of water, resulting in fruit abscission (Rajput and Haribabu, 1985). Contrast results at might be associated with different climatic conditions of the research areas (Hittalmani, 1977 and Hittalmani *et al*., 1977).

**Fruits per plant**

SS recorded greater number of fruit plant$^{-1}$ (132.80) followed by the WS and RS. An average increase of 33.60 and 31.20 fruits/ plant has been noticed in SS over the RS and WS respectively at P<0.0001 each. Wide variation in terms of fruits yield per plant in acid lime is due to genetic variability (Siddappa, 1952; Bhattacharya and Dutta, 1956; Bhan, 1972; Ranpise and Desai, 1994 and Badiyala *et al*., 1994). Higher fruit set and retention (Table 3) during SS might be the cause of maximum fruit per plant in Kuliana lime at the same period.

**Days to fruit maturity**

WS recorded highest number of days taken to fruit maturity which was statistically superior over the other two seasons. The days to fruit maturity of RS was statistically at par with that of SS and an increasing trend was observed in WS over both SS and RS at P < 0.0001 each (Table 3). Spring season bloom produces mature fruit at the early period of the summer hence fruit development was accelerated at higher temperature reducing the total number of days taken for fruit maturity. The lower temperature during the winter months increases the total duration taken for fruit maturity (Thirugnanavel *et al*., 2017). However, similar result has not previously been described (Saunt, 1990 and Khan *et al*., 2007).

**Fruit Yield**

Significantly maximum yield/ plant were observed during SS which was significantly superior over RS and WS (Table 3). An average increase of 2.317 kg and 1.4695 kg has been observed in SS over WS and RS respectively at P<0.0001 each. The impact of RS in increasing the mean fruit yield per plant was 0.8475 kg over the WS (P=0.0002). The productivity of any crop is dependent on photosynthesis process for which the chlorophyll content of the leaves is of most essential. During the spring season the chlorophyll content of leaves were more (Mishra and Dash, 2018a) hence it might have helped in efficient production of photosynthates, maximum fruit set and retention, number and weight of fruit thereby enhancing the yield (Khanna-Chopra, 1982; Tomer and Singh, 1988; Sema and Sanyal, 2002; Xie *et al*., 2012 and Mishra, 2017).

From our study, it can be concluded that the contribution of spring season on the different fruit and yield parameters of Kuliana Lime were immense. Fruit and various yield attributing characters like fruit weight, specific gravity, number of seeds, pulp weight, fruit set, fruit retention and yield were maximum in the spring season flowering. For success in future crop improvement and breeding programmes the spring season flowering must be considered in this specific variety.

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