Effect of season on growth and development of Kuliana lime (*Citrus aurantifolia*)

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CERTIFICATE-I

This is to certify that the thesis entitled **"Effect of season on growth and development of Kuliana lime (*Citrus aurantifolia*)"** submitted in partial fulfilment of requirements for the award of the degree of **Master of Science in Agriculture (Fruit Science and Horticulture Technology)** to the **Orissa University of Agriculture and Technology, Bhubaneswar** is a faithful record of bonafide and original research work carried out by **Subhrajyoti Mishra** under my guidance and supervision. No part of this has been submitted for any other degree/diploma.

It is further certified that the assistance and help received by her from various sources during the course of investigation has been duly acknowledged.

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CERTIFICATE-II

This is to certify that the thesis entitled **"Effect of season on growth and development of Kuliana lime (*Citrus aurantifolia*)"** submitted by **Subhrajyoti Mishra** to the **Orissa University of Agriculture and Technology, Bhubaneswar** in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture (Fruit Science and Horticulture Technology)** has been approved/ disapproved by the students' advisory committee and the external examiner.

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CONTENTS

CHAPTER	PARTICULARS	PAGE NO.
1	INTRODUCTION	1-3
2	REVIEW OF LITERATURE	4-19
3	MATERIALS AND METHODS	20-32
4	RESULTS	33-54
5	DISCUSSION	55-62
6	SUMMARY AND CONCLUSION	63-64
7	CHARACTERISATION OF KULIANA LIME	65-66
	REFERENCES	i-x

LIST OF FIGURES

FIGURE NO.	TITLE
3.1	Weather data pertaining to temperature in the period May 2016-17
3.2	Weather data pertaining to relative humidity in the period May 2016-17
3.3	Weather data pertaining to rainfall in the period May 2016-17
3.4	Weather data pertaining to bright sunshine hour in the period May 2016-17
4.1	Overview of flower in Kuliana lime
4.2(a)	Chronology of bud development in Kuliana Lime
4.2(b)	Chronology of bud development in Kuliana Lime
4.3	Cross section of hermaphrodite and staminate flower of Kuliana lime
4.4	Pollen viability of staminate flower of Kuliana lime
4.5	Pollen viability of hermaphrodite flower of Kuliana lime
4.6	Influence of Season on Number of bud per plant and per shoot of Kuliana lime
4.7	Different grades of fruit of Kuliana lime
4.8	Cross section of fruit of Kuliana lime
4.9	Fruiting twig of Kuliana lime
4.10	Influence of Season on percentage of fruit set in Kuliana lime
4.11	Influence of season on yield of Kuliana lime

LIST OF TABLES

TABLE NO.	TITLE
3.1	Type 3 Tests of fixed effects
3.2	Least square means
3.3	Differences of least squares means
4.1	Influence of season on plant height and girth of Kuliana lime
4.2	Influence of season on Canopy spread and canopy volume of Kuliana lime
4.3	Influence of season on production of number of new shoot or tertiary shoot of Kuliana lime
4.4	Influence of season on shoot length, shoot diameter, internode length, fresh weight of shoot and dry weight of the shoot of Kuliana lime
4.5	Influence of season on number of leaves per shoot, number of spines per shoot, fresh weight of leaves, dry weight of leaves and leaf area of Kuliana lime
4.6	Influence of season on chlorophyll content of the leaves of Kuliana lime
4.7	Influence of season on the reproductive shoot, duration of flowering and the days to anthesis of Kuliana lime
4.8	Influence of season on production of axillay bud, terminal bud, staminate flower and hermaphrodite flower in Kuliana lime
4.9	Influence of season on pollen viability of Kuliana lime
4.10	Influence of season on time of anthesis in Kuliana lime
4.11	Influence of season on time of anther dehiscence in Kuliana lime

4.12	Stigma receptivity in Kuliana lime
4.13	Mode of pollination in Kuliana lime
4.14	Influence of season on length, breadth, weight, volume and specific gravity of Fruit in Kuliana lime
4.15	Influence of season on of seeds per fruit, weight of seed, thickness of rind, number of segments per fruit and weight of pulp per fruit in Kuliana lime
4.16	Influence of season on TSS of fruit juice, volume of juice, percentage of juice and acidity of the fruit juice in Kuliana lime.
4.17	Influence of season on reducing sugar, non-reducing sugar and ascorbic acid content of fruit juice of the Kuliana lime
4.18	Influence of season on fruit set percentage, fruit retention percentage, number of fruit per plant, yield per plant and days to maturity in the Kuliana lime

ABBREVIATIONS

%	:	Percentage
cm	:	Centimetre
mm	:	Millimetre
g	:	Gram
Kg	:	Kilogram
LSM	:	Least Square Mean
SE(d) (±)	:	Standard error difference
Fig.	:	Figure
i.e.	:	That is
DW	:	Dry weight
FW	:	Fresh weight
MAX	:	Maximum
MIN	:	Minimum
ha	:	Hectare
Mha	:	Million hectares
°C	:	Degree Celsius
E-W	:	East- West
N-S	:	North- South
a.m.	:	After meridiem
p.m.	:	Post meridiem
cv.	:	Cultivar
viz.	:	Namely
cc	:	Cubic Centimeter
TSS	:	Total soluble solids
BSH	:	Bright sunshine hours
MT	:	Metric tonnes

ABSTRACT

An experiment was carried out on "Effect of seasons on growth and development of Kuliana lime (*Citrus aurantifolia*)" at Horticultural Research Station, Department of Fruit Science and Horticulture Technology, O.U.A.T., Bhubaneswar during May 2016 to May 2017 adopting three seasons as treatment and replicated ten times. Biometrical observations on vegetative growth dynamics, reproductive behaviour and yield and yield attributes were recorded time to time.

The vegetative characters viz. relative plant height (35.76cm), girth (13.41 mm), canopy volume (4403.81 cm^3) and shoot length (16.78 cm) and diameter (4.04 mm), inter node length (1.37cm), fresh weight (5.23 g) and dry weight (2.11 g) of the shoot recoded maximum growth during the rainy season flush, where as canopy spread of 21.61 cm, 18.36 cm in E-W and N-S respectively, number of new growth flush (153.8), total chlorophyll content of leaves (1.69 mg/g of FW) were maximum during the spring season flush.

Spring season flowering recorded the maximum number of reproductive shoot (90.41%), maximum duration of flowering (58 days), hermaphrodite flowers (18.45 %) and pollen viability (77.42 %), but the duration of anthesis was more (11.08 days) in rainy season flowering. Kuliana lime is mostly an axillary flower bearer. Peak period of anthesis in Kuliana lime was 10 a.m. to 12 noon in rainy and spring season while 12 a.m. to 2 p.m. in winter season. Anther dehiscence starts 15 to 30 minutes after anthesis.

It was found that yield attributes viz. fruit length (4.69 cm) and diameter (4.39 cm), fruit volume (29.68 cc) and Volume of juice per fruit (16.52 ml) were maximum in rainy season flowering. Maximum fruit weight, specific gravity, TSS (6.77 °Brix), sugar content (0.46 %), ascorbic acid content (32.87 mg/ 100 ml of juice), fruit set (91.6 %), fruit retention (25.18 %) and yield (4.252 Kg per plant) were recorded in the spring season flowering.

It can be concluded from the above findings that the spring season flowering was superior to the other two season. To achieve good yield bahar treatment should be imposed for spring season flowering with adequate irrigation facility. Crop improvement work can also be taken up in this season to achieve success.

INTRODUCTION

Citrus (*Citrus* sp.) is the World's leading tree-fruit crop. It is the third most important fruit crop in India next to mango and banana. It occupies a place of considerable importance in the economy of country. The fruits are economically important with a large scale production of both the fresh fruit and processed products. Citriculture as a garden industry existed for centuries in India.

Citrus (*Citrus* sp.) belongs to the family Rutaceae, sub family Aurantioidae consisting of as many as 144 species (Tanaka, 1951). Most of the citrus species are native to Tropical and subtropical regions. Species such as Citron (*C. medica* L.), sour pummelo (*C. megalaxycarpa*), rough lemon (*C. jambhiri*) and sour orange (*C. aurantium* L.) have been found to be grown in wild and semi wild condition in different northeastern states of India (Verma and Ghosh, 1979).

Acid Lime *(Citrus aurantifolia* Swingle), from the family Rutaceae originated in India and then spread to the Middle East and other tropical and subtropical countries (Salunkhe and Desai, 1984). It is commonly known as Nimbu or sour lime. It is the third most important citrus fruit crop in India next to mandarin and sweet orange and a highly polyembryonic species. It is generally grown under both tropical and subtropical conditions in the plain and up to 1000 m above mean sea level with low humid climate.

The major citrus producing countries are Brazil, Spain, USA, Israel, Morocco, China, Mexico, Russia, India, Canada, South Africa etc. In India, it is cultivated in 1.042 Mha area with the production of 10.089 MT, among which lemon and lime contribute about 0.255 Mha in area, 2.523 MT on production basis and the major producing states are Maharastra, Andhra Pradesh, Punjab etc. (NHB, 2014).

Odisha accounts for 2.4 % and ranked 9th to the national production of citrus fruits. Mayurbhanj, Keonjhar, Koraput, Ganjam, Gajapati, Dhenkanal are the major lime growing areas (NHB, 2014). The area and production of lime and lemon is 26.63 thousand ha and 261.07 thousand tonnes respectively in Odisha (Ministry of Agriculture, Horticulture Statistics at a Glance 2015). Acid lime is the third most important fruit crop in citrus sp. It plays an important position in daily life of human

beings for reliving thirsty during summer period and contributes an important place in rituals and festivals. Though its production is confined to homestead garden in parts of Odisha, it is considered for the vast medicinal properties.

The lime plants are small and bushy in nature with small but sharp spines. Leaves are small with narrowly winged petioles. The Flowers are white with numerous stamens, produced laterally in leaf axils or terminally and bear flower singly or in clusters. Every bud is a potential fruit bud in lime. Acid lime being evergreen, it has no specific requirement of winter chilling but cessation of growth during winter helps in flower bud induction resulting in spring flowering. Fruits are small, round to oval in shape, greenish yellow in colour, solid core, and thin skin with highly acidic juice. Limes fruits are typically round, green to yellow in color, 3-6 cm in diameter, and containing sour and acidic pulp. The fruits are very much liked for their cool refreshing juice. Limes are a good source of vitamin C, and are often used to accent the flavors of foods and beverages. The peel contains volatile oil, which is used in the production of perfumes and different kinds of sweets. Also lime has medicinal uses like citric acid, which is used in a drug (Sumaya, 2005).

Kuliana lime is a local elite land race of Mayurbhanj district of Odisha, where it is extensively grown as the hot summer and cold winter climate of the area is highly suitable for its cultivation. This local land race is traditionally grown in village Kuliana from which the name has come as Kuliana lime and is widely popular in the state for its size and juice content. It covers more than 500 Hectare in the district and being widely grown on both sides of river Budhabalanga.

Generally lime has peculiar tendency of bearing more number of fruits in one season and lean in subsequent season. Thus, acid lime exhibits some sort of alternate bearing that leads to fluctuation in production which renders continuous supply of fruits to the market. The major constraints faced by the growers of acid lime are the peak and lean production in consecutive years. Flowering in acid lime is recurrent under tropical and sub-tropical conditions unless synchronized into well defined period of external stress.

Since the lime plant has a wide range of soil and climatic adaptation, it is necessary to improve this fruit crop through planned breeding. Hence as a prerequisite, it is essential to study the floral biology of the fruit crop as this will provides the useful information regarding the period of anthesis, anther dehiscence and stigmatic receptivity.

Apart from the need of quality fruit, it is also desirable to manipulate the bearing at the time of demand. Bahar treatment or growth regulators are practiced in fruit crops like guava, pomegranate and citrus for regulation of the bearing habit of the fruit plant. Before adopting such practices, a detailed study of the growth dynamics of the Kuliana lime plant in different seasons is necessary.

The physical and chemical characters of the lime fruit varies with seasons. It is also desirable to have the acid lime with bigger fruits, higher TSS, higher juice content, higher acidity and thin skin, under Odisha conditions. Hence a detailed study these aspects of Kuliana lime fruits require to know the season on which the best quality of fruit can be obtained.

With a view of this above requirement, the present investigation entitled **"Effect of seasons on growth and development of Kuliana lime (*Citrus aurantifolia*)"** has been planned and carried out with the following objectives:

1) To study the effect of season on vegetative growth dynamics of Kuliana lime.
2) To study the effect of season on floral biology of Kuliana lime to enable further improvement.
3) To determine the effect of season on yield and yield attributing characters to enable regulation of bearing for obtaining the best quality fruit in Kuliana lime.

REVIEW OF LITERATURE

In this chapter, an attempt has made to review the finding of past workers which are directly or indirectly related to Lime *(Citrus aurantifolia* Swingle*)* and especially the research entitled **"Effect of seasons on growth and development of Kuliana lime (*Citrus aurantifolia*)''**. The research works reviewed in this concerned are given below.

Citrus belongs to the family Rutaceae, sub family Aurantioidae consisting of as many as 144 species (Tanaka, 1951). Spiegel and Goldschmidt (1996) reported that the *Citrus aurantifolia* plants grown and produced fruit under varied climatic conditions, ranging in latitude from over 40°N (Japan) to all most 40°S (Newzeland) from equatorial, low humid climates through warm subtropical and even cooler maritime climates. Moore, 2001; Sharma *et al*., 2004; Ladaniya, 2008 Singh, 2010 believed that the genus *Citrus* has its origin from south and southeast tropical and subtropical region of the world.

The Rutaceae are a family of approximately 160 genera and 1650 species of mostly trees and shrubs. The leaves are compound, with glands and without stipuls, often thorny, the flowers are tetra or pentamerous, regular and perfect, usually with a superior ovary and 3-5 locules, fruit varies usually capsule or berry. The sub family aurantioideae is further characterized by leaves and bark with oil glands, and most characteristically a fruit which is a hesperidium, i.e. a berry whose fleshy parts are divided into segments surrounded by a rind or hard shell, the seed of which are without endosperm and some time with 2 or more nucellar embryos (Lyrene, 2007). Citrus is the common term used for genus of a flowering plant of family Rutaceae. It falls under subfamily Aurantioideae and tribe Citreae (Dorji and Yapwattanaphun, 2011).

Citrus aurantifolia Swingle was a good source of vitamin C and has good antioxidant properties. It was well known to be an appetizer, stomachic, antiscorbutic and antihelmintic and it checks biliousness, Chadha (2002).

Most of the aurantioideae genera were native to and have their centre of diversity in Northeastern India, Southern China, Indo-Chinese Peninsula and nearby

archipelagos although some related aurantioideae genera were native to Asia, Africa and Australia. Acid lime (*Citrus aurantifolia* Swingle) considered as the third important citrus crop in India next to mandarins and sweet oranges. Sweet orange, mandarins and grape fruit were sub-tropical, whereas lime and lemon were tropical in their climatic requirements (Devi *et al.,* 2011).

Citrus occupies a place of considerable importance in the economy of the country. *Citrus* fruits were recognized as an important component of the human diet, providing a variety of constituents important to human nutrition, including vitamin C, folic acid, potassium, flavonoids, coumarins, pectin and dietary fibres. *Citrus* flavonoids have a broad spectrum of biological activities including antibacterial, antioxidant, antidiabetic, anticancer cardiovascular, analgesic, anti-inflammatory, antianxiety etc (Sidana *et al*., 2013).

3.1 Vegetative growth dynamics

Cooper *et al*. (1963) studied on "tree growth and fruit quality of Valencia oranges in relation to climate" they observed an extensive early spring flush occurred in all 7 locations of United States of America. The duration of extension growth and of flowering however was greatly accelerated or slowed by climatic conditions. Extensive growth and flowering were completed earlier where warm days and nights prevailed as compared to where relatively cool days and nights prevailed in early spring. A period of relative inactivity in late spring always followed the spring flush regardless of climatic conditions. Substantial increase in areas of cross section of the trunk occurred in all trees at all stations during the fall, but very little or none occurred during the winter. Shrinkage of the trunk observed during the winter and this was a indicative of winter dormancy.

The vegetative growth occurs in distinct flushes (Sing and Samaddar, 1965) which is cyclic with period of active growth alternating with a period of quiescence (Hittalmani *et al*., 1977). The time of initiation of thee flushes, the magnitude of growth and productivity vary with number of factors such as environment, species, varieties and age of the tree (Hittalmani *et al.*, 1977; Soni and Randhawa, 1975). Soni and Randhawa (1975) observed significant variation in extension of growth, leaf size, number of leaves and leaf area per shoot in different growth flushes of lemon.

Four growth flushes per year were produced by both Kagazi lime and Tahiti lime, in January, May-June, July-August and October. The major flushes occurred in January and May/June, and January and October in Kagazi and Tihati lime respectively (Hittalamani, 1977).

Under higher temperatures leaves, buds, flowers and young fruits, particularly in lemon and navels, get scorched, while young twigs showed injury. Lemons and limes, due to lack of dormancy even, in winter, are readily subjected to winter injury, as they have new foliage, flowers and younger fruits at almost any time (Rajput and Haribabu, 1985).

Singh *et al*. (1985) reported both the lemon cultivar pant lemon-1 and malta followed a sigmoid growth curve and winter flush have higher rate of growth (length and diameter) than other flushes though the cumulative length of shoot was higher in rainy flush. Tomer and Singh (1988) reported irrespective of solar treatment, spring flush leaves of Pant lemon-1had higher level of chlorophyll-b and total chlorophyll than autumn flush. The total chlorophyll content with light intensity had an inverse relationship.

The production of photosynthates takes place through the process of photosynthesis. The disruption of photosynthesis might ultimately affect the distribution of carbohydrates thereby altering sink-source relationships in the plant. Like any other plant component and process, vegetative growth is sensitive to any form of stress as in extreme temperatures, high light intensities and water deficit. (Cull, 1991).

Sema and Sanyal (2002) observed that the pattern of increase in shoot growth of lemon plant followed a sigmoid curve. The shoots after emergence grew rapidly for about four months and slowed down there after. They suggested the higher rate of growth of winter season flush might be due to the favourable climatic condition prevailing during growth period after the emergence of new shoots in December-January. They also reported that there is no significant difference in the number of leaves per shoot as influenced by the growth flushes. The samples collected from spring flush contained more chlorophyll (1.91 mg per g of sample than rainy (1.58 mg per g of sample) and winter season flush (1.36 mg per g of sample).

Devi *et al.* (2011) reported shoot growth in acid lime as well defined waves (growth flushes) though default flushes were also seen. Acid lime plant puts forth three to four flushes in phases: uncontrolled flushing results in perpetuation of diseases and pests. In that experiment, he put forth 0.88, 2.56 and 0.79 numbers of flushes per shoot during Nov - Dec, Dec - Jan and Jan - Feb respectively. Thorn less Rodan lime (*Citrus aurantifolium* Swingle) has a slow growth rate (Vand and Abdullah, 2012).

Dalal *et al*. (2013) reported, in the early bearing stage of Kinnow, the magnitude of vegetative growth was maximum in spring flush (47.08 %) followed by in the rainy season flush (42.07 %), whereas, the winter fall flush bore only minor flush of the annual vegetative growth (10.85 %). Similarly, the spring flush leaves showed the minimum values of leaf sclerophylly i.e. leaf area, leaf fresh and dry weight, specific leaf weight, density of foliar tissue and leaf tissue succulency as compared to rainy and winter fall flushes leaves, implying that spring season growth most serves as a sink to developing fruits. Trunk growth rate was influenced significantly during the different seasons. However, the maximum trunk growth rate was measured in the spring season (0.587cm) closely followed by in rainy season (0.551 cm) and significantly lowest growth rate was measured in the winter fall season (0.404 cm). Rainy season flush leaves showed the maximum leaf area (15.79cm^2/leaf), fresh leaf weight (0.448g/leaf) and leaf succulency (0.018mg H_2O/cm^2) which were also significantly higher over spring and winter flush leaves. This may be due to the better availability of soil moisture and high relative humidity resulting in low transpirational losses, which favours the better leaf growth in terms of leaf area, leaf weight and succulency during rainy season. The minimum leaf area (14.45 cm^2 per leaf), fresh leaf weight (0.320 g per leaf) and succulency (0.014 mg H_2O per cm^2) was measured from spring flush leavers, which were also significantly more than the winter flush. This may be due to higher summer temperatures at sampling time resulting in rapid transpirational losses, hence decreased leaf area, leaf weight and succulency. Winter season flush leaves showed the significantly highest leaf dry weight (0.320 g per leaf), specific leaf weight (0.013 g per cm^2) and density of foliar tissue (45.46 g per kg). This may be because soluble sugars increased towards mid winter in cool areas, as an osmotic, cryoprotective measure against cold injury (Torikata *et al.,* 1974). However, the minimum leaf dry weight (0.124 g per

leaf), specific leaf weight (0.009 g per cm^2) and density of foliar tissue (37.89 g per kg) were observed in the spring flush leaves. Low dry weight in spring flush leaves indicates that reserve carbohydrates were utilized to sustain the early stage of reproductive development.

It was revealed from the observed data of Deshmukh *et al*. (2015) that different varieties of acid lime had exhibited significant differences in plant height, spread and plant volume. The highest height of the plant was recorded in PDKV lime (4.01 m), followed by Pramalini (3.73 m) while; Mangali-Pattu recorded the lowest height of plant (2.93 m). In respect to plant spread in hasta bahar the maximum plant spread was recorded in PDKV lime (30.82 m^2) followed by Vikram (28.96 m^2) and minimum in Mangali-Pattu (20.68 m^2). However, significantly highest plant volume was observed for variety PDKV lime (53.90 m^3) whereas the Mangali-Pattu recorded the lowest tree volume (27.06 m^3).

In Valencia Late and Washington Navel the vegetative development corresponds to the behavior of accumulated annual rainfall, as they increase, the vegetative development was higher. The foliar area was directly related to fruiting and production of both cultivars. Increased foliar area per tree and foliar area reduction per canopy volume mainly contributed to an increased fruiting (number of fruits per tree) and production (kg of fruits per tree) (Garlobo *et al*., 2015).

Acid lime is highly polyembryonic. Trees were small bushy with small but sharp spines. Leaves were small with narrowly winged petiols (Debbarma and Hazarika, 2016).

3.2 Reproductive behaviour

In citrus, the differentiation of floral organs occurred at the first stages of bud swelling and sprouting. The time of initiation of differentiation varies by citrus cultivar and environmental conditions (Abbott, 1935).Webber (1943) observed that the time of flowering was reported to vary with temperature. Flowering was about a month earlier in higher temperature zone (Florida) than in cooler temperature zone (California).

By means of the ringing and defoliation method and microscopic observations, it has been shown that flower induction may precede by 3 or 4 weeks the first microscopical appearance of differentiation. Flower bud development follows without interruption and blossoms will open about three and half months after induction, in oranges in the main subtropical citrus growing areas (Monselise and Halevy, 1963).

Motial (1964) reported that kagzi lime flowered only once a year under Saharanpur conditions. Cassin *et al.* (1969) reported that unrestricted growth gives rise to more vegetative growth than the reproductive growth, as temperature or moisture stress is essential for flowering. Once induced, the release of the stress by higher temperatures triggers the beginning of reproductive growth provided that other conditions are not limiting.

As hours of low temperature accumulate, bud sprouting shifts from vegetative (with no flowers) to mixed (flowers and leaves) to mostly reproductive (leafless with at least one flower). In case of sweet orange high temperatures during sprouting were reported to increase inflorescence leafiness and to inhibit flowering (Moss, 1969). Ambient temperature not only has a direct effect on induction and differentiation but also affects flowering date and intensity (Cassin *et al*., 1969; García-Luis *et al*., 1992).

Nir *et al.* (1972) reported that increased intensity of flowering due to stress showed that flower differentiation occurred during moisture stress and that generative buds formed did not undergo flower development till water was supplied. During winter, low-temperature conditions caused the inactivity of buds while inducing them to flower in Citrus (Reuther *et al*., 1973).

Hittalmani (1977) and Hittalmani *et al.* (1977) reported that the maximum flowering occurred only during December - January and May - July periods. The percentage of hermaphrodite flowers was highest during June and flowering was related to the season rather than to the physiological age of the shoots. *Citrus aurantifolia* bore flowers mainly on lateral shoots, whereas *C. latifolia* flowered mainly on terminal shoots.

Sustained periods of low temperature in winter caused late anthesis by delaying initiation of differentiation and reducing the subsequent growth rate of the bud (Lomas and Burd, 1983).

Chemical tests have been developed to determine the stigma receptiveness and one involves the enzymatic reactions of the peroxidase enzyme, based on the hypothesis that the presence of this enzyme reflects in the receptiveness of the stigma (Galen *et al*., 1985).

Under more uniform temperatures limes and lemons flower throughout the year with varying intensities, particularly in coastal areas. However, this tendency is inhibited by high temperatures in hot interiors. It is not uncommon to find, particularly in lime, flowers, developing fruits and mature fruits all at a given time. The acid lime bloom throughout year but main blooming period is February- March, with lean period from July-August. (Rajput and Haribabu, 1985).

Kagzi lime flowered in three distinct seasons i.e. Ambia (January- February), Mrig (June-July) and Hasta (October-November). The fruit from October-November flowering (Hasta bahar) mature in summer and fetch higher remunerative prices. However, cropping intensity of this season is only about 15-20 percent or less (Sartale and Desai, 1986).

The acid lime trees under Tamil Nadu condition flowers normally twice a year during January – February and June – July and yield mainly during July – August and December – January and causes glut in the market which results in poor returns to the growers (Shrestha, 1988).

Rohidas and Chakrawar (1989) studied the ambe bahar (Jan-Feb) flowering under Parbhani, Maharashtra, India condition and reported that flowering started as early as in November and continued till February with a duration of 50 to 55 days and peak between 15 to 31 January.

Anthesis in navel orange occurs after the induction and differentiation processes have been completed, usually when warmer spring time conditions exist (Bellows and Morse, 1986). Floral differentiation involves the anatomical and morphological transition of vegetative meristems to floral meristems (Davenport, 1990).

As for flower intensity, greater accumulation of hours of low temperature increases floral induction in Satsuma mandarin, thus increasing number of flowers per tree, number of flowers per node and sprouting (Poerwanto and Inoue, 1990).

Seasonal duration of flowering and fruiting mainly determine phonological behaviour in tropical trees. These phenological events are not mutually independent in woody species, and flowering may be partly or wholly dependent on leaf activity (Van *et al*., 1993). Nevertheless, tree species with similar leaf phenology often differ in the timing of their flowering and fruiting (Seghieri *et al*., 1995).

The flowering process in citrus consists of several discrete phases: flower bud induction, bud differentiation and anthesis. The induction process is associated with environmental factors and results in the commitment of meristematic cells to form reproductive structures. Under subtropical conditions, citrus flowered primarily during the spring following the inductive winter season (Garcíaluis *et al*., 1995). Following differentiation, the rate of flower bud development depends on temperature and the number of flowers differentiating (Guardiola, 1997; Moss, 1973).

The newly formed shoots arise from lateral resting buds and may form either leaves (vegetative shoots), flowers (generative shoots also called leafless inflorescences), or both flowers and leaves (mixed-type inflorescences). The earliest signs of flower morphogenesis ware detectable at the onset of bud sprouting, and are ensued by the uninterrupted development of the flower organs leading to anthesis. Under subtropical climate conditions most citrus cultivars have three main flushes of growth. The main one occurs in late winter or early spring (spring flush). Two additional ones occur at the end of the June drop (summer flush) and late in September (autumn flush). In most cases, only vegetative shoots ware formed in the summer and the autumn flushes of growth. Inflorescences ware formed in the spring flush of growth as a response to the low winter temperatures. The shoots developed during the flushes of growth arise mainly from the axillary buds present in the vegetative shoots formed in previous flushes of growth. Bud behavior in spring depends critically both on the time the buds were formed (bud age) and in the position of the bud along the shoot (Guardiola, 1997).Athani *et al.* (1998) noticed that the flowering was twice in Kamataka, once during December - January and again during July - August.

In Subtropical areas during the winter months, air and soil temperature falls below about 15°C. This condition causes growth to cease for three to four months.

Such a cessation of growth Induces greater tolerance to frost damage and causes changes within the buds which Induce flowering when subjected to warmer temperatures. In a typical subtropical climate with cool winters, citrus tends to bloom profusely in the spring and set only one major crop which matures in late fall, or winter, or even the following spring depending on variety and seasonal temperature regime. Flower formation in citrus species is promoted by drought or low temperature, followed by restoration of climatic conditions that are favourable for the growth (Srivastava *et al*., 2000).

High day time temperatures during floral differentiation shorten development time and advance date of anthesis in sweet range (Valiente and Albrigo, 2002; Moss, 1973). Ghawede *et al*. (2002) revealed that in Akola, India, there were only two main flowering seasons of acid lime, the first and the major one occurring in December - February (ambe bahar)constituting more than 50% of total number of flowers produced in the year and second one in June - July (Mrig Bahar)constituting about 25% of total number of flowers.

Many deciduous tree species show flowering and fruiting during the leafless period, exhibiting wide separation between leafing and flowering phenophases. In many ever green and in some deciduous species leaf flush and flowering occur close in time on the same new shoot. An analysis of the proximate controls of flowering in tropical deciduous forest species indicates that the timing of vegetative phenology strongly determines the flowering periods, and thus flowering at least depends indirectly on environmental periodicity (Rivera *et al*., 2002).

Variation in flowering time relative to vegetative phenology, induced by a variety of factors (significant rain in winter/summer, decreasing or increasing photoperiod, or drought-induced leaf fall), results in a number of flowering patterns in tropical trees (Borchert *et al*., 2004).

Pio *et al*. (2004) tested the receptivity of the stigma as per the technique of Zeisler (1933) and found at the balloon stage with 80 to 100% receptivity of stigma, while for the open flower the receptivity presented maximum (100%) indexes in natal, Valencia and pera varieties of orange. The small buds did not show receptiveness.

Citrus flowering is a complex phonological process influenced by a number of interacting factors. Low winter temperatures are recognized as an important factor, but the flowering response has not been quantified under variable natural conditions. The flowering response in Valencia and Hamlin sweet orange trees was quantified and related to shoot age, bud position along the shoot, local weather information and crop load status. Results indicate that buds on previous summer shoots developed 2.52 and 3.59 to 1 flower on spring shoots, for Hamlin and Valencia, respectively. In addition, buds at apical positions produced more flowers than buds located far from the apex. Under Florida conditions, greater accumulation of hours of temperatures 11 to 15°C increased floral intensity by the combined effect on the number of sprouting buds with reproductive growth and the number of flowers per flowering bud. High winter temperatures reduced flowering. The presence of fruit consistently reduced reproductive response for both cultivars. Crop load reduced flowering by an average of 41.5% compared to no crop and varied by cultivars (Valiente and Albrigo, 2004).

Tripathi and Dhakal (2005) Studied different accession of 14 month old plants of acid lime. Flowering in acid lime started only after the third week of March, which was normal flowering season of lime under Chitwan condition of Nepal. The days taken to first flower, days taken to anthesis (after emergence of flower bud), no of flower shoot per plant, and fruit set to be 243.3, 10.14, 3.3 and 0.66 respectively.

Devi *et al.* (2011) reported acid lime being tropical fruit crop, its flushing and fruiting is dependent on the variation of climatic factors. Flowering was related to the season rather than physiological maturity of the shoot. Flowering occurs mainly on previous season growth and in axillary, rarely terminal, but never on current growth. Acid lime being evergreen, it has no specific requirement of winter chilling but cessation of growth during winter helps in flower bud induction resulting in spring flowering. The lemon, lime and citron are considered as continuous bloomers, particularly under tropical climate producing some flowers throughout the year, though the spring bloom is the heaviest. The acid limes bloom throughout the year but the main blooming period is February - March, with lean period from July to August. They also reported that citrus species in general show a relatively long juvenility (2 to 5 years) for commercial production. This gestationperiod in acid lime varies under ecological set up. In dry tropical regions of Telangana of Andhra Pradesh commercial

fruiting starts after 7 years. Insub humid tropical places, it may take more time for commercial flowering.

Karmakar (2013) while studying pollination biology of *Citrus aurantifolia* found that, the lime plant produces 4-5 day flowers and the flowers are white or creamish white in colour. He also reported that the flowers are borne in axillary cymes and the flowering pattern is of cornucopia type. The plant shows both autogamous and allogamous (primarily geitonogamous) type of pollination.

Debbarma and Hazarika (2016) reported that the acid lime flowers are smaller than other *citrus* species and the days to first flowering (Days) and number of flowers per shoot found these to be 75 and 3.38 respectively.

Kumatkar *et al*. (2016) reported, in sweet orange flowering takes place only once in year *i.e.* February–March under North Indian conditions. The duration of floral bud development was 19-23 days and the duration of flowering was 20-23 days in the cultivars. Sweet orange came to full bloom in first week of March. The maximum opening of flowers and dehiscence of anthers took place in morning hours (10.00 A.M. to 12.00 noon) in all the cultivars. The maximum receptivity of Stigma was recorded on the day of anthesis. They classified the development of flower bud into seven different stages based on the visual observation of the flower bud. Two types of flowers were observed in sweet orange, *viz.* hermaphrodite (complete) and staminate (incomplete).

Thirugnanavel *et al.* (2017) reported that the, days to first flowering (Days) and number of flowers per shoot in the T1 (Control + water spray) are 63 and 3.42 respectively in five year old *Citrus aurantifolia* plant. Lime flowers are white and fragrant and they are borne in clusters of 5 to 10 on the tip and several nodes back. The trees bloom continuously throughout the year, but peak bloom are in February to April, and fruit requires 100 to 120 days maturing (Thirugnanavel *et al.,* 2017). However, this result has not previously been described (Khan, 2007; Saunt, 1990).

3.3 Yield and yield attributing characters

Green colour orange has less vitamin C than the orange coloured ones when harvested at the same time. Fruits growth on the south side of the tree has higher acidity than fruit on the other side (Hattori *et al*., 1959).

Cooper *et al.* (1963) reported the higher day time temperatures and cool nights appeared to slow the fruit growth in Valencia orange. Fruit growth came to a complete stop in mid November and was resumed at an accelerated rate in the warmer months of early and late spring. Soil moisture was also known to influence fruit enlargement. The oranges grown in the moist climates have thinner rinds and more juice than that of the drier climate. In cool temperature of winter the concentration of soluble solids of the juice was more than that of the summer. This decrease in concentration of acid was much greater relative magnitude than changes in soluble solid concentrations. High temperatures in late spring and early and late summer were associated with a low acid content. The low acid content of fruit cannot be accounted for by dilution resulting from continuous abundant soil moisture. At high temperatures most rapid rate of acid loss occurred in fruit. The slowest rate of acid loss occurred in fruit grown in cool nights.

Leopold and Kriedemann (1964) opined that the growth of the fruit involved an enlargement of ovary and receptacular tissue. Jahn (1970) observed an increasing trend in fruit weight, size, juice content and soluble solids and decreasing trend in chlorophyll level, firmness, percentage rind and acid in respect to Hamlin, Valencia orange and grape fruit. The juice percent in the fruit increased continuously with some fluctuation and the maximum value of 51.1% was attained at maturity (Hitalmani and Rao, 1970).

According to Soni and Randhawa (1970) ascorbic acid, reducing, non-reducing and total sugars decreased with advancing maturity. 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).

Under the tropical condition level of TSS increases due to high vegetative growth and fruits have good colour, smooth surface and high acidity due to low humidity and good sunshine, whereas in humid zone fruits have thick peel, rough surface and juicy fruits (Hayes, 1975). The magnitude of fruit setting and retention was higher in June flowering than in January (Hittalmani *et al.,* 1977).

Yoshida (1977) observed that during first growth stage of Satsuma fruits from early July to early August, the fruit cell enlarged and juice viscosity increased, while

at the second stage the cells enlarged further from early August to end of September but viscosity decreased. During third stage, he found accumulation of sugars and other compounds with consequential increase in viscosity.

Raju (1978) observed the fruits of Rangpur lime grew rapidly up to 90 days and slowed down there after till they reached maturity at 165 days after fruit set with a comparative spurt in growth in terms of diameter and length between 135 and 150 days after fruit set. Rind thickness gradually increased up to 105 days and steadily decreased thereafter. Fruits exposed on sun light have significantly had higher ascorbic acid content (Sinclair, 1984). Side of the tree affects the maturity of fruits, due to uneven sunlight (Gill *et al*., 1985).

Fruit set was low under high temperatures at the time of bloom. Extreme hot and dry weather during the month of May-June causes shedding of half developed fruits (June drop). In general low humidity developed good colour and external appearance, where as high humidity favoured thin skinned and juicy fruits, which were smaller in size but high in quality. Fruits grown near coastal areas tend to be more spherical than those grown in interiors. Low humidity promoted transpiration and loss of water, resulting in fruit abscission (Rajput and Haribabu, 1985).

Lime is a highly polyembryonic species with the fruit surface smooth, greenish-yellow in colour and thin-skinned, core solid at maturity, and juice highly acidic. Lime used for the extraction of juice, preparation of squash, concentrates, beverages and byproducts, such as citric acid and pectin etc (The Wealth of India, 1986).

Acid lime contents juice 50% - 52%, acidity of 6.2% - 6.9%, TSS of 6.2% - 8% could be used as index of harvesting maturity in acid lime (Jawaharlal *et al*., 1992). In Andhra Pradesh quality standard for acid lime fruits content was 45% - 58% juice and 6.7% - 7.7% citric acid. The acid lime grown in South India had average yield of juice varied from 45% - 58% of acidity from 6.2% - 7.6% in maturity and number of seed was 12 per fruit (Siddapa, 1992).

All the citrus fruits have the same anatomical structures: flavedo, albedo, carpel segments, although these structures vary according to species and variety. The

number of carpels varies in acid lime fruits from 8-11 segment or locules (Loussert, 1992). Fruit size was inversely related to crop load, and this effect may be a result of competition among the developing fruits for a limited supply of metabolites (Guardiola, 1997).

Citrus fruits unlike deciduous fruits do not undergo rapid physical or chemical changes after harvesting. Mature fruits show non-climacteric respiration pattern during ripening. The colour break stage from dark green to light green was reported to coincide with maturity in acid lime fruit (Selvaraj and Raja, 2000).

The higher the intensity of light during the growing season, the greater the vitamin C content in plant tissues. Vitamin C content can be increased with less frequent irrigation. Vitamin C losses will be accelerated at higher temperatures. Although light is not essential for the synthesis of ascorbic acid in plants, the amount and intensity of light during the growing season have a definite influence on the amount of ascorbic acid formed. Ascorbic acid is synthesized from sugars supplied through photosynthesis in plants. In general, the lower the light intensity during growth, the lower the ascorbic acid content of plant tissues (Lee and Kader, 2000).

Gaikwad (2003) studied different kagzi lime varieties and reported diameter in Local kagzi lime (3.59 cm), Vikram (3.51 cm) and Pramalini (3.35 cm). Tirthakar *et al*. (2004) evaluated the fruit of acid lime from fourteen locations of Akola district of Maharashtra. The length, breadth, weight and volume of fruit ranged between 3.52 to 5.12 cm, 3.41 to 4.93 cm, 32.34-48.20 gm and 33.79-48.6 cc, respectively.

There was significant positive relation between seed number and weight of the fruit. The size of fruit may not be a reliable criteria for maturity depending on the bearing and nutrient status of the plant (Paudyal and Shrestha, 2004).

Late season water stress decreased fruit grade and increased soluble solids concentration (SSC), titratable acidity (TA), the BrimA index, and orange color. Fruit juiciness and SSC: TA ratios were unaffected by late-season water stress. Summer, fall, and season-long water deficits have increased the concentration of juice SSC, especially sugars, through short-term fruit dehydration or longer-term osmotic adjustment, although the ratio of SSC to percent TA changed little. Summer, fall, and

season-long water deficits have been shown to decrease fruit size in oranges and mandarins. Although there was reduction in yield but quality of fruit can be increased by providing water stress condition to the plant to some extend during the latter part of fruit growth (Kallsen and Sanden, 2011).

Typically, acid, sugar and juice volume of lime was 5.0 to 6.0 %, 8 to 10 % and 42 to 55 % of the total volume of fruit respectively. While the fruit pH of thorn less and thorny limes were 2.2. Fruit juice of thorn less and thorny lime were 47 % and 43 %, ascorbic acid were 39.6 % and 51.7 %, fruit dry matter were 18.7 % and 15.7 % respectively. Thorn less Rodan lime has vitamin C of about 36.6 mg per 100g edible. The flower clusters at the end of the branch and average weight of fruit was 30g (Vand and Abdullah, 2012).

Highest ascorbic acid 79.6 mg and 69.9 mg was observed in south side fruits whereas lowest 62.8 mg and 55.1 mg was observed in centre fruits in the high and mid hills zone respectively, but in low hills, highest ascorbic acid 58.7 mg was observed in north side and lowest 41.8 mg was observed in centre. Highest amount of juice 43.9 percent was observed in south side fruits and lowest 36.6 percent in centre fruits, but amount of TSS 8.2 percent and titrable acid 7.2 percent was observed in south side fruits and lowest 7.3 percent TSS and 7.0 percent titrable acid was observed in centre fruits in high hills. In low hills highest TSS 8.3 percent and titrable acid 7.4 percent was observed in north side fruits and lowest TSS 7.3 percent and titrable acid 6.7 percent was observed in centre fruits in acid lime (Shrestha, 2012).

Comparison between thorn less and thorny lime has been showed the fruit weight to be 28.27-49.98 g. Trees produced fruits in two sections. The first section was from May-July and the second from November to December. While fruits in the first section were not much but the peak fruiting was in the second section fruiting. While the peak season of fruiting on south of Iran was in May and July (Vand and Abdullah, 2012).

There were two main seasons of production of fruit i.e. February to April and October to December. The fruits which harvested during November to March were round in shape and good test. The rainy season fruits were oblong and have inferior test. A good acid lime plant (7-year old) may yield 2000-5000 fruits annually. The average yield being 3000 to 3,500 fruits/tree. Harvesting of lime and lemons differs

with different species, verities and regions of cultivation. The peak season of harvesting was from March to April and lean season May to June in Maharashtra (Pawar *et al*., 2015).

Deshmukh *et al*. (2015) reported the PDKV lime (3.99 cm) recorded significantly maximum diameter of fruit whereas minimum diameter was observed in Chakradhar (3.40 cm). There was significant variation ascorbic acid content of acid lime from 27.17-30.33 mg/100 g. Significantly higher TSS was found in Pramalini (7.83 °Brix) and lowest in Tenali (7.40 °Brix). Acidity was lowest (7.13 %) in Sai Sarbati and highest in Chakradhar (8.23 %). The fruit set, fruit per plant, yield, number of seed per fruit, juice content and peel thickness were from 24 to 31 %, 502.67 to 1126.67, 16 to 29.73 Kg per plant, 1.67 to 14.67, 41.67 to 50.33 % and 1.16 to 1.77 (mm) respectively in different cultivars. However, Desai *et al*., 1994 observed lowest (7.29 %) acidity in Sai Sharbati.

Debbarma and Hazarika (2016) observed the biochemical parameters of a four year acid lime pant. The TSS (°Brix), titrable acidity (%), reducing sugar (%), non reducing sugar (%), total sugar (%) and ascorbic acid (mg per 100 ml juice) were 6.20, 6.07, 0.24, 0.22, 0.46 and 30.41 respectively.

Debbarma and Hazarika (2016) observed fruits were round, long or oblong in shape with smooth porous skin, fruit are small to medium size, its pulp was juicy greenish with strong adherence to the yellowish, green, thin or papery and shiny. Length of fruit (cm), diameter of fruit (cm), volume of fruit(cc), weight of fruit (g), number of seeds per fruit and juice content per fruit (ml) were to be 3.65, 3.64, 36.06, 27.00, 12.27 and 13.09 respectively in a four year old acid lime plant. Fruit set (%), fruit retention per shoot at harvest, number of fruit per tree and yield per tree (kg) to be 63.52, 1.12, 87.00 and 2.35. They found the polar diameter of Kagzi-lime was in the range of 3.33 cm to 4.48 cm whereas equatorial diameter was in the range of 3.34 cm to 4.47 cm.

The highest fruit set was recorded in cultivar Jaffa sweet orange under open pollination (32.84 %) followed by self-pollination (29.81 %) Kumatkar *et al*. (2016). Thirugnanavel *et al.* (2017) found the initial fruit set, fruit retention at harvest, number of fruit per tree and yield per tree (kg) to be 2.42, 1.12, 152 and 5.04 respectively in five year old acid lime plant.

MATERIALS AND METHODS

The detailed account of the materials and methods followed during the course of investigations for the study of research entitled **"Effect of seasons on growth and development of Kuliana lime (*Citrus aurantifolia*)''** were described below.

3.1 Experimental site

The experiment entitled "Effect of season on growth and development of Kuliana lime (*Citrus aurantifolia*)'' was carried out at Horticultural Research Station, Department of Fruit Science and Horticulture Technology, O.U.A.T., Bhubaneswar during May 2016-17 on 4 year old Kuliana lime plants planted at 4×4 m distance. The research station is situated around 60 km away from Bay of Bengal having an altitude of 25.9 m above Mean Sea Level. It is located at 20°.15'N latitude and 85°.52'E longitude.

3.2 Climate

The experimental site comes under the eighteenth agro climatic region of the country i.e. "Eastern Coastal Plain'' and is termed as sub humid. The climate here is warm, humid with distinct summer, rainy and winter seasons. Among the agro climatic zones of Odisha the experimental site comes under "East and South East Coastal plain zone''. The average annual rainfall of Bhubaneswar is 1552 mm (Based on average of preceding 10 years). Most of the rainfall i.e. 85% is received from July to September.

Monthly average meteorological data (temperature, relative humidity, rain fall and bright sunshine hour) during the cropping season was recorded at Meteorological Observatory of Orissa University of Agriculture and Technology, Bhubaneswar and is presented in Fig. 3.1, 3.2, 3.3 and 3.4.

3.3 Soil

The soil condition is sandy loam reddish brown in colour, acidic in pH (4 - 5.5), moderately fertile and with proper drainage.

3.4 Intercultural operation

The various intercultural operations like irrigation, manuring, weeding etc. are done according to the recommendation for acid lime plant. Plant protection measures were taken as and when required to control the seasonal pests and diseases.

3.5 Vegetative growth

Ten uniform Kuliana lime plant were selected. Season and duration of new vegetative flush were recorded. The flush was observed from May 2016 to May 2017 and the different period of flush growth was distinctly noted. The duration of rainy season was from May-2016 to September-2016, the winter season from October-2016 to December-2016 and that of the spring season was from January-2016 to March-2017 in Bhubaneswar condition.

3.5.1 Height of the plant

The height of a plant in centimeter was measured with the help of a measuring bamboo having metre marking from the ground level to the tip of the highest shoot of the plant in the beginning and cessation of each season. The plant height at the end of the three seasons was recorded and the relative growth of the plant in height (cm) on the three seasons was calculated.

3.5.2 Girth of the plant

The circumferences of the stem at the base were measured with the help of a thread and scale and were expressed in terms of cm. The relative growth of the girth of the plant on the different season were computed and expressed in millimeter.

3.5.3 Canopy spread

Canopy spread of each tree in North-South and East-West was measured in meter using measuring tape in cm. The relative growth of canopy of the plant on the three seasons was recorded.

3.5.4 Canopy volume

Canopy volume in m^3 was calculated by the following formula given by Roose *et al*. (1986) and the relative growth in canopy volume was determined in the particular season and expressed in (cm^3).

$$\text{Canopy volume} = \frac{4 \times \pi \times h \times r^2}{6} \ (cm^3)$$

Where, $\pi = 2.14$, h = Plant height (cm) and b = $\frac{(N - S) + (E - W)\,\text{canopy spread}}{4}$ (cm)

3.5.5 Number of primary branches

Numbers of primary branches were calculated by counting the branches which were found at the base.

3.5.6 Number of secondary branches

The branches which emerged from primary branches are considered to be secondary branches and their numbers were calculated.

3.5.7 Number of tertiary branch

Subsequent branches emerging from secondary branches were called tertiary branches. Three representative secondary branches from upper, middle and lower portion of the plant on each direction were selected. The number of newly emerged shoot was recorded from those shoot and converted for the plant.

3.5.8 Length and diameter of shoot

The length and diameter of the shoot of the particular flush was measured in meter tape after two month from the emergence and expressed in centimeter and millimeter respectively.

3.5.9 Internode length of shoot

The internode length in each newly emerged shoot was measured after two month with the help of measuring scale and expressed in centimeter.

3.5.10 Fresh weight of shoot

The weight of 10 two month old sample shoot per replication was taken and their weight was measured in electrical weighing balance just after removal from the tree. The average weight of the ten samples was taken as the fresh weight of the shoot (Dubey and Yadav, 2004).

3.5.11 Dry weight of shoot

The ten sample shoot after taking fresh weight were dried on hot air oven at 40±1°C till they attain a constant weight and weighed to record the dry weight. The average of the ten samples was taken as the dry weight of the shoot (Dubey and Yadav, 2004).

3.5.12 Number of leaves per shoot

The leaves in each newly emerged shoot after they attain full growth were counted as Number of leaves per shoot.

3.5.13 Number of spines per shoot

The spines in each newly emerged shoot after attaining complete growth were counted as Number of spines per shoot.

3.5.14 Leaf Fresh weight

The weight of ten mature sample leaves per replication was taken and their weight was measured in electrical weighing balance just after removal from the tree. The average weight of the ten samples was taken as the fresh weight of the leaf and expressed in gram.

3.5.15 Leaf dry weight

The ten sample leaf after taking fresh weight were dried on hot air oven at 40±1°C till they attain a constant weight and weighed to record the dry weight in gram. The average of the ten samples was taken as the dry weight of the leaf (Dubey and Yadav, 2004).

3.5.16 Leaf area

Ten representative leaves per plant were selected in different flush. The leaf area of leaves was measured with the help of the formula given by Shrestha and Balakrishnan (1985). After computing the average value the leaf area was duly recorded in cm^2.

$$A = K (L \times W)$$

Where, A= Leaf area, L = Maximum length of leaf, W = the maximum breadth of the leaf and K = Leaf area constant (0.608 could be used in acid lime for non-destructive leaf area calculation).

3.5.17 Chlorophyll content of leaves

Chlorophyll content of the leaf samples of different seasons were measured by the 80% acetone method. The absorbance of the leaf and 80% acetone extract was taken in spectrophotometer keeping 80% acetone as blank. Then the amount of total chlorophyll, chlorophyll-A and chlorophyll-B are calculated by using the following formulae.

$$\text{Chlorophyll a} = (12.7 \times A_{663}) - (2.69 \times A_{645}) \times V/1000 \times W$$

$$\text{Chlorophyll b} = (22.9 \times A_{645}) - (4.68 \times A_{663}) \times V/1000 \times W$$

$$\text{Total chlorophyll} = (8.02 \times A_{663}) + (20.2 \times A_{645}) \times V/1000 \times W$$

Where, A= Absorbance at particular given wavelength.

V= Final volume of 80% acetone (ml).

W= Fresh weight of leaf sample (g).

Unit of chlorophyll content = mg/g of fresh weight.

3.6 Reproductive behaviour

Following observations relating to the reproductive behavior of Kuliana lime are studied by methods described as follows:

3.6.1 Reproductive shoot

The shoots which produce flower were known to be the reproductive shoot. The number of tertiary shoot from the previous season growth which have flower in the season are recorded and converted to percentage of the reproductive shoot.

3.6.2 Blooming season and duration of flowering

Flowering period from May 2016-17 was observed. The interval between the date of initiation and date of cessation of flower in the plants are recorded.

3.6.4 Flower bud development

For flower bud development nine arbitrary stages were selected based on the growth of the bud from emergence to full bloom. The morphological characters of the bud in different stages were described below. At every stage the length and diameter of 50 flowers were measured with the help of vernier caliper and the average was recorded.

Stage 1: The bud is fully or partially covered with the calyx. These were roundish, tiny and greenish white in colour. The length of corolla tube and calyx tube were almost equal.

Stage 2: This stage commenced when the calyx lobes were observed to have just separated at the apex and the corolla tube and the corolla tube was visible. These were also roundish and greenish white in colour.

Stage 3: In stage 3 the bud started to became conical. The partition on the petal was visible. The corolla tube was whiter than the stage 2.

Stage 4: In this stage the bud was spherical in shape and white in colour. The partition on the petal was more prominent.

Stage 5: At this stage the bud was conical in shape and white in colour and half developed.

Stage 6: The buds were usually elliptic to ovate in shape and white in colour. The length of flower bud and flower stalk was almost same.

Stage 7: At this stage the hermaphrodite and the male flowers can easily be differentiated by visual observation. The hermaphrodite flowers were elongated and in male flowers the diameter if the corolla cup was increased

instead of length as in the hermaphrodite flowers. For the male flowers it was the full growth stage.

Stage 8: The hermaphrodite flowers attained the full size (balloon shape). No further elongation took place in hermaphrodite flowers. A faint suture was visible on the hermaphrodite flowers. The male flowers were fully open at this stage.

Stage 9: In this stage the hermaphrodite flowers were fully open.

3.6.4 Days to anthesis

The total number of days taken by the bud till opening of flower was recorded and presented as the days to anthesis.

3.6.5 Blooming habit

Flower whether borne terminally or in the axil of the shoot was observed and recorded and the values were converted to percentage.

3.6.6 Flower types and flower morphology

Two types of flower generally found in the lime plant i.e. Hermaphrodite and male. The male or staminate flowers are those in which the style is present in rudimentary form and the stamens are well developed.

The hermaphrodite or perfect flower are those in which the style protrudes distinctly beyond the staminal column and also have the well developed stamens.

To observe the proportion of hermaphrodite and staminate flowers, 100 flower buds were selected and tagged. After full bloom, they were categorized as hermaphrodite or staminate flowers based on their reproductive organ and produced in percentage.

3.7.7 Time of anthesis

Fifty flower buds, which were to be open on the next day, were tagged. The number of flower opened were counted and marked with distinctive ink on the tag

after their opening at intervals of two hours starting from 6 a.m. to 6 p.m. for three consecutive days in the three different seasons.

3.6.7 Anther dehiscence

Fifty flowers were examined for a period of three days in order to find out the time of anther dehiscence in the three seasons. The mode and time of anther dehiscence was recorded with the help of hand lens.

3.6.8 Receptivity of stigma

Receptivity of stigma of Kuliana lime plant was observed by three methods, which are described as follows-

By visual method-

On the basis of appearance and colour of stigma observed through hand lens. Twenty five flowers were observed per plant and the result was converted to percentage.

By fruit set method-

Five sets of 25 flowers each were emasculated two day prior to anthesis and bagging and tagging were done properly. They are hand pollinated during the morning hour (8 a.m. to 10 a.m.) and again bagged. Observation on fruit set was recorded 10 days after pollination and then converted to percentage of fruit set. The Fruit set percent indirectly represents the stigmatic receptivity percentage.

By H_2O_2 test-

The stigmas were immersed in hydrogen peroxide (3%) for 3 min to observe the release of air bubbles, since the reaction of hydrogen peroxide with the enzyme peroxidase indicates the stigma is receptive (Zeisler, 1933). Twenty five flowers were observed per plant and the result was converted to percentage.

3.6.9 Pollen morphology and viability

The pollen grains from freshly opened flowers were mounded on clean glass slides and examined under microscope. The shape and colour of pollen grain were recorded. Pollen fertility of both hermaphrodite and staminate flower are studied by

acetocarmine test. All the pollen grain which took pink stain after two hours are considered as fertile one and others as sterile.

3.6.10 Mode of pollination

Twenty five numbers of unopened flower bud were selected and the following 4 methods of pollination were tried to assess the effectiveness of fruit set.

1. Not crossed, not emasculated but bagged to assess self pollination
2. Emasculated, not crossed, but kept open to assess role of insect and wind in pollination.
3. Not emasculated, not crossed but kept open to assess natural open pollination
4. Emasculated, crossed and bagged to note the extent of fruit set by hand pollination.

3.7 Yield and yield attributing characters

3.7.1 Length of fruit

The maximum equatorial diameter of five randomly selected fruits from each plant was measured in cm with the help of vernier caliper and the average equatorial diameter of fruit was worked out and presented.

3.7.2 Diameter of fruit

The maximum polar diameter of five randomly selected fruits from each plant was measured in cm with the help of vernier caliper and the average polar diameter of fruit was worked out and presented.

3.7.3 Fruit volume

The volume of five randomly selected fruit from each plant was measured separately by the water displacement method. The mean volume of the fruit for each treatment was calculated in ml separately and presented.

3.7.4 Average fruit weight

The weight (g) of five observational fruit from each tree was recorded on the electrical balance. The values were summed up and average fruit weight was computed by dividing total weight of fruits by total number of fruits.

3.7.5 Specific gravity of the fruit

The specific gravity (g/cc) of five observational fruit from each tree in different season was calculated. The values were summed up and average fruit specific gravity was computed.

$$\text{Specific gravity} = \frac{\text{Fruit weight}}{\text{Fruit volume}}$$

3.7.6 Number of seeds per fruit

The 5 fruits from each plant were taken and from each fruit, number of seeds was counted and mean number of seeds per fruit was calculated.

3.7.7 Weight of seeds per fruit

After extracting the juice from fruit, the seeds were separated out and washed. The seeds were wiped dry with blotting paper and weighed (g) on an electronic balance.

3.7.8 Rind thickness

The rind thickness of each fruit was measured by a pair of vernier caliper. The average rind thickness of five fruits was worked out and presented in mm.

3.7.9 Pulp weight

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 weight of the fruit in gram.

3.7.10 Number of segment per fruit

The number of segments of 10 fruits from each plant was recorded and the average value was determined.

3.7.11 Volume of juice

The juice of 10 fruit from each plant was extracted by lemon squeezer and was measured by the measuring cylinder then represented in ml. The average value denotes the volume of juice per fruit.

3.7.12 Juice

The juice from fruit was extracted by lemon squeezer. The percentage of juice content was calculated in relation to volume of fruit.

3.7.13 Total soluble solids

The total soluble solid was recorded with the help of Erma Hand refractometer (0-30 °Brix). One drop of juice was placed on the prism of refractometer facing the light source and value was recorded (AOAC, 1999). Care was also taken to clean the prism with distilled water and dry it before taking next reading.

3.7.14 Titrable acidity

Four ml of juice was taken in a beaker, a little amount of water was added to it and mixed thoroughly. The volume was then made up to 20 ml. Then 10 ml of sample solution was taken and titrated against 0.1N sodium hydroxide using phenolphthalein indicator. Appearance of light pink color indicated the end point. The acidity was expressed in terms of percentage of citric acid (Ranganna, 1977).

$$\textbf{Acidity (\%)} = \frac{\text{Titrate value} \times \text{Normality of alkali} \times \text{volume made up} \times 64 \times 100}{\text{Volume of filtrate taken for estimation} \times \text{volume of sample taken} \times 1000}$$

3.7.15 Total sugar

10 ml of filtrate juice was taken in a 250 cc volumetric flask. Then 5 ml of 1N HCl was added to it followed by addition of 30ml distilled water. Then it was heated for 3-5 minutes and cooled (for inversion) in water bath. The content was transferred to a conical flask and 2 drops of phenolphthalein indicator was added to it. Then it was titrated with 1N NaOH taken in a burette. The appearance of pink color showed the end point. Now, the non-reducing sugar present in the fruit pulp was converted to reducing form. Then this content was taken in a burette after making the volume up to 100 ml. 5 ml each of Fehling's A and Fehling's solution B were taken in a 250ml conical flask and 40 ml of distilled water was added and heated. When first bubble appeared, methylene blue indicator (2drops) was added to it and it was titrated against the juice content of the burette. The end point was noticed by brick red color (Ranganna, 1977).

$$\text{Percentage of total sugar} = \frac{\text{Factor} \times \text{dilution} \times 100}{\text{Titrate} \times \text{volume of sample taken}}$$

3.7.16 Reducing sugar

10 cc of filtrate fruit juice was taken in a 100 cc volumetric flask and volume was made up to 100 cc by adding distilled water. Then the content was transferred to 100 cc burette. 5 cc each of Fehling's solution A and B were taken followed by addition of 40 ml of distilled water and thoroughly mixed in a 250 cc conical flask. Conical flask was put over gas furnace and was heated. When first bubble comes out, then 2-3 drops of methylene blue indicator was added. Finally it was titrated against sample in a burette till the end point comes to brick red color (Ranganna, 1977).

$$\text{Percentage of reducing sugar} = \frac{\text{Factor} \times \text{dilution} \times 100}{\text{Titrate} \times \text{volume of sample taken}}$$

3.7.17 Non reducing sugar

Percentage of non reducing sugar = Percentage of Total sugar- Percentage of reducing sugar

3.7.18 Ascorbic acid content

Ascorbic acid content in fruit juices was estimated by volumetric method (Ranganna, 1977). 5 ml of standard ascorbic acid (100 µ g/ml) was taken in a conical flask containing 10 ml 4% oxalic acid and was titrated against the 2, 6-dichlorophenol indophenols dye. The appearance and persistence of pink colour was taken as end point. The amount of dye consumed (V_1 ml) is equivalent to the amount of ascorbic acid. 5 ml of sample (prepared by taking 5 g of juice in 100 ml 4% oxalic acid) was taken in a conical flask having10 ml of 4% oxalic acid and titrated against the dye (V_2 ml). The amount of ascorbic acid was calculated using the formula,

Ascorbic acid (mg/100 g)=(0.5 mg/V_1 ml)×(V_2/5 ml)×(100 ml/weight. of sample)× 100

3.7.19 Fruit set

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.

3.7.20 Fruit retention

Fifty fruits after set were tagged randomly in each plant. The numbers of fruit which reach maturity were recorded and fruit retention percentage was calculated by the following formula

$$\text{Fruit retention} = \frac{\text{Number of fruit set} - \text{number of fruit reached maturity}}{\text{Number of fruit set}} \times 100$$

3.7.21 Number of fruits per tree

Fruits of each tree in every season were counted at each harvesting.

3.7.22 Days taken to maturity

Ten numbers of fruit in each replication were tagged just after fruit set and the average time taken for maturity was determined.

3.7.23 Yield per tree

At each picking, the weight of the harvested fruits from each tree was recorded separately. Yield per tree (kg) was calculated by the following formula.

$$\text{Yield per tree (kg)} = \frac{\text{Total number of fruits per tree} \times \text{average fruit weight (g)}}{1000}$$

3.8 Experimental details

The present experiment was conducted in "Random Effect Model under PROC MIXED through Statistical Analysis System (SAS) software" with three treatment (season) and ten replication (plant). The plants were four years old. In each replication normal recommended cultural practices were followed during the period of investigation.

Null Hypothesis: All the three seasons are equally effective on growth and development of Kuliana lime.

Alternative Hypothesis: The three seasons have different effect on growth and development of Kuliana lime.

Table 3.1: Type 3 Tests of Fixed effects

Effect	Num DF	Den DF	F Value	Pr > F
Season	2	18		

Table 3.2: Least Square Means

Effect	Season	Estimate	Standard Error	DF	t Value	Pr > |t|
Season	Rainy			18		
Season	Spring			18		
Season	Winter			18		

Table- 3.3 Differences of Least squares Means

Effect	Season	Season	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
Season	Rainy	Spring							
Season	Rainy	Winter							
Season	Spring	Winter							

Difference of LSM or increase in specific parameter taken under consideration in this experiment was calculated by deducting the LSM of one season over another.

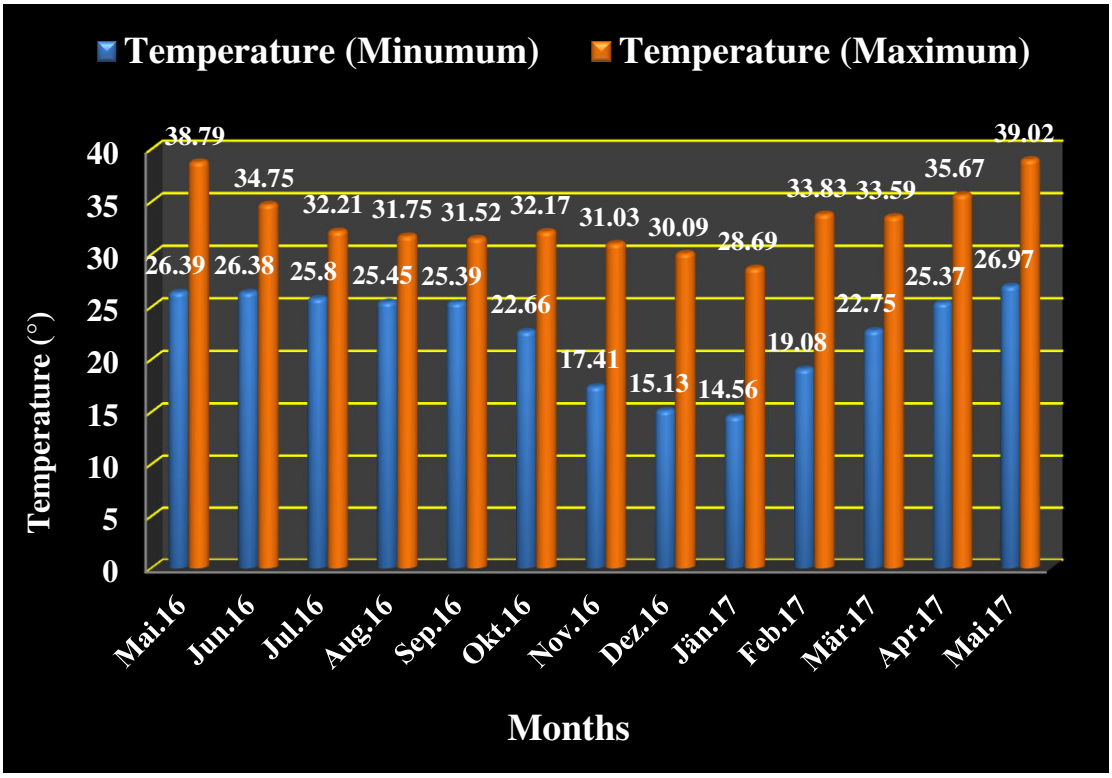


Fig. 3.1: Weather data pertaining to temperature in the period May 2016-17

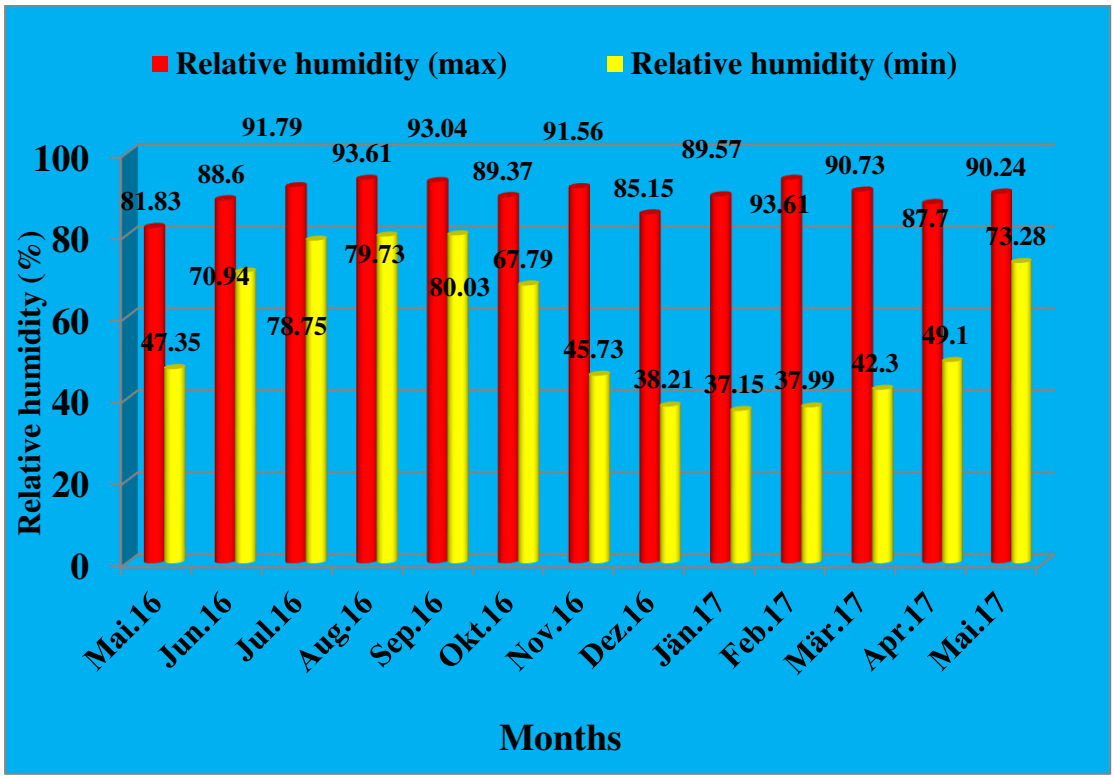


Fig. 3.2: Weather data pertaining to relative humidity in the period May 2016-17

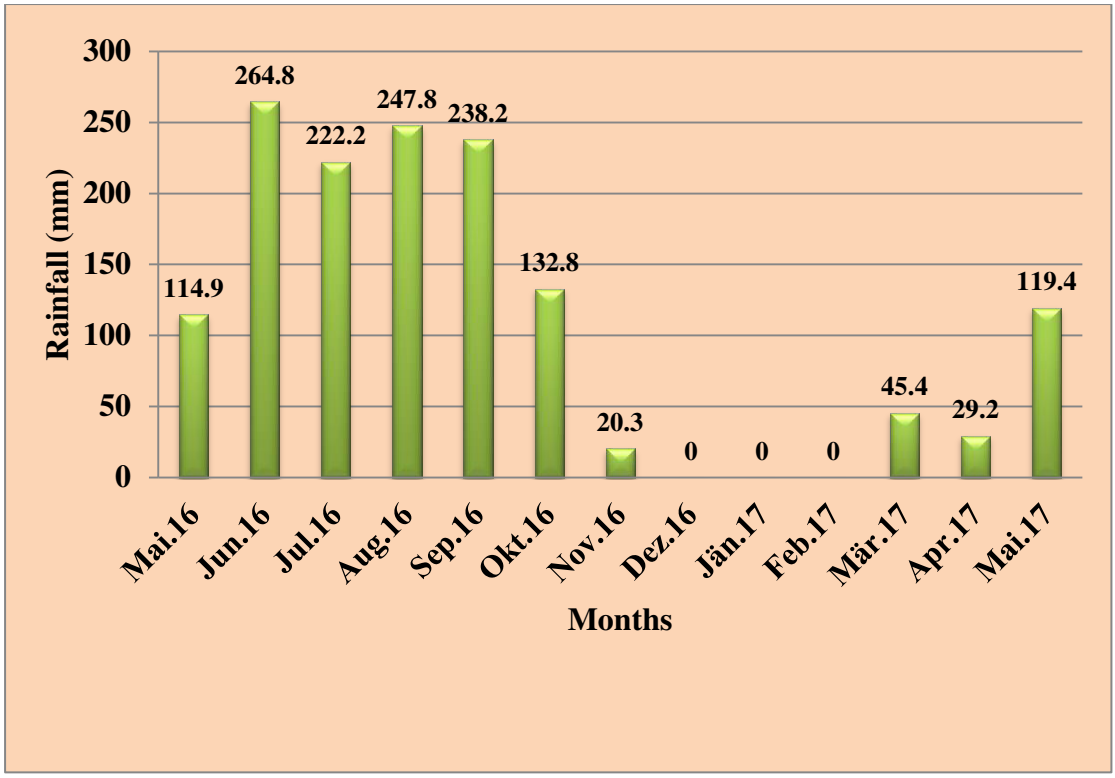


Fig. 3.3: Weather data pertaining to rainfall in the period May 2016-17

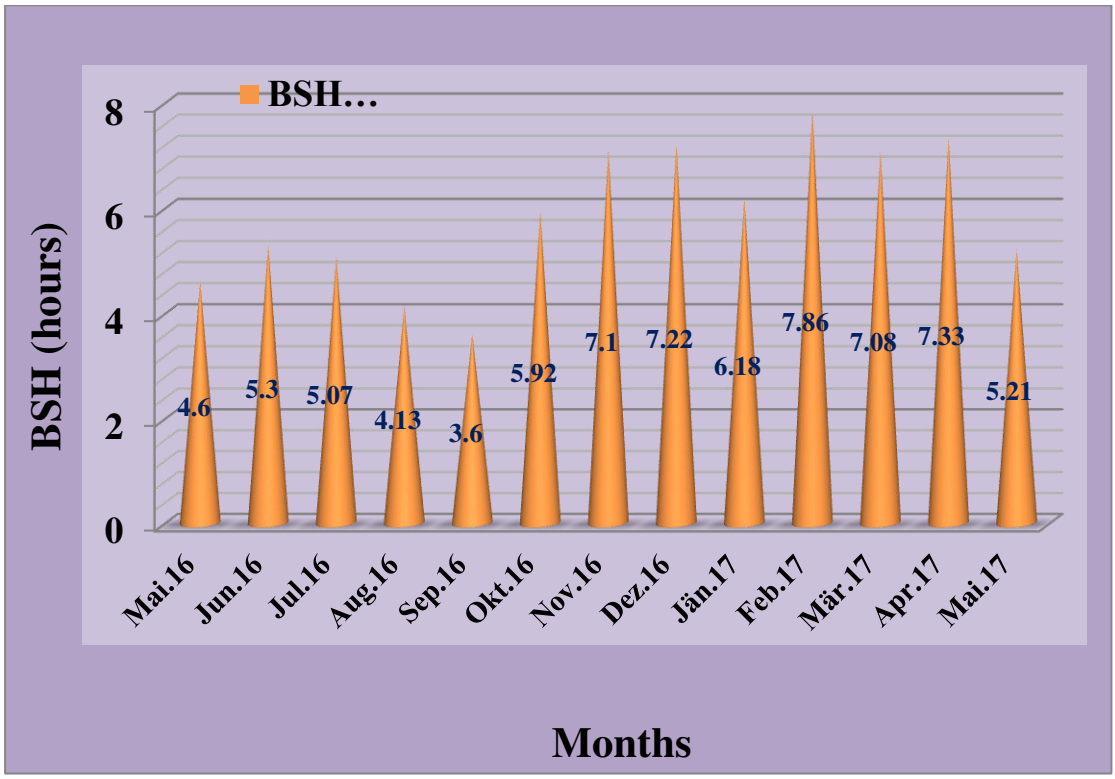


Fig. 3.4: Weather data pertaining to bright sunshine hour in the period May 2016-17

RESULTS

The biometric observations of different plant characters were recorded to study the **"Effect of seasons on growth and development of Kuliana lime (*Citrus aurantifolia*)''**. The experiments were conducted during the year 2016-17. The detail investigations on findings of experiment are presented in this chapter. Various data were tabulated and were analysed statistically with a view to find out the significant effect of different seasons on the plant growth and development. The data pertaining to various studies have been presented in the form of summarized tables along with necessary illustrations wherever deemed appropriate

4.1 Vegetative growth dynamics of Kuliana lime

4.1.1 Plant height

Data relevant to plant height presented on the Table-4.1 indicated that the plant height was significant in the different seasons.

Among the three seasons rainy season recorded maximum (35.76 cm) growth in average plant height followed by spring season (20.61 cm). The minimum (10.9 cm) mean growth in plant height was noticed in the winter season.

Among the differences of LSM of the seasons rainy season shows the statistically superior increase (24.86 cm) in average plant height over the winter season ($P<0.0001$) followed by 15.15 cm in the rainy season over the spring season ($P=0.0036$) and the spring season recoded the minimum increase in average plant height of 9.70cm over the winter season ($P=0.0460$).

4.1.2 Plant girth

The analysis revealed the growth in girth of the plant varied significantly among the rainy season, winter season and spring season (Table-4.1).

Rainy season recorded the maximum (13.41 mm) average growth in plant girth followed by spring season (9.97 mm). The minimum (3.81 mm) was obtained in the winter season.

However from the differences of LSM it was noticed that rainy season has significant Influence on increasing the plant girth of 9.60 mm over the winter season (P=0.0001). The increase of plant girth of 6.16 mm has been observed in spring season over the winter season (P=0.0053) and there is no significant difference for the same character in rainy season over the winter season.

4.1.3 Canopy spread (E-W)

Seasons have significant Influence to the increase in the canopy spread in the E-W direction of the Kuliana lime plant (Table-4.2).

In spring season maximum (21.61 cm) average canopy spread was recorded which was at par with the rainy season (19.00 cm) and the lowest (9.07 cm) average canopy spread was obtained in the winter season.

Spring season over the winter season has significant Influence (P=0.0039) in increasing (12.54 cm) the average canopy spread of the plant in East- West direction followed by rainy season (9.93 cm) over winter season (P=0.0173). Rainy season and spring season are similar in this aspect.

4.1.4 Canopy spread (N-S)

It is seen from Table-4.2 that the canopy spread in the North- South (N- S) direction was found statistically different among the seasons.

In spring season maximum (18.37 cm) average canopy spread was recorded which was at par with the rainy season (16.34 cm) and the lowest (9.28 cm) was obtained in the winter season

Between the seasons there was no significant difference in increasing the canopy spread of the plant in N-S direction.

4.1.5 Canopy volume

Canopy volume among the rainy season, winter season and the spring seasons showed significant variation (Table-4.2).

The rainy season recorded the maximum (4403.81cm^3) growth in plant canopy volume which is statistically at par with that of the spring season (4310.63 cm^3) and the minimum (556.35 cm^3) growth was observed in the winter season in Kuliana lime plant.

Data presented on the differences of LSM of the season clearly shows that there was significant increase of 3847.6 cm^3 and 3754.28 cm^3 in the canopy volume of the plant in the rainy season (P=0.006) and spring season (P=0.0071) over the winter season respectively. Spring season and rainy season are at par in increasing the canopy volume of Kuliana lime.

4.1.6 New growth flush or tertiary shoots

Seasons were having profound significant Influence on the number of new growth flush or tertiary produced in the Kuliana lime plant (Table-4.3).

The spring season produced the highest (153.80) average number of tertiaries which is statistically superior to that of the rainy season (125.40) and the winter season produced lowest (93.57) average number of tertiaries.

Data presented for the differences of LSM of season on Table 3 shows that there was significant increase in the average production of tertiary of 60.23 in the spring season in the Kuliana lime plant over the winter season (P<0.0001) followed by 31.83 numbers in the rainy season over the winter season (P=0.0158) and an average increase of 28.40 numbers has been noticed in the spring season over the rainy season (P=0.0287).

4.1.7 Length of the shoot

It is observed from Table-4.4 that the length of the shoot was statistically significant among the three seasons during 2016-17 in Kuliana lime plant.

Maximum shoot length was observed in the rainy season flush (16.78 cm) which is statistically at par with that of the spring season flush (15.32 cm). The winter season flush recorded the minimum length of the shoot (12.31 cm).

The result of differences of LSM of the season clearly indicated that there was 4.47 cm and 3.01 cm increase in the length of the shoot in Kuliana lime in rainy season (P <0.0001) and spring season (P=0.0004) over the winter season and there is no significant Influence of rainy season over the spring season.

4.1.8 Diameter of the shoot

Data relevant to shoot diameter presented on the Table 4.4 indicated that the diameter of the shoot have significant difference among the seasons.

In rainy season maximum (4.04 mm) average shoot diameter was observed followed by the spring season (3.23 mm) and the minimum (2.75mm) was in the winter season.

An increase of 1.29 mm and 0.81mm has been observed in the average diameter of the shoot in rainy season over the winter season (P<0.0001) and the spring season (P=0.0002) respectively. The spring season recorded an increase of average shoot diameter of 0.48 mm over the spring season (P=0.0148).

4.1.9 Inter-node length

It was revealed from Table-4.4 that the inter node length of new growth flush of Kuliana lime was found significant during the course of investigation.

Maximum average inter-node length was obtained in the rainy season flush (1.37 cm) followed by the spring season flush (1.25 cm) and the minimum in winter season flush (1.10 cm).

All the three seasons have significant Influence on increasing the inter-node length of the shoot. An average increase in inter node length of shoot of 0.27 cm was noticed in the rainy season over the winter season (P=0.0004) followed by 0.16 cm in the spring season over the winter season (P<0001) and the lowest was 0.12 cm in the rainy season over the spring season (P<0.0001).

4.1.10 Fresh weight of the shoot

Data relevant to shoot fresh weight presented on the Table-4.4 indicated that the fresh weight of the shoot have significant difference among the seasons.

Maximum (5.23 g) fresh weight of the shoot was observed in the rainy season flush which was statistically at par with that of the spring season flush (4.22 g) and the minimum (3.80g) fresh weight of the shoot was obtained in the winter season growth flush.

Rainy season and spring season have significant Influence on increasing the fresh weight of the season. An average increase 1.43 g and 1.01 g in fresh weight of the shoot has been observed in rainy season over the winter season (P= 0.0001) and spring season (P=0.0029) respectively. The impact of spring season in increasing fruit length is at par with the winter season.

4.1.11 Dry weight of the shoot

It is seen from the Table-4.4 that the dry weight of the shoot of the new flushes were found statistically different among the different seasons.

Rainy season recorded the highest (2.11 g) dry weight of the shoot of the new growth flush followed by the spring season (1.61 g). The lowest (1.26 g) dry weight of shoot was recorded in winter season growth flush.

All the three seasons have significant contribution for the dry weight of the shoot. An average increase of 0.85 g, 0.50 g and 0.35 g were observed in the dry weight of the shoot in rainy season over winter season (P<0.0001), rainy season over spring season (P=0.0003) and spring season over winter season (P=0.0056) respectively.

4.1.12 Number of leaves per shoot

The analysis revealed the number of leaves per shoot varied significantly among the different seasons in Kuliana lime (Table-4.5).

Rainy season recorded the maximum (14.23) number of leaves per shoot which is at par with that of the spring season (13.73). Winter season have the minimum (11.29) number of leaves per shoot. Both the rainy season and the winter season were significantly superior in production of leaves per shoot.

There was no significant Influence of rainy season over the spring season on increasing the number of leaves per shoot but winter season shows a reduction of 2.94 number of leaves per shoot and 2.44 numbers of leaves per shoot in rainy season (P=0.0033) and spring season (P=0.0117) respectively.

4.1.13 Number of spines per shoot

The number of spines varies significantly among the different seasons in Kuliana lime (Table-4.5).

The maximum numbers of spines per shoot are recorded by the rainy season flush (14.92) followed by the spring season flush (14.10) and the lowest were in the winter season flush (11.37).

The difference of LSM shows that there was no significant difference among the rainy season and winter season, however both rainy season (P=0.0006) and spring season (P=0.0053) were recorded to be superior to the winter season by 3.54 and 2.73 numbers of spines per shoot.

4.1.14 Fresh weight of the leaf

Data relevant to Fresh weight of the leaf presented on the Table-4.5 indicated that the fresh weight of the leaf had significantly different among the different seasons.

Rainy season recorded the maximum (0.39 g) leaf fresh weight which was statistically superior to the spring season and winter season. Rainy season was followed by the spring season (0.27 g) and the minimum (0.22 g) leaf fresh weight was obtained in the winter season.

An increase of 0.17 g and 0.12g in the average fresh weight of the leaves in Kuliana lime in the rainy season over the winter (P<0.0001) and spring season (P=0.001) respectively and there is no significant difference among the winter and spring season.

4.1.15 Dry weight of the leaf

Dry weight of the leaf varies significantly among the rainy season, winter season and spring season as shown in Table-4.5.

Maximum (0.18 g) leaf dry weight was obtained in the rainy season which was statistically superior to the spring season and winter season. Rainy season was followed by the spring season (0.11 g) and the minimum (0.04 g) leaf dry weight was obtained in the winter season.

Rainy season have significant Influence in increasing the average dry weight of the leaf over the winter season (P<0.0001) and spring season (P<0.0001) to 0.11 g and 0.07g respectively. The increase in average dry weight of the shoot in the spring season was 0.04 g over the winter season (P=0.0289).

4.1.16 Leaf area

Data relevant to Fresh leaf area presented on the Table-4.5 indicated that the leaf area was significantly different among the different seasons.

The rainy season flush have maximum leaf area of 16.19 cm^2 which was significantly superior to that of the winter season (10.36 cm^2) and spring season (9.06 cm^2). Rainy season shows significant Influence on the leaf area of the flush.

Rainy season recorded the maximum increase in leaf area of 7.11 cm^2, 5.82 cm^2 over the spring season (P<0.0001) and winter season (P<0.0001) respectively but the winter season was at par with the spring season for increase in leaf area.

4.1.17 Chlorophyll content of the leaves

It was seen from table 6 that the chlorophyll content of leaves of Kuliana lime varies significantly among the different seasons.

In the spring season (1.19 mg per g of FW) maximum amount of average chlorophyll A content was observed which was followed by the rainy season (1.10 mg per g of FW) and the minimum was found in the winter season (1.05 mg per g of FW) growth flush.

An average increase of 0.10 mg per 100 g of FW and 0.15 mg per 100 g of FW of chlorophyll-A content have been observed in spring season (P=0.0013) over the rainy season (P= <.0001). Rainy season and winter season have no significant Influence in production of the chlorophyll content of the leaves.

Spring season recorded the (0.61 mg per g of FW) maximum amount of average chlorophyll-B content followed by the rainy season (0.53 mg per g of FW) and the minimum was found in the winter season (0.50 mg per g of FW) growth flush.

All the three seasons have significant Influence for the production of chlorophyll-B in the leaves. However, in spring season there was significant increase (0.12 mg per g of FW) in average chlorophyll-B content of leaves over winter season (P= <.0001), followed by the rainy season at 0.09 mg per g of FW (P= <.0001). The rainy season shows an increase of 0.03 mg per g of FW (P= 0.002) in the average chlorophyll content of the leaves.

The total chlorophyll content of the spring season (1.81 mg per g of FW) growth flush recorded the highest amount which was statistically superior among the three seasons. The total chlorophyll content of spring season was followed by the rainy season (1.63 mg per g of FW) which was at par with the winter season (1.55 mg per g of FW).

The impact of spring season in increasing the total chlorophyll content of leaves over winter season (P= <.0001) and rainy season (P= <.0001) were 0.27 mg per g of FW and 0.18 mg per g of FW respectively. Rainy season recorded an average increase of 0.08 mg per g of FW (P= 0.007) over that of the winter season.

4.2 Reproductive behaviour of Kuliana lime

4.2.1 Reproductive shoot

It was seen from Table-4.7 that the vegetative shoot which are converted to flowering shoot or reproductive shoot in Kuliana lime varies significantly among the different seasons.

In spring season maximum (90.41 percent) vegetative shoot of previous season growth were converted to the reproductive shoot by producing flower buds and it was followed by the winter season (73.74 percent). The lowest (64.1 percent) conversion of vegetative to reproductive shoot was obtained in the rainy season.

All the three seasons were having significant Influence on conversion of vegetative shoot to reproductive shoot. Spring season has positive impact in

increasing the conversion of vegetative shoot to reproductive shoot at P<0.0001 over the rainy season (10.9 percent) and winter season (4.88 percent). The impact of winter season was greater (1.16 percent) in conversion of vegetative shoot to reproductive shoot than that of the rainy season.

4.2.2 Duration of flowering

Data pertaining to duration of flowering were presented on Table-4.7 was found significantly different among the three seasons.

The average duration of flowering was extended to 58.00 days (20/12/2016 to 15/02/2017) in spring season followed by the rainy season (50.00 days) from 24/04/2016 to 13/06/2016 and minimum (45.00 days) was recorded in the winter season from 01/09/2016 to 15/10/2016. All the seasons showed significant Influence on the average duration of flowering.

Spring season over winter season and rainy season recorded an increase of 13 days and 8 days in the average duration of flowering (P<0.0001 each) and in rainy season over winter season it was 5 days (P<0.0001).

4.2.3 Chronology of bud development in Kuliana lime

The bud developmental stages were categorized in to nine arbitrary stages. The different stages could be differentiated by the following characters [Fig. 4.1, 4.2(a) and 4.2(b)].

Stage-1 to 2: Bud was fully or partially covered by the calyx with 0.3 cm, 0.13 cm and 0.1cm length of bud, diameter of the bud and length of flower stalk respectively in the stage one. On an average the bud stage require one day to pass from stage-1 to stage-2.

Stage-2 to 3: In stage-2 the corolla tube was visible and bud have 0.35 cm, 0.21 cm and 0.15 cm length, diameter of the bud and length of flower stalk respectively. The bud stage-2 took one day to pass to the stage-3.

Stage-3 to 4: Bud became conical with 0.4 cm, 0.29 cm and 0.25 cm of length, diameter of bud and length of flower stalk respectively in stage-3 and took one day to reach the stage-4.

Stage-4 to 5: Partition on petal was prominent at stage-4 and the length, diameter of bud and the length of flower stalk were 0.5 cm, 0.35cm and 0.3 cm respectively. Stage-4 needed one day to pass to stage-5.

Stage-5 to 6: Bud was half developed and conical in shape with a 0.55 cm, 0.36 cm and 0.4cm length, diameter of bud and length of stalk respectively in stage-5. The flower bud took one day to pass to the stage-6.

Stage-6 to 7: After this stage there was no growth in the length of the stalk and the length and diameter of bud were 0.6 cm and 0.38 cm respectively in stage-6. The bud of stage-6 needed one day to reach the stage-7.

Stage-7 to 8: Diameter of male flower increases instead of the length and hermaphrodite flowers were elongate in shape. At this stage one can distinguish the male and hermaphrodite flower. The length and diameter of bud were 0.7 cm and 0.41cm (for male bud the diameter was 0.43 cm). The bud of stage-7 took two days to pass to stage-8.

Stage-8 to 9: Male flowers were opened and hermaphrodite flowers were balloon shape. The length and diameter of bud were 0.85 cm and 0.42 cm respectively at stage-8. Bud took one day to pass to stage-9.

Stage-9: Hermaphrodite flower was fully open at this stage

4.2.4 Days to anthesis

Total days taken for anthesis among the rainy season, winter season and the spring seasons showed significant variation (Table-4.7).

The rainy season flowering takes maximum (11.08 days) from flower bud initiation to anthesis followed by the winter season (9.01 days) and spring season (9.0 days). Winter season and spring season were statistically at par with each other in total number of days taken for anthesis.

Rainy season over spring season and winter season recorded an increase of 2.08 and 2.07 days in the average days taken for anthesis in Kuliana lime with a $P<0.0001$ each but there is no significant variation in spring season over the winter season.

4.2.5 Axillary buds and terminal buds

It was evident from Table-4.8 and Fig. 4.1 that in Kuliana lime plant there is no significant difference in the percentage of axillary buds among the rainy season, winter season and spring season.

However the spring season recorded the maximum (93.15 percent) number of axillary buds followed by the rainy season (92.89 percent) and the minimum (92.55 percent) percentage of axillary buds were seen in the winter season flowering.

In case of terminal bud percentage the same situation also persists that there is no significant difference in the percentage of terminal buds among the rainy season, winter season and spring season.

In the winter season the terminal bud percentage was more (7.47 percent) followed by the rainy season (7.23 percent) and the spring season recorded the minimum (6.84) percentage of terminal flower. All the three seasons have similar Influence in production of the terminal and axillary buds in Kuliana lime.

4.2.6 Staminate flower

The percentage of staminate flower per plant (Table-4.8 and Fig. 4.3) was found significant among the seasons.

Rainy season recorded the maximum (84.99 percent) percent of staminate flower followed by the winter season (82.49 percent) and the minimum (81.52 percent) was in the spring season. All the three season have significant Influence in the production of staminate flowers.

Among the seasons the rainy season recorded an increase in production of staminate flower of 0.27 percent and 0.14 percent over the spring and rainy season respectively ($P<0.0001$ each), whereas the winter season shows 0.01 percent over the spring season ($P= 0.0005$).

4.2.7 Hermaphrodite flower

Data relevant to hermaphrodite flower per plant presented on the Table-4.8 and Fig. 4.3 indicated that the hermaphrodite flower per plant was significantly different among the different seasons.

Spring season recorded the maximum (18.45 percent) hermaphrodite flower followed by the winter season (15.2 percent) and the minimum (15 percent) was observed in the rainy season.

The percentage of hermaphrodite flower produced in the spring season were 0.21 percent and 0.01 percent more than that of the rainy season ($P<0.0001$) and winter season ($P=0.0064$) respectively and in the winter season there was a increase of 0.17 percent of production of hermaphrodite flower in Kuliana lime over the rainy season.

4.2.8 Pollen viability of staminate flower

The pollen viability data of staminate flower on percentage (Table-4.9 and Fig. 4.4) of total pollen illustrated significant difference among the seasons.

The percentage of viable pollen in staminate flower during the spring season (77.42 percent) was significantly superior to the winter season (75.64 percent) and the lowest was observed in the rainy season (70.09 percent).

There was no significant variation of pollen viability of staminate flower in rainy season and winter season but spring season recorded an increase of 0.026 percent and 0.046 percent over the rainy season ($P=0.0025$) and winter season ($P=0.0002$) respectively.

4.2.9 Pollen viability of hermaphrodite flower

The pollen viability data of hermaphrodite flower on percentage (Table-4.9 and Fig. 4.5) of total pollen illustrated significant difference among the seasons.

Highest percent of viable pollen in the hermaphrodite flower was obtained in rainy season (75.17 percent) which is at par with the spring season (74.21 percent) and the lowest was in the winter season (70.22 percent).

The rainy season and spring season have similar Influence in pollen viability of hermaphrodite flower. Rainy season over winter season (P=0.0133) followed by the spring season over winter season (P=0.0403) have impact in increasing the pollen viability of Kuliana lime.

4.2.10 Anthesis in Kuliana lime

The anthesis in Kuliana lime took place from 8 a.m. to 2 p.m. in rainy and spring season and 10 a.m. to 2 p.m. in winter season. The peak period of anthesis was recorded at 10 am to 12 noon in rainy season and spring season, whereas 12 noon to 2 p.m. was recorded in winter season (Table-4.10).

4.2.11 Anther dehiscence in Kuliana lime

The anther dehiscence in Kuliana lime took place ten to fifteen minutes after the anthesis. The splitting of anther starts longitudinally releasing light yellow coloured pollen. During rainy season and spring season the anther dehiscence starts from 8 a.m. and continue till 2 p.m. but in winter season it starts 10 a.m. onwards and continued till 2 p.m. (Table-4.11).

4.2.12 Receptivity of stigma

The stigma became receptive one day prior to anthesis (88-96 percent) and the receptivity lasted for one day after anthesis in Kuliana lime. Stigma receptivity was 100 percent on the day of anthesis and reduces to 80 percent on one day after anthesis but there was drastic reduction thereafter.

4.2.13 Mode of pollination in Kuliana lime

The highest percentage of fruit set was observed in the natural open pollination (96 percent) followed by hand pollination (92 percent), insect and wind pollination (76 percent) and self-pollination (36 percent).

4.2.14 Number of flower per node and per shoot

During the rainy season there was the highest (6.38) average number of flower per node followed by the spring season (5.9) and winter season (5.24). The average number of flower per shoot was also recorded to be highest in the rainy season (28.43) followed by the spring season (27.96) and the winter season (27.85) (Fig. 4.6).

4.3 Yield and yield attributing characters of Kuliana lime

4.3.1 Fruit length

Data relevant to fruit length from the Table-4.14 and Fig. 4.7 indicated that the length of fruit was significant in the different seasons.

Among the three seasons Rainy season gave the highest (4.68 cm) average length of the fruit followed by spring season (4.66 cm). The average fruit length in winter season was the lowest (4.43 cm).

An average fruit length increase (0.24 cm) has been observed in rainy season over the winter season (P= 0.04) and the impact of spring season in increasing fruit length is at par with the rainy season. Hence the rainy season and spring season have significant Influence in increasing the fruit length in Kuliana lime.

4.3.2 Fruit diameter

Fruit diameter among the rainy, winter and the spring seasons shows significant variation (Table-4.14 and Fig. 4.7).

Rainy season fruit recorded the maximum (4.39 cm) average fruit diameter which is statistically superior to the other two seasons and it was followed by the spring season (4.14cm). The fruit diameter of winter season (4.13 cm) was at par with that of the spring season.

There is no significance difference among spring season over winter season on the fruit diameter but rainy season shows an increase of 0.26 cm (P= 0.0027) and 0.25 cm (P= 0.0034) over winter season and spring season respectively.

4.3.3 Fruit weight

It was seen from Table-4.14 that the fruit weight of Kuliana lime was statistically different among the seasons.

Fruit weight of spring season was statistically superior (32.11 g) over the rainy season and the winter season and it was followed by rainy season (28.95g). The lowest (19.40g) fruit weight was recorded by the winter season.

An average increase in fruit weight (12.71g) has been observed in spring season over the winter season (P<0.0001) and 9.55 g increase in rainy season over that of the winter season (P=0007). The impact of spring season in increasing fruit length is at par with the rainy season. Hence both the spring season and rainy season have significant Influence on increasing the fruit weight over the winter season, however the Influence of spring season was superior.

4.3.4 Fruit volume

The fruit volume showed significant difference among all the three seasons in Kuliana lime.

Data presented in Table-4.14 revealed that rainy season recorded the maximum (29.68 cc) mean fruit volume which is statistically higher than the spring season (24.85cc) and winter season (20.92 cc).

The impact of rainy season in increasing the average fruit volume over winter season was significant (P= 0.0012) and an increase of 8.76 cm has been recorded. Rainy season over the winter season and spring season over that of the winter season have similar Influence in increasing the fruit volume of Kuliana lime.

4.3.5 Fruit specific gravity

Data pertaining to the specific gravity of the fruit presented in Table-4.14 were found statistically significant difference among the seasons.

Maximum (1.30 g per cc) fruit specific gravity was obtained in the spring season which is statistically superior over the rainy season (0.97 g per cc) and the winter season (0.93 g per cc).

The increase in average specific gravity of fruit of spring season over the winter season (0.37 g per cc) and rainy season (0.33 g per cc) and were significant at P <0.0001 each. The rainy season over winter season was at par in increasing the specific gravity of the fruit.

4.3.6 Number of seeds per fruit

The data presented in Table-4.15 and Fig. 4.8 clearly indicated that, there was significant difference among the season with respect to the number of seeds per fruit.

Spring season recorded the maximum (9.20) number of seed per fruit which was statistically superior over the winter season (5.38) and the rainy season (5.34).

The number of seeds per fruit in winter season was at par with that of that of the rainy season. Spring season recorded an increase of 3.86 and 3.82 in average number of seeds over the rainy season and the winter season respectively ($P < 0.0001$ each).

4.3.7 Weight of seeds per fruit

Data on the weight of seeds per fruit presented in Table-4.15 illustrated significant difference among the seasons.

Maximum (0.55g) weight of seeds per fruit was recorded in the winter season which was statistically superior over that of the spring season (0.52g) and the rainy season (0.36g).

Spring season recorded an average increase of 0.165 g over the rainy season and winter season have an increase of 0.20 g over the rainy season with respect to weight of the seed per fruit at $P = 0.0005$ and $P < 0.0001$ respectively. The spring season and winter season have similar Influence in increasing the average seed weight per fruit of Kuliana lime.

4.3.8 Rind thickness

The seasons have significant Influence on the rind thickness of Kuliana lime as shown in Table-4.15 and Fig. 4.8.

Maximum (1.30 mm) rind thickness was observed in the spring season which is statistically superior over the other seasons. It was followed by the winter season (1.07mm) and the rainy season recorded lowest (1.03mm) rind thickness.

An average increase in rind thickness has been observed in spring season of 0.27 mm over the rainy season ($P < 0.0001$) and 0.23 mm over the winter season ($P=0.0001$). The impact of winter season in increasing the rind thickness of the fruit was at par with the rainy season. Hence the spring season have significant Influence in increasing the rind thickness in Kuliana lime.

4.3.9 Number of segments per fruit

It is seen from the Table-4.15 and Fig. 4.8 that the number of segment per fruit was not statistically different among the different seasons.

Winter season recorded the highest (10.72) number of segments per fruit which was at par with spring season (10.64) and the rainy season recorded the lowest (10.32) number of segments per fruit.

All the three season have similar Influence on numbers of segment per fruit. Hence the number of segment per the fruit were not affected by a particular season,

4.3.10 Weight of rag per fruit

The seasons have significant different on the weight of rag per fruit (Table-4.15).

The spring season recorded the maximum (17.52 g) rag weight per fruit followed by rainy season (12.22 g) and the lowest (9.34 g) rag weight per fruit was in the winter season.

The spring season have a positive Influence in increasing the average rag weight of the fruit over the winter season (8.18 g) at P <0.0001 and that of the rainy season (5.30 g) at P= 0.0015. Rainy season have no significant Influence in increasing the rag weight of the fruit.

4.3.11 Total Soluble Solid (TSS)

Significant variation was observed in TSS content of fruit juice of Kuliana lime in different seasons of 2016-17 (Table-4.16).

Spring season recorded the maximum (6.77 °Brix) TSS in fruit juice which, was statistically superior over the winter season (6.49 °Brix). The lowest (5.66 °Brix) TSS was observed in the rainy season crop.

It has been observed that the rainy season shows a decrease of 1.11°Brix and 0.83°Brix in the average TSS content of the fruit on spring season and winter season respectively (P=<0.0001 each) and winter season and spring season were having similar influence for this character of Kuliana lime fruits.

4.3.12 Volume of juice per fruit

It is observed from Table-4.16 that the volume of juice per fruit of Kuliana lime was found statistically significant difference among the various seasons.

The rainy season recorded the maximum (16.52 ml) volume of juice per fruit followed by the spring season (13.66 ml) and the lowest value (9.60 ml) was obtained in the winter season crop.

There was no significant Influence of rainy season over spring season for enhancing the mean juice content per fruit in Kuliana lime. However, winter season shows a decrease in the same over the rainy season (6.92 ml) at P= 0.0007 and spring season (4.06 ml) at P=0.028.

4.3.13 Juice per fruit

The analysis revealed that the percentage of juice per fruit varied significantly among the different seasons (Table-4.16).

During the spring season the maximum (54.5) percentage of juice per fruit was recorded and was statistically at par with that of the rainy season (52.99%). The winter season recorded the lowest (45.59) percentage of juice per fruit.

An average increase (2.4%) in juice per fruit has been observed in spring season over the winter season (P=0.0027) and (1.52%) in rainy season over winter season (P=0.0092). The impact of rainy season in increasing fruit juice percentage was at par with the spring season.

4.3.14 Acidity of fruit juice

Significant variation was observed in the acidity percentage of fruit juice among rainy, winter and spring season crop of Kuliana lime (Table-4.16).

Maximum (7.44%) acidity of fruit juice was observed in the rainy season followed by that of the winter season (6.69%) and the minimum (6.19%) acidity percentage was recorded by the spring season.

Among the seasons the higher 1.25 and 0.75 percent of acidity was found in the rainy season over the spring season (P= 0.0001) and winter season (P=0.0095) respectively. There was no significant variation for the same character for the spring season over the winter season.

4.3.15 Reducing sugar

The analysis revealed that the percentage of reducing sugar in the fruit of Kuliana lime varied significantly among the different seasons (Table-4.17).

Spring season recorded the maximum (0.25) percent of reducing sugar which was found significantly superior. It was followed by the winter season (0.24 percent) and the lowest (0.19) percent of reducing sugar was obtained in rainy season.

The rainy season recorded a decrease of 0.06 percent and 0.05 percent of average reducing sugar over spring season and winter season at P <0.0001 each, however the spring season over the winter season have no significant variation.

4.3.16 Non reducing sugar

Significant variation was observed in the percentage of non-reducing sugar among the seasons in Kuliana lime (Table-4.17)

Spring season recorded the maximum (0.22) percentage of non-reducing sugar followed by the winter season (0.21%) and the lowest percent of non-reducing sugar was obtained in rainy season (0.14).

The rainy season recorded a decrease of 0.08 percent and 0.07 percent of average non reducing sugar over spring season and winter season at P <0.0001 each, however the spring season over the winter season have no significant variation.

4.3.17 Total sugar

The analyzed data associated with the percentage of total sugar varied significantly among different seasons (Table-4.17)

Spring season recorded the maximum (0.46) percent of total sugar followed by the winter season (0.45%) and the lowest (0.33) percent of total sugar was obtained in rainy season.

The rainy season recorded a decrease of 0.13 percent and 0.12 percent of average total sugar over spring season and winter season at P <0.0001 each, however the spring season over the winter season have no significant variation.

4.3.18 Ascorbic acid content of fruit juice

Significant variation was recorded in the ascorbic acid content of the fruit of Kuliana lime among the three different seasons (Table-4.17).

The maximum (32.8760 mg per 100 ml of juice) ascorbic acid content was observed in the spring season crop followed by the winter season (32.055 mg per 100 ml of juice) and the lowest (31.67 mg per 100 ml of juice) was recorded in the rainy season. All the three seasons have similar Influence in increasing the ascorbic acid content of the fruit.

4.3.19 Fruit set percentage

Data on the percentage of fruit set presented in Table-18 and Fig. 4.10 illustrated significant difference among the seasons.

The maximum fruit set percentage was recorded by spring season i.e. 91.6 (73.272) percent which was significantly superior to winter season i.e.84.1 (66.447) percent. The lowest fruit set percentage was recorded by the rainy season with 78.46 (62.411) percent of the hermaphrodite flower.

An average reduction in fruit set of 3.55 percent and 0.45 percent has been observed in rainy season over the spring season (P<0.0001) and the winter season (P=0.0004) respectively, whereas the spring season recorded an increase of 1.36 percent in the mean fruit set over the winter season (P<0.0001). Hence the spring season followed by the winter season have significant Influence in increasing the fruit set percent in Kuliana lime.

4.3.20 Fruit retention percentage

The fruit retention percentage shows significant difference among the seasons (Table-18).

The highest fruit retention percentage was recorded by the spring season i.e. 25.18 (30.011) percentage followed by the rainy season i.e. 21.3 (27.502) percentage and the winter season i.e. 19.69 (26.347) percentage.

The average increase in fruit retention percentage of the spring season was significantly superior over the winter season (0.48%) at P=0.0001 and the rainy season (0.19%) at P=0.0033. No significant variations in the same character have been noticed in the rainy season over the winter season.

4.3.21 Number of fruit per plant

Significant variation was observed in the number of fruit per plant in Kuliana lime among the three different seasons (Table-18 and Fig. 4.9).

Spring season recorded the maximum mean number of fruit per plant (132.80) which is significantly superior. It was followed by the winter season (101.60) and the lowest in rainy season (99.20) which was at par with each other.

An average increase in number of fruits per plant has been noticed in spring season over the rainy season (33.60) and winter season (31.20) at P<0.0001 each. The impact of the rainy season in increasing the number of fruits per plant was at par with the winter season.

4.3.22 Total number of days taken for fruit maturity

The seasons have significant Influence on the total number of days taken for fruit maturity of Kuliana lime as shown in Table-18.

Winter season recorded the highest average number of days taken for fruit maturity (122.10 days) which was statistically superior over the rainy season (114.16 days) and the spring season (113.44 days) and the rainy season was at par with the spring season.

The average number of days taken for fruit maturity of the rainy season was statistically at par with that of the spring season and an increasing trend was observed in winter season over both the spring season (8.66 days) and the rainy season (7.94 days) at P < 0.0001 each.

4.3.23 Yield per plant

The analysis revealed the yield per plant varied significantly among the different seasons (Table-18 and Fig. 4.11).

The maximum yield per plant was observed in the spring season (4.252 Kg per plant) which was significantly superior to that of the rainy season (2.7825 Kg per plant). The lowest yield per plant was recorded by the winter season (1.935 Kg per plant).

All the three seasons have significant Influence in increasing the yield per plant of Kuliana lime. An average increase in yield per plant of 2.317 Kg and 1.4695 Kg has been observed in spring season over the winter season and the rainy season respectively at $P<0.0001$ each. The impact of rainy season in increasing the mean fruit yield per plant was 0.8475 Kg over that of the winter season ($P=0.0002$).

Table 4.1: Influence of season on plant height and girth of Kuliana lime

Season	Plant	Plant height (cm)	Relative growth of height (cm)	Girth of plant (cm)	Relative growth of girth (mm)
Rainy	1	264	29.46	16	7.6
	2	254	30.72	32	5.29
	3	187.5	42.8	14	24.5
	4	229	44.3	11.33	22.36
	5	190	28.9	11.5	11.9
	6	190	47.6	17.74	18.32
	7	196.5	29.4	36.5	14.67
	8	157	46.2	15	13
	9	153	27.5	15.5	6.8
	10	181.5	30.7	26	9.7
	Mean		**35.76**		**13.41**
Winter	1	270	6	16.1	1
	2	256	2	32.45	4.5
	3	189.3	1.8	14.5	5
	4	241.5	12.5	11.6	3
	5	197.8	7.8	11.76	2.6
	6	200.5	10.5	17.97	2.3
	7	208.8	12.3	37.1	6
	8	171.6	14.6	15.4	4
	9	177.5	24.5	15.77	2.7
	10	198.5	17	26.7	7
	Mean		**10.90**		**3.81**
Spring	1	273.35	3.35	16.7	6
	2	284.2	28.2	32.95	5
	3	206.8	17.5	16.75	22.5
	4	253	11.5	13.5	19
	5	199.3	1.5	12.93	11.7
	6	213.5	13	18.8	8.3
	7	229.3	20.5	37.8	7
	8	207.6	36	16.07	6.7
	9	201.5	24	16.92	11.5
	10	249	50.5	26.9	2
	Mean		**20.61**		**9.97**
SE ($\pm$) Season			3.3705		1.7094
SE(d) ($\pm$) of LSM			4.5273		1.9413
Pr >|t|	Rainy spring		0.0036		NS
	Rainy winter		<0.0001		0.0001
	Spring winter		0.046		0.0053

Table 4. 2: Influence of season on Canopy spread and canopy volume of Kuliana lime

Season	Plant	Canopy spread (E-W), cm	Relative growth (E-W) (cm)	Canopy spread (N-S), cm	Relative growth (N-S) (cm)	Canopy volume (m^3)	Relative growth of canopy volume (cm^3)
Rainy	1	275	18.46	304	8.2	7.89	1867.05
	2	250	22.37	263.5	9	5.97	2695.58
	3	234.5	16.2	285.5	12.4	4.52	3121.61
	4	236	37.2	252.4	4.7	4.87	6934.8
	5	268.5	8.6	262.5	29.65	4.78	3770.18
	6	310.5	10.5	305.5	18.9	6.43	3668.63
	7	303	39.45	252.3	32	5.4	13383.03
	8	211	9.46	218.5	24.3	2.58	4695.15
	9	221	11.4	225.4	8	2.72	992.86
	10	237	16.37	222	16.23	3.41	2909.22
	Mean		**19.00**		**16.34**		**4403.81**
Winter	1	280.1	5.1	308	4	7.89	44.3
	2	258.09	8.09	269.7	6.2	5.97	36.42
	3	242.4	7.9	289.46	3.96	4.52	22.58
	4	245.3	9.3	256.8	4.4	4.87	209.19
	5	276	7.5	266.4	3.9	4.78	90.39
	6	317.6	7.1	311	5.5	6.43	148.64
	7	316	13	267.3	15	5.40	859.85
	8	236.5	25.5	240.5	22	2.58	2937.26
	9	224.3	3.3	242.1	16.7	2.72	873.82
	10	240.9	3.9	233.1	11.1	3.41	341.06
	Mean		**9.07**		**9.28**		**556.35**
Spring	1	292.6	12.5	314	6	7.89	102.23
	2	284.39	26.3	293.7	24	5.98	6361.91
	3	253.8	11.4	293.76	4.3	4.52	348.62
	4	259.5	14.2	282.8	26	4.87	1657.05
	5	290	14	269.2	2.8	4.78	37.75
	6	352.6	35	319.36	8.36	6.43	2179.26
	7	347	31	301.3	34	5.41	7722.77
	8	369.5	33	262.9	22.4	2.60	9852
	9	239	14.7	274.4	32.3	2.72	4727.26
	10	264.9	24	356.5	23.4	3.42	10117.44
	Mean		**21.61**		**18.36**		**4310.63**
SE ($\pm$) Season			2.8852		3.0318		998.55
SE(d) ($\pm$) of LSM			3.79		3.7298		1236.93
Pr >|t|	Rainy spring		NS		NS		NS
	Rainy winter		0.0173		NS		0.006
	Spring winter		0.0039		NS		0.0071

Table 4.3: Influence of season on production of number of new shoot or tertiary shoot of Kuliana lime

Season	Plant	Number of primaries	Number of secondaries	Number of tertiaries
Rainy	1	10	45	130
	2	4	19	167
	3	4	20	127
	4	7	39	144
	5	8	30	127
	6	8	22	108
	7	4	36	164
	8	5	28	96
	9	3	23	100
	10	3	15	91
	Mean			**125.40**
Winter	1	10	45	120
	2	4	19	76
	3	4	20	33.35
	4	7	39	104
	5	8	30	70
	6	8	22	80.67
	7	4	36	156
	8	5	28	104
	9	3	23	111
	10	3	15	80.67
	Mean			**93.57**
Spring	1	10	45	210
	2	4	19	171
	3	4	20	86.66
	4	7	39	156
	5	8	30	180
	6	8	22	176
	7	4	36	174
	8	5	28	130.66
	9	3	23	168.7
	10	3	15	85
	Mean			**153.80**
SE ($\pm$) Season				10.8139
SE(d) ($\pm$) of LSM				11.948
Pr >|t|	Rainy spring			0.0287
	Rainy winter			0.0158
	Spring winter			<0.0001

Table 4.4: Influence of season on shoot length, shoot diameter, internode length, fresh weight of shoot and dry weight of the shoot of Kuliana lime

Season	Plant	Shoot length (cm)	Shoot diameter (mm)	Inter-node length (cm)	Fresh weight of shoot(g)	Dry weight of shoot(g)
Rainy	1	19.3	3.5	1.46	5.75	2.17
	2	14.95	3.9	1.38	4.96	2.09
	3	17.58	4.6	1.39	6.92	2.18
	4	16.5	4.1	1.46	4.98	2.13
	5	16.4	2.9	1.32	4.05	1.98
	6	19.1	4.8	1.4	5.95	2.48
	7	17.36	4.6	1.34	4.02	1.95
	8	14.8	4.1	1.35	4.18	1.96
	9	15.93	3.7	1.32	4.56	1.86
	10	15.86	4.2	1.3	6.93	2.32
	Mean	**16.78**	**4.04**	**1.37**	**5.23**	**2.11**
Winter	1	12.47	2.7	1.09	3.19	1.5
	2	9.93	2.4	1.12	4.12	1.13
	3	16.25	3.6	1.07	4.05	1.22
	4	15.25	3.3	1.15	3.29	1.34
	5	13.62	2.1	0.98	3.55	1.37
	6	9.45	2.2	1.11	4.12	1.12
	7	12.8	3.4	1.13	3.48	1.13
	8	12.96	2.8	1.16	3.96	1.09
	9	10.2	2.7	1.08	4.15	1.39
	10	10.16	2.3	1.1	4.12	1.34
	Mean	**12.31**	**2.75**	**1.10**	**3.80**	**1.26**
Spring	1	14.6	3.2	1.17	4.27	1.8
	2	14.37	2.9	1.26	4.57	1.6
	3	19.23	4.5	1.33	4.6	2.1
	4	17.33	4.3	1.33	4.26	2
	5	15.6	2.4	1.27	4.33	1.57
	6	12.83	2.5	1.13	3.5	1.13
	7	16.6	3.6	1.38	3.8	1.77
	8	15.87	3.4	1.26	4.13	1.87
	9	13.47	2.9	1.26	4.46	1.2
	10	13.3	2.6	1.16	4.27	1.1
	Mean	**15.32**	**3.23**	**1.25**	**4.22**	**1.61**
SE ($\pm$) Season		0.6317	0.1947	0.02028	0.2231	0.07894
SE(d) ($\pm$) of LSM		0.6946	0.1780	0.0273	0.2941	0.1116
Pr >|t|	Rainy Spring	NS	0.0002	0.0004	0.0029	0.0003
	Rainy Winter	<0.0001	<0.0001	<0.0001	0.0001	<0.0001
	Spring Winter	0.0004	0.0148	<0.0001	NS	0.0056

Table 4.5: Influence of season on number of leaves per shoot, number of spines per shoot, fresh weight of leaves, dry weight of leaves and leaf area of Kuliana lime

Season	Plant	No of leaves per shoot	No of spines per shoot	Leaf FW (g)	Leaf DW (g)	Leaf area (cm^2)
Rainy	1	15	15.4	0.27	0.15	13.77
	2	12.82	15.25	0.25	0.18	15.75
	3	13.29	13.2	0.33	0.14	13.55
	4	12.8	15.3	0.41	0.18	16.14
	5	13.2	13.4	0.43	0.2	18.06
	6	17	17.4	0.35	0.16	13.32
	7	13	13.2	0.45	0.21	16.15
	8	14.2	14.2	0.62	0.26	22.08
	9	14.83	15.2	0.34	0.16	15.05
	10	16.2	16.6	0.45	0.19	18.01
	Mean	**14.23**	**14.92**	**0.39**	**0.18**	**16.19**
Winter	1	11.44	11.44	0.24	0.08	11.01
	2	8.86	8.92	0.2	0.06	9.28
	3	15.18	15.26	0.24	0.08	10.59
	4	13.26	13.26	0.26	0.1	11.67
	5	13.89	13.95	0.26	0.1	9.85
	6	8.51	8.51	0.2	0.06	11.56
	7	11.33	11.45	0.19	0.06	10.86
	8	11.77	11.89	0.18	0.06	9.94
	9	9.44	9.44	0.16	0.05	7.52
	10	9.24	9.62	0.28	0.09	11.37
	Mean	**11.29**	**11.37**	**0.22**	**0.07**	**10.37**
Spring	1	12	12	0.28	0.1	9.43
	2	16.33	16.33	0.21	0.09	9.24
	3	17.67	18	0.28	0.08	9.27
	4	14.33	14.67	0.26	0.08	9.02
	5	13.34	14.34	0.28	0.09	9.62
	6	13	13	0.31	0.19	8.97
	7	13.33	14.33	0.3	0.09	9.34
	8	13.67	13.67	0.24	0.08	8.22
	9	12.67	13.33	0.23	0.18	7.29
	10	11	11.33	0.34	0.11	10.35
	Mean	**13.73**	**14.10**	**0.27**	**0.11**	**9.06**
SE ($\pm$) Season		0.6157	0.6073	0.02212	0.01042	0.5602
SE(d) ($\pm$) of LSM		0.8707	0.8589	0.02983	0.01474	0.7826
Pr >|t|	Rainy spring	NS	NS	0.001	<0.0001	0.0001
	Rainy winter	0.0033	0.0006	<0.0001	<0.0001	<0.0001
	Spring winter	0.0117	0.0053	NS	0.0289	NS

Table 4.6: Influence of season on chlorophyll content of the leaves of Kuliana lime

Season	Plant	Chlorophyll-A (mg per g of FW)	Chlorophyll-B (mg per g of FW)	Total chlorophyll (mg per g of FW)
Rainy	1	0.97	0.46	1.43
	2	1.04	0.49	1.53
	3	0.76	0.38	1.15
	4	1.14	0.51	1.65
	5	1.63	0.78	2.4
	6	1.03	0.53	1.57
	7	0.88	0.46	1.34
	8	1.58	0.71	2.29
	9	0.95	0.5	1.45
	10	1.04	0.45	1.5
	Mean	**1.10**	**0.53**	**1.63**
Winter	1	0.93	0.43	1.36
	2	0.98	0.43	1.41
	3	0.72	0.38	1.1
	4	1.09	0.47	1.56
	5	1.42	0.76	2.18
	6	1.01	0.51	1.52
	7	0.86	0.41	1.27
	8	1.52	0.68	2.2
	9	0.94	0.48	1.42
	10	1.02	0.42	1.44
	Mean	**1.05**	**0.61**	**1.66**
Spring	1	1.27	0.58	1.85
	2	1.18	0.54	1.72
	3	0.86	0.43	1.29
	4	1.18	0.59	1.77
	5	1.67	0.92	2.59
	6	1.19	0.63	1.82
	7	0.96	0.52	1.48
	8	1.62	0.79	2.41
	9	0.97	0.61	1.58
	10	1.09	0.53	1.62
	Mean	**1.19**	**0.50**	**1.69**
SE ($\pm$) Season		0.08406	0.0412	0.1229
SE(d) ($\pm$) of LSM		0.02542	0.00834	0.02809
Pr >|t|	Rainy spring	0.0013	<0.0001	<0.0001
	Rainy winter	NS	0.002	0.0073
	Spring winter	<0.0001	<0.0001	<0.0001

Table 4.7: Influence of season on the reproductive shoot, duration of flowering and the days to anthesis of Kuliana lime

Season	Plant	Reproductive shoot (%)	Duration of flowering (days)	Days to anthesis
Rainy	1	66.5 (54.63)	50	11
	2	61.4 (51.59)	52	10.2
	3	70.4 (57.04)	49	10
	4	65.2 (53.85)	51	12.2
	5	57.6 (49.37)	50	10.68
	6	65.5 (54.03)	49	11.49
	7	54.6 (47.64)	50	11.98
	8	65 (53.73)	51	12
	9	71.4 (57.67)	48	9.8
	10	62.9 (52.48)	50	11.47
	Mean	**64.1 (53.20)**	**50**	**11.08**
Winter	1	76.3 (60.87)	45	9
	2	79.6 (63.15)	46	9.09
	3	62.4 (52.18)	45	9.46
	4	82.4 (65.2)	47	9.2
	5	71.7 (57.86)	45	9
	6	80.2 (63.58)	44	8.92
	7	63.5 (52.83)	45	9.02
	8	69.5 (56.48)	43	9
	9	77.5 (61.68)	45	9.01
	10	72.9 (58.63)	45	8.4
	Mean	**73.74 (59.25)**	**45**	**9.01**
Spring	1	90.6 (72.15)	57	9.46
	2	87.5 (69.3)	56	9.03
	3	95.2 (77.34)	59	8.91
	4	95 (77.08)	55	9.1
	5	91.3 (72.84)	60	8.9
	6	90.4 (71.95)	58	9
	7	88.3 (70)	61	9.12
	8	82.9 (65.57)	59	8.27
	9	90.2 (71.76)	58	9.16
	10	90.5 (72.05)	57	9.05
	Mean	**90.41 (72.00)**	**58**	**9**
SE ($\pm$) Season		1.1764	0.4389	0.1765
SE(d) ($\pm$) of LSM		1.5004	0.6206	0.2497
Pr >|t|	Rainy spring	<0.0001	<0.0001	<0.0001
	Rainy winter	0.0008	<0.0001	<0.0001
	Spring winter	<0.0001	<0.0001	NS

(Figure in the parenthesis denotes arc sine transformed value)

Table 4.8: Influence of season on production of axillay bud, terminal bud, staminate flower and hermaphrodite flower in Kuliana lime

Season	Plant	Axillary bud (%)	Terminal bud (%)	Staminate flower per plant (%)	Hermaphrodite flower per plant (%)
Rainy	1	93.2 (74.88)	6.8 (15.12)	85 (67.21)	15 (22.79)
	2	94 (75.82)	6 (14.18)	84.6 (66.89)	15.4 (23.11)
	3	91.56 (73.11)	8.44 (16.89)	85.1 (67.29)	14.9 (22.71)
	4	90.56 (72.11)	9.44 (17.89)	84.35 (66.7)	15.65 (23.3)
	5	94.58 (76.54)	5.42 (13.45)	85.6 (67.7)	14.4 (22.3)
	6	92.9 (74.55)	7.1 (15.45)	84.89 (67.05)	15.2 (22.95)
	7	93.56 (75.29)	6.44 (14.7)	85.89 (67.86)	14.2 (22.14)
	8	92.58 (74.19)	7.42 (15.81)	84.8 (67.05)	15.2 (22.95)
	9	92.56 (74.17)	7.44 (15.83)	84.9 (67.13)	15.1 (22.87)
	10	92.1 (73.57)	7.9 (16.32)	84.9 (67.13)	15.1 (22.87)
	Mean	**92.89 (74.42)**	**7.23 (15.56)**	**84.99 (67.20)**	**15 (22.79)**
Winter	1	93 (74.66)	7 (15.34)	82.6 (65.35)	17.4 (24.65)
	2	91.7 (73.26)	8.3 (16.74)	82.6 (65.35)	17.4 (24.65)
	3	92.9 (74.55)	7.1 (15.45)	81.6 (65.35)	18.4 (25.4)
	4	92.46 (74.07)	7.54 (15.94)	82.7 (65.42)	17.3 (24.58)
	5	93.76 (75.55)	6.24 (14.47)	82.5 (65.27)	17.5 (24.73)
	6	92.56 (74.17)	7.44 (15.83)	81.2 (64.3)	18.8 (25.7)
	7	91.3 (72.84)	8.7 (17.16)	81.8 (64.75)	18.2 (25.25)
	8	92.6 (74.21)	7.4 (15.79)	83.4 (65.96)	16.6 (24.04)
	9	92.6 (74.21)	7.4 (15.79)	83.4 (65.96)	16.6 (24.04)
	10	92.52 (74.13)	7.48 (15.87)	82 (64.9)	18 (25.1)
	Mean	**92.55 (74.16)**	**7.47 (15.84)**	**82.49 (65.26)**	**15.02 (24.81)**
Spring	1	94.7 (76.69)	5.3 (13.31)	81.9 (64.92)	18.1 (25.18)
	2	93.2 (74.88)	6.8 (15.12)	81.2 (64.3)	18.8 (25.7)
	3	94.5 (76.44)	5.5 (13.56)	81.8 (64.75)	18.2 (25.25)
	4	91.98 (73.55)	8.02 (16.45)	81.2 (64.3)	18.8 (25.7)
	5	91.7 (73.26)	8.3 (16.74)	82.8 (64.75)	17.2 (24.5)
	6	94.3 (76.19)	5.7 (13.81)	81.2 (64.3)	18.8 (25.7)
	7	93.4 (75.11)	6.6 (14.89)	81.1 (64.23)	18.9 (25.77)
	8	93.1 (74.77)	6.9 (15.23)	81.3 (64.38)	18.7 (25.62)
	9	91.97 (73.54)	8.03 (16.47)	81.7 (64.67)	18.3 (25.33)
	10	92.35 (73.93)	7.65 (16.05)	81.75 (64.71)	18.25 (25.29)
	Mean	**93.15 (74.83)**	**6.84 (15.16)**	**81.52(64.53)**	**18.45(25.40)**
SE ($\pm$) Season		0.359	0.358	0.1218	0.1383
SE(d) ($\pm$) of LSM		0.5077	0.5064	0.1714	0.1911
Pr >|t|	Rainy spring	NS	NS	<0.0001	<0.0001
	Rainy winter	NS	NS	<0.0001	<0.0001
	Spring winter	NS	NS	0.0005	0.0064

(Figure in the parenthesis denotes arc sine transformed value)

Table 4.9: Influence of season on pollen viability of Kuliana lime

Season	Plants	Pollen viability (%)	
		Staminate flower	Hermaphrodite flower
Rainy	1	77.02 (60.68)	72.34 (58.27)
	2	75.98 (60.66)	73.54 (59.03)
	3	76.96 (60.95)	71.65 (57.83)
	4	76.12 (60.74)	72.96 (58.67)
	5	76.84 (61.23)	72.5 (58.37)
	6	73.42 (58.96)	73.2 (58.82)
	7	76.2 (60.8)	72.4 (58.31)
	8	74.56 (59.71)	71.98 (72.52)
	9	75.56 (60.37)	73.2 (58.82)
	10	79.54 (63.1)	75.83 (60.54)
	Mean	**70.09 (60.72)**	**75.17 (60.12)**
Winter	1	75.8 (60.53)	69.5 (56.48)
	2	74.92 (59.94)	69.8 (56.66)
	3	76.32 (60.88)	70.82 (57.29)
	4	75.65 (60.435)	70.24 (56.93)
	5	75.86 (60.57)	71.2 (57.54)
	6	74.32 (59.55)	71.34 (57.63)
	7	75.92 (60.61)	71 (57.42)
	8	75.56 (60.37)	68.7 (55.98)
	9	76.1 (60.73)	69.8 (56.66)
	10	76.05 (60.7)	70 (56.79)
	Mean	**75.64 (60.43)**	**70.22 (56.94)**
Spring	1	77.32 (61.56)	75.44 (60.29)
	2	77.44 (61.64)	74.24 (59.5)
	3	77.98 (62.02)	73.12 (58.76)
	4	77.86 (61.93)	74.86 (59.9)
	5	77.21 (61.48)	74.52 (59.68)
	6	77.01 (61.34)	73.35 (58.9)
	7	76.98 (61.33)	73.2 (58.82)
	8	77.79 (61.88)	74.26 (59.51)
	9	77.43 (61.63)	73.98 (59.33)
	10	77.38 (61.61)	75.43 (60.280)
	Mean	**77.42 (61.64)**	**74.21 (59.49)**
SE ($\pm$) Season		0.2124	0.8186
SE(d) ($\pm$) of LSM		0.2623	1.1577
Pr >|t|	Rainy spring	0.0025	NS
	Rainy winter	NS	0.0133
	Spring winter	0.0002	0.0403

(Figure in the parenthesis denotes arc sine transformed value)

Table: 4.10 Influence of season on time of anthesis in Kuliana lime

Season of flowering	Anthesis in hermaphrodite flower (%)			Anthesis of staminate flower (%)		
	8 a.m.-10 a.m.	10 a.m.-12 noon	12 - 2 p.m	8 a.m.-10 a.m.	10 a.m.-12 noon	12 -2 p.m.
Rainy (May– June)	33.34	50	16.66	50	25	25
Winter (Sept.- Oct.)	0	26.74	73.26	8.33	64	27.67
Spring (Jan - Mar)	8.33	54.17	37.5	0	45.5	54.5

Table: 4.11 Influence of season on time in anther dehiscence of Kuliana lime

Season of flowering	Anther dehiscence at two hours interval (%)		
	8a.m. – 10 a.m.	10 a.m.-12 noon	12 - 2. p.m
Rainy (May– June)	33.34	43.26	23.4
Winter (Sept.- Oct.)	0	41.67	58.33
Spring (Jan - Mar)	8.33	48.33	43.34

Table: 4.12 Stigma receptivity in Kuliana lime

Sl. No.	Days at which pollination was carried out	Number of flower selected	Visual method (%)	By H_2O_2 test (%)	Artificial hand pollination (%)
1	Two day before anthesis	25	20	20	16
2	One day before anthesis	25	88	96	88
3	On the day of anthesis	25	100	100	92
4	One day after anthesis	25	80	80	80
5	Two day after anthesis	25	16	20	16

Table: 4.13 Mode of pollination in Kuliana lime

Mode of pollination	Type of pollination	Number of flower pollinated	Fruit set (%)
Not crossed, not emasculated but bagged	Self-pollination	25	36
Emasculated, not crossed, but kept open	Insect and wind in pollination	25	76
Not emasculated, not crossed but kept open	Natural open pollination	25	96
Emasculated, crossed and bagged	Artificial hand pollination	25	88

Table 4.14: Influence of season on length, breadth, weight, volume and specific gravity of Fruit in Kuliana lime

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

Table 4.15: Influence of season on seed per fruit, weight of seed, thickness of rind, number of segments per fruit and weight of rag per fruit in Kuliana lime

Season	Plant	Number of seed per fruit	Weight of seed per fruit (g)	Rind thickness (mm)	Number of segment per fruit	Weight of rag (g)
Rainy	1	5.2	0.5	0.96	11	18.22
	2	3.9	0.19	0.97	10.6	7.05
	3	4.7	0.4	1.02	10	17.2
	4	5	0.3	1.05	9.8	7.4
	5	6.3	0.3	1	10	10.2
	6	7.1	0.5	1.2	10	13.27
	7	7.2	0.32	1	10.2	14.94
	8	5.6	0.49	1.1	10.6	11.52
	9	4.5	0.35	0.9	10.8	12.6
	10	3.9	0.2	1.1	10.2	9.8
	Mean	**5.34**	**0.36**	**1.03**	**10.61**	**12.22**
Winter	1	5.6	0.51	1.1	10.4	10.18
	2	4.9	0.63	1.02	10.8	7.36
	3	4.3	0.46	1.05	11	8.07
	4	5.7	0.62	1.2	10.6	12.41
	5	5.2	0.59	1.08	11	4.64
	6	4.3	0.56	0.98	10.8	13.25
	7	5.9	0.48	1.03	10.8	6.8
	8	6.7	0.5	1.09	10.6	6.76
	9	6.2	0.6	1.1	10.2	11.43
	10	5.05	0.58	1.09	11	12.48
	Mean	**5.38**	**0.55**	**1.07**	**10.72**	**9.34**
Spring	1	8.2	0.47	1.2	9.8	11.74
	2	8.6	0.48	1.2	10.8	18.75
	3	10.6	0.61	1.2	10.8	17.585
	4	8.2	0.47	1.13	11	20.75
	5	8.6	0.44	1.2	10.8	19.16
	6	7.2	0.42	1.36	10.6	19.3
	7	9	0.53	1.3	10.4	15.08
	8	11.2	0.56	1.34	10.6	19.05
	9	9.6	0.59	1.6	10.6	16.96
	10	10.8	0.63	1.5	11	16.82
	Mean	**9.20**	**0.52**	**1.30**	**10.64**	**17.52**
SE (±) Season		0.3545	0.02749	0.03347	0.1091	1.001
SE(d) (±) of LSM		0.5013	0.03888	0.04733	0.1543	1.4156
Pr >|t|	Rainy spring	<0.0001	0.0005	<0.0001	NS	<0.0001
	Rainy winter	NS	<0.0001	NS	NS	NS
	Spring winter	<0.0001	NS	0.0001	NS	0.0001

Table 4.16: Influence of season on TSS of fruit juice, volume of juice, percentage of juice and acidity of the fruit juice in Kuliana lime.

Season	Plant	TSS °Brix	Volume of juice per fruit (ml)	Juice per fruit (%)	Acidity of fruit juice (%)
Rainy	1	6.1	19.98	49.99 (44.99)	7.02
	2	5.9	8.45	41.02 (39.82)	7.4
	3	5.2	22.12	59.62 (50.53)	8.1
	4	4.7	28.48	69.02 (56.18)	7.96
	5	6.1	14.44	62.78 (42.4)	6.63
	6	5.9	18.19	58.96 (50.16)	8.75
	7	6	13.95	46.72 (43.12)	8.24
	8	5.4	10.22	47.09 (43.32)	6.71
	9	5.3	17.22	57.4 (49.26)	6.63
	10	6	12.17	54.08 (47.34)	6.94
	Mean	**5.66**	**16.52**	**52.99 (46.71)**	**7.44**
Winter	1	6.2	9.82	44.23 (41.68)	6.23
	2	6.4	9.186	45.7 (42.53)	6.54
	3	5.9	9.29	47.2 (43.39)	7.2
	4	6.4	10.06	43 (40.98)	6.92
	5	6.6	8.1	45.29 (42.29)	5.8
	6	6.4	14.91	47.5 (43.57)	6.87
	7	6.8	8.136	46.23 (42.83)	6.54
	8	6.5	6.98	45.9 (42.65)	6.83
	9	6.9	8.77	43.2 (41.09)	7.14
	10	6.8	10.78	48 (43.85)	6.86
	Mean	**6.49**	**9.60**	**45.59 (42.49)**	**6.69**
Spring	1	6.5	11.64	49.97 (44.99)	6.07
	2	6.8	10.98	51.06 (45.61)	5.9
	3	6.2	14.49	53.46 (46.98)	5.86
	4	7.1	10.99	48.21 (43.97)	6.54
	5	6.9	18.32	62.75 (52.39)	6.73
	6	6.1	18.12	54.9 (47.81)	5.69
	7	7.1	13.32	59.8 (50.65)	7.1
	8	7	13.24	53.4 (46.95)	6.23
	9	7.1	11.97	53.92 (47.24)	5.64
	10	6.9	13.55	56.46 (48.61)	6.15
	Mean	**6.77**	**13.66**	**54.5 (47.52)**	**6.19**
SE (±) Season		0.124	1.2623	1.0247	0.1824
SE(d) (±) of LSM		0.159	1.6978	1.4491	0.2566
Pr >|t|	Rainy spring	<0.0001	NS	NS	0.0001
	Rainy winter	<0.0001	0.0007	0.0092	0.0095
	Spring winter	NS	NS	0.0027	NS

(Figures in parenthesis denotes arc sine transformed value)

Table 4.17: Influence of season on reducing sugar, non-reducing sugar and ascorbic acid content of fruit juice of the Kuliana lime

Season	Plant	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)	Ascorbic acid content of juice (mg per 100 ml of juice)
Rainy	1	0.19	0.17	0.36	33.24
	2	0.21	0.13	0.34	31.76
	3	0.18	0.14	0.32	32.94
	4	0.16	0.12	0.28	30.2
	5	0.19	0.16	0.35	29.5
	6	0.17	0.13	0.3	32.43
	7	0.2	0.14	0.34	30.33
	8	0.17	0.15	0.32	32.01
	9	0.22	0.14	0.36	30.99
	10	0.16	0.12	0.28	33.3
	Mean	**0.19**	**0.14**	**0.33**	**31.67**
Winter	1	0.24	0.21	0.45	33.45
	2	0.23	0.2	0.43	33.69
	3	0.25	0.22	0.47	30.43
	4	0.23	0.2	0.43	31.67
	5	0.23	0.2	0.43	32.2
	6	0.24	0.21	0.45	30.95
	7	0.25	0.22	0.47	32.45
	8	0.24	0.22	0.46	33.56
	9	0.23	0.21	0.44	31.7
	10	0.25	0.23	0.48	30.45
	Mean	**0.24**	**0.21**	**0.45**	**32.06**
Spring	1	0.24	0.22	0.44	32.41
	2	0.25	0.24	0.49	35.79
	3	0.24	0.21	0.45	34.23
	4	0.25	0.22	0.47	30.7
	5	0.26	0.22	0.48	31.64
	6	0.24	0.23	0.47	33.32
	7	0.25	0.22	0.47	33.9
	8	0.25	0.22	0.47	30.47
	9	0.25	0.23	0.48	32.78
	10	0.23	0.2	0.4	33.52
	Mean	**0.25**	**0.22**	**0.46**	**32.87**
S.E. ($\pm$) Season		0.00438	0.00406	0.008051	0.4497
SE(d) ($\pm$) of LSM		0.006194	0.005741	0.01139	0.6269
Pr >|t|	Rainy spring	<0.0001	<0.0001	<0.0001	NS
	Rainy winter	<0.0001	<0.0001	<0.0001	NS
	Spring winter	NS	NS	NS	NS

Table 4.18: Influence of season on fruit set percentage, fruit retention percentage, number of fruit per plant, yield per plant 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
SE(d) (±) 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 transformed value)



Fig. 4.1: Overview of flower in Kuliana lime

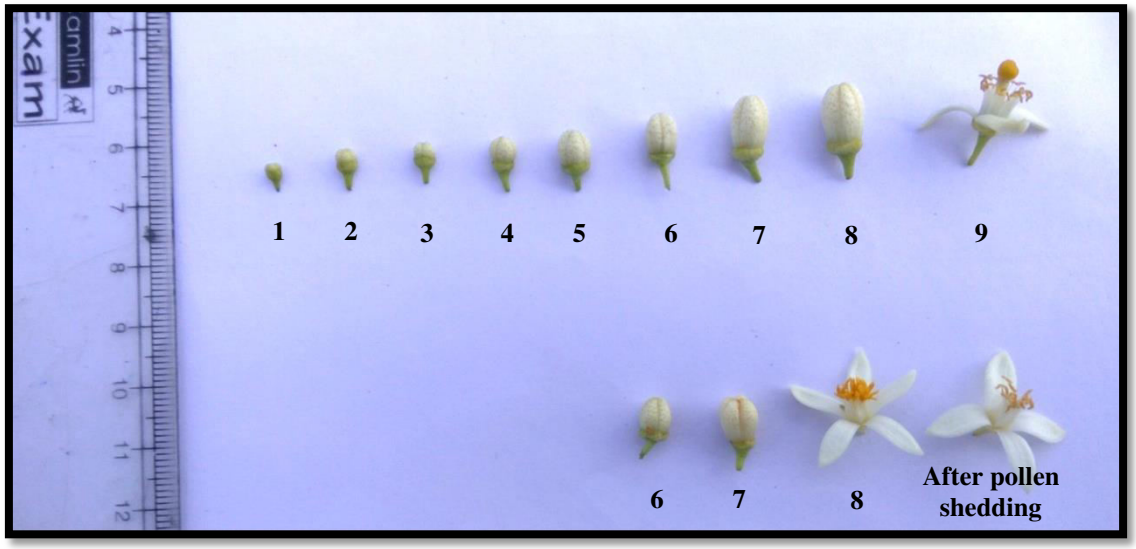


Fig. 4.2(a): Chronology of bud development in Kuliana lime

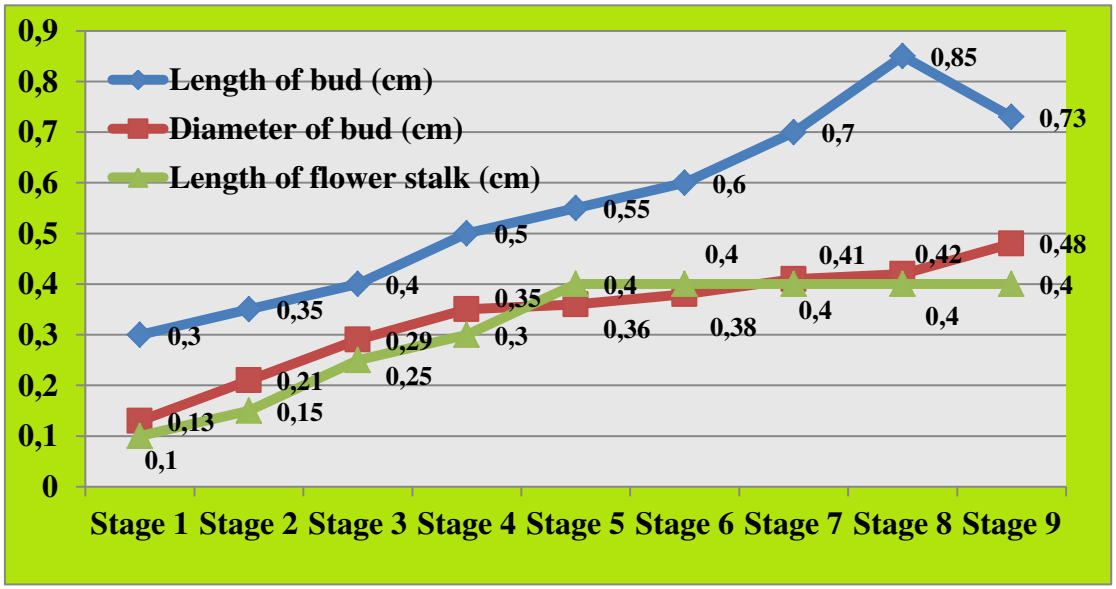


Fig. 4.2(b): Chronology of bud development in Kuliana lime



Fig. 4.3: Cross section of hermaphrodite and staminate flower of Kuliana lime

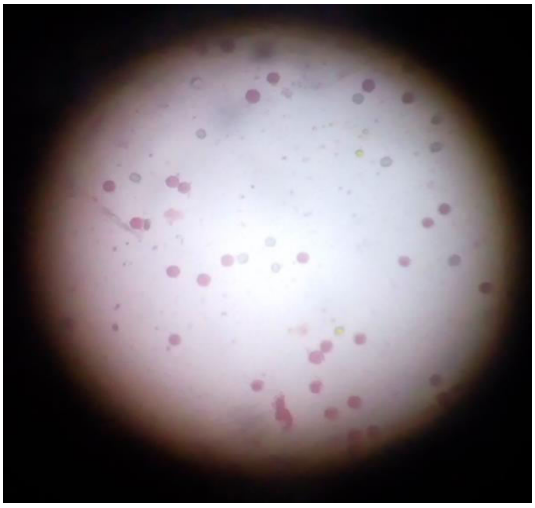


Fig. 4.4: Pollen viability of staminate flower of Kuliana lime

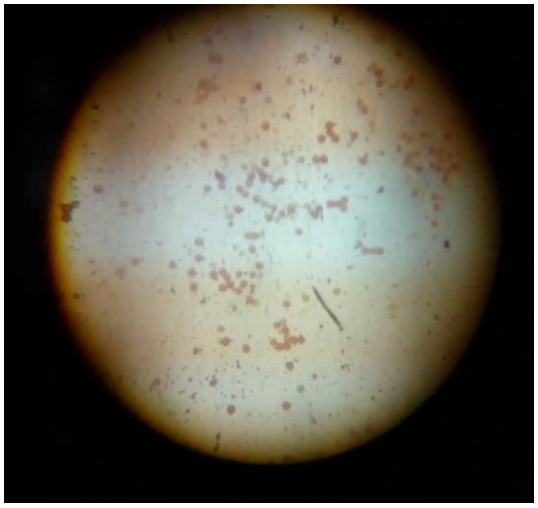


Fig. 4.5: Pollen viability of hermaphrodite flower of Kuliana lime

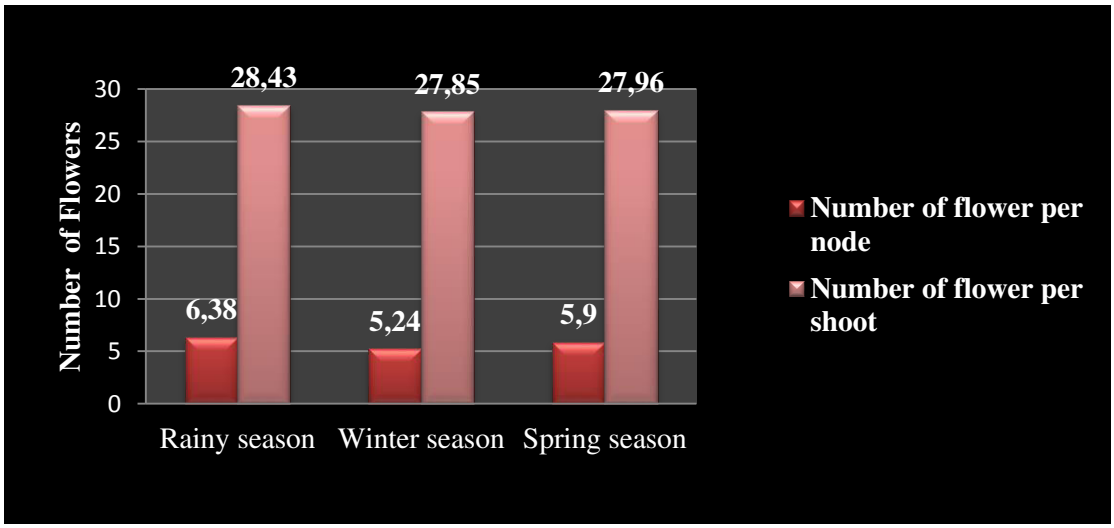


Fig. 4.6: Influence of Season on Number of bud per plant and per shoot of Kuliana lime



Fig. 4.7: Different grades of fruit of Kuliana lime



Fig. 4.8: Cross section of fruit of Kuliana lime



Fig. 4.9: Fruiting twig of Kuliana lime

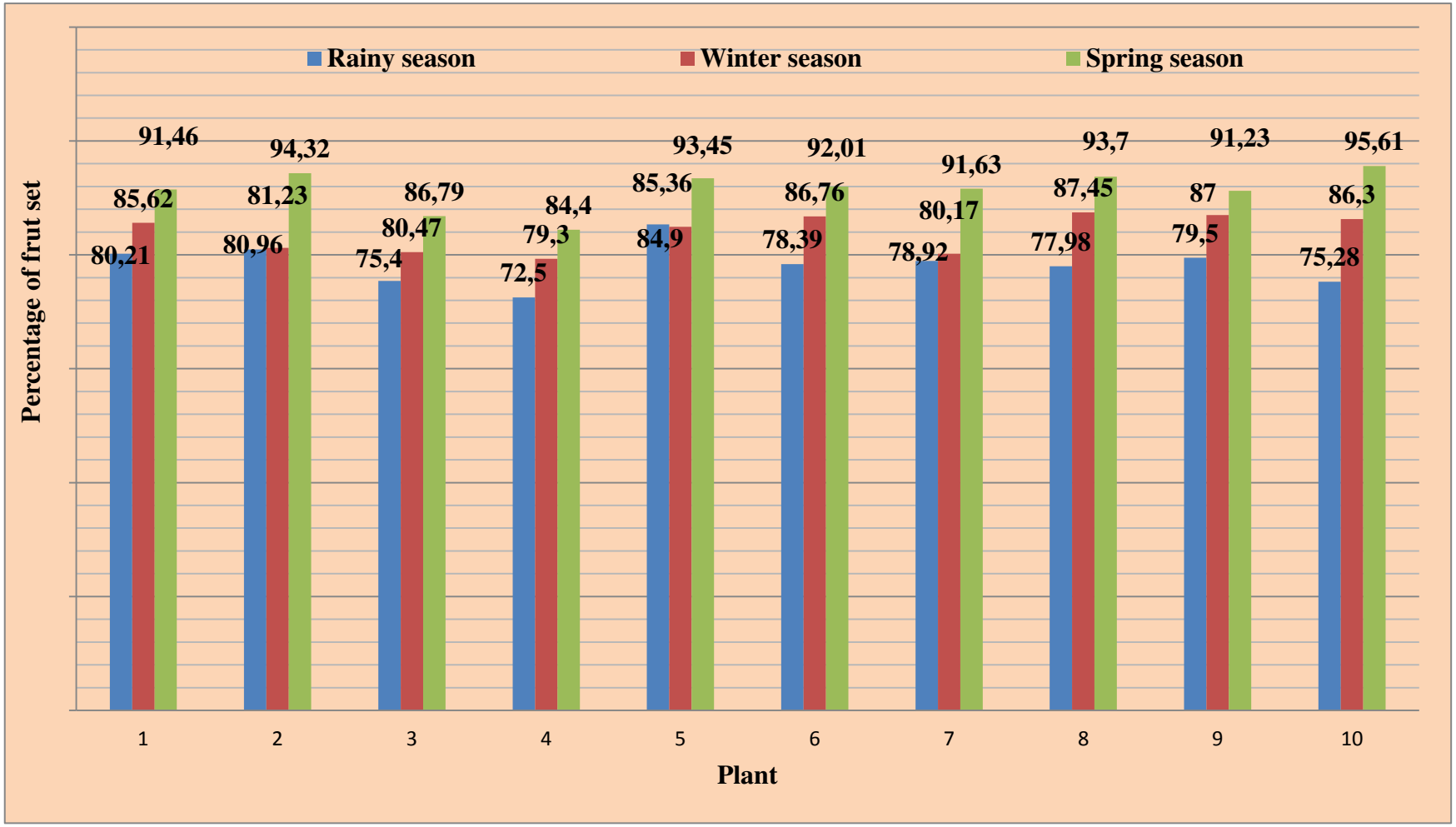


Fig. 4.10: Influence of Season on percentage of fruit set in Kuliana lime

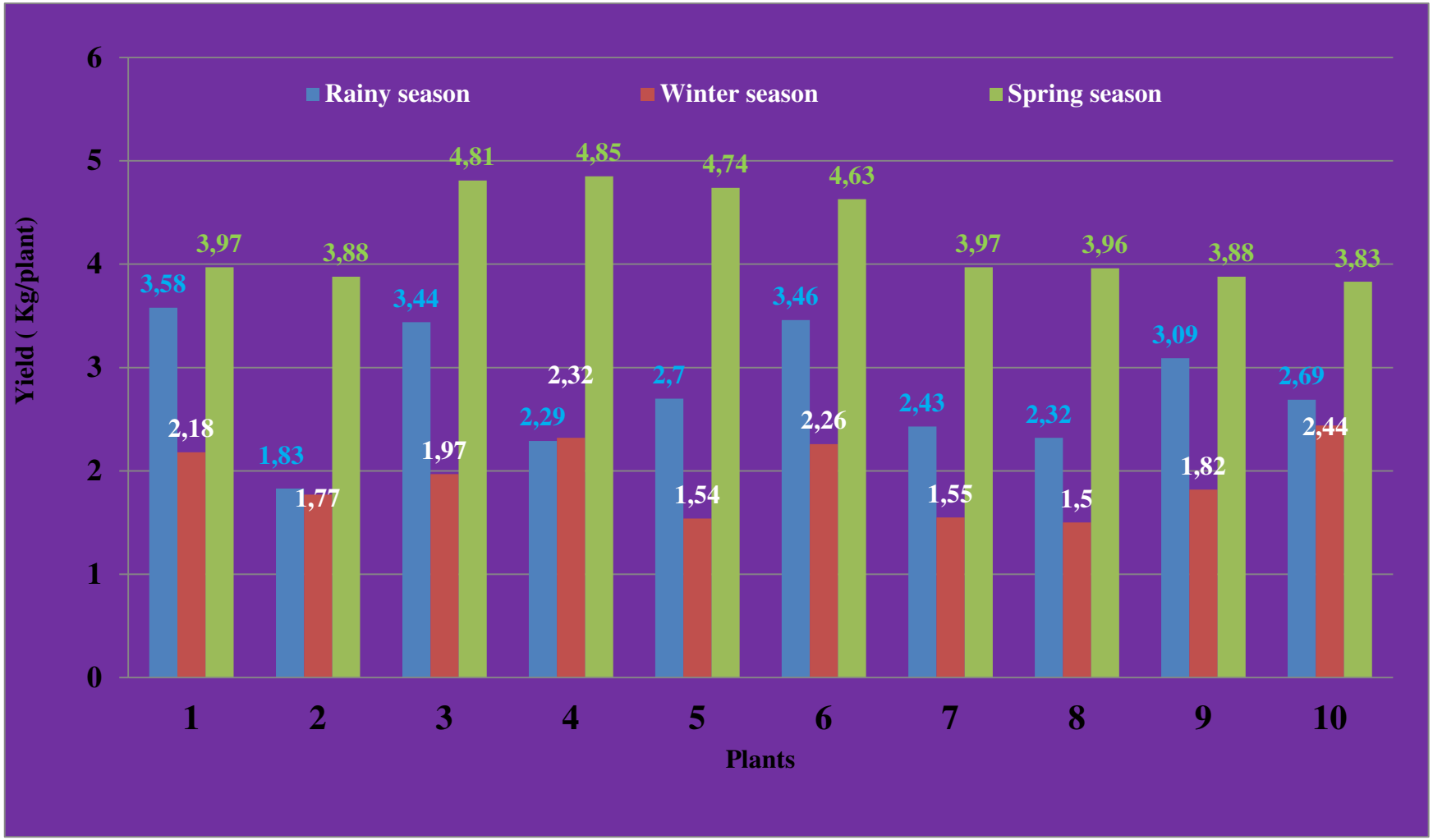


Fig. 4.11: Influence of season on yield of Kuliana lime

DISCUSSION

The present investigation was carried out to study the "Effect of seasons on growth and development of Kuliana lime (*Citrus aurantifolia*) ''during the year 2016-17. In this chapter the effect of treatments on the vegetative growth dynamics, reproductive behavior and yield and yield attributing characters of the plant were discussed in detail.

5.1 Vegetative growth dynamics of Kuliana lime

The vegetative parameters like plant height, girth, canopy spread, new shoot, leaf area and chlorophyll content of the leaves are the indicator of final yield.

The tree height was significantly influenced by the different season. Among the three seasons rainy season recorded maximum relative growth in average plant height (35.76 cm) and minimum (10.9 cm) was noticed in the winter season. Higher plant height in the rainy season may be attributed to the favourable climatic condition with higher relative humidity which helps in reducing the evapotranspirational loss of the plant and thereby more of the photosynthates for the vegetative growth.

The plant girth of rainy season has the maximum average growth (13.41 mm) and the minimum (3.81 mm) was in the winter season. Similar findings were obtained by Dalal *et al*., 2013 in Kinnow mandarin at Hisar.

The canopy spread both in E-W and N-S direction is the reflection of fruiting area to the plant and varies significantly among the seasons. The canopy spread in the E-W and N-S direction was highest in the spring season (21.61 cm and 18.36 cm respectively) and at par with the rainy season (19.00 cm and 16.34 cm respectively). The lowest canopy spread was observed in the winter season both in the E-W (9.07 cm) and N-S (9.28 cm). The maximum growth in canopy volume was in the rainy season (4403 cm^3) which was at par with the spring season (4310.63 cm^3) and the minimum was in winter season (556 cm^3).

The number of new shoot or tertiary produced found highest in the spring season (153.8) and lowest in the winter season (93.57). Shoot length of the rainy season flush was maximum (16.78 cm) and statistically at par with that of the spring

season flush (15.32 cm) whereas the winter season flush recorded the minimum (12.31 cm). Maximum (4.04 mm) shoot diameter was observed in the rainy season flush and minimum (2.75mm) in the winter season. It was in line with the observation of Sema and Sanyal (2002) who reported that winter flush have higher rate of growth (length and diameter) but the cumulative length of shoot was higher in rainy season flush in lemon trees. Inter-node length was maximum in the rainy season flush (1.37 cm) minimum in winter season flush (1.10 cm).

Higher number of leaf and spines per shoot were recorded in the rainy season and lowest in winter season. It was also noticed that the number of spines per shoot was higher than that of the leaves.

Rainy season showed the best result in both the fresh weight and dry weight of the newly developed shoot as well as the leaves followed by the spring flush and winter season flush was the lowest. Rainy season flush have maximum leaf area of 16.19 cm^2 which was significantly superior to that of the winter season (10.36 cm^2) and spring season (9.06 cm^2). Rainy season shows significant Influence on the leaf area of the flush. The present findings are in conformity with the findings of Dalal *et al*. (2013) in Kinnow mandarin. They reported the leaves of rainy season flush showed the maximum leaf area and leaf fresh weight which may be due to the better availability of soil moisture and high relative humidity resulting in low transpirational losses which favours the better leaf growth in terms of area and fresh weight. The minimum leaf area of the spring season may be due to higher summer temperature at sampling time in April resulted in rapid transpirational loss and the spring season growth must serve as a sink for the developing fruits. The low dry weight of spring flush leaves as compared to rainy flush indicated that reserve carbohydrate were utilized to sustain the early stage of reproductive development. The rainy season flush leaves were having higher leaf dry weight it might be due to less catabolic (respiration) loss of the plant due to favourable climatic condition which increases the storage of more solutes in plant leaves. Similar results were also observed by Shimizu *et al*. (1978) and Akao *et al*. (1981) who reported the reserved carbohydrate in spring flush leaves were utilized mainly to support reproductive growth while old leaves photosynthesis supplied the need of vegetative growth.

Spring season recorded the maximum chlorophyll (1.81 mg per g of FW) content in the leaf tissue and the minimum was recorded in the winter season flush (1.55 mg per g of FW). The current findings are in line with Sema and Sanyal (2002) in lemon plant who reported that samples collected from spring flush contains more than rainy and winter season flush. It was also reported by Tomer and Singh (1988) that irrespective of solar treatment, spring flush of Pant lemon-1 leaves had higher level of total chlorophyll than the autumn or rainy season flush as the total chlorophyll content with light intensity has an inverse relationship.

5.2 Reproductive behavior of Kuliana lime

In spring season maximum (90.41%) vegetative shoot of previous season growth were converted to the reproductive shoot by producing flower buds and it was followed by the winter season (73.74%). The lowest (64.1%) conversion of vegetative to reproductive shoot was obtained in the rainy season. This result was in line with Moss (1969); Cassin *et al*. (1969); Garcialuis *et al*. (1995) and Guardiola (1997). When the hours of low temperature increases with a period of water stress bud sprouting shifted from the vegetative bud (no flowers) to mixed bud (both flowers and leaves) or reproductive bud (leafless at least one flower). Reuther *et al*. (1973) reported during the winter low temperature conditions causes the inactivity of buds while inducing them to flower in *Citrus*.

The average duration of flowering was extended to 58 days in spring season followed by the rainy season (50 days) and minimum (45 days) were recorded in the winter season. The less number of days in the winter season may be attributed to the less diurnal variation in temperature and lowered relative humidity with higher bright sunshine hour during the flowering period. The spring season recorded the maximum duration of flowering may be due to the low temperature at the time of flowering in December to February. Similar findings were observed by Cooper *et al*. (1963); Rohidas and Chakrawar (1989); Moss (1973); Valiente and Albrigo (2002) who observed the duration of extension of growth and of flowering were greatly accelerated or slowed by climatic conditions.

In the rainy season, flower takes maximum (11.08 days) time from flower bud initiation to anthesis followed by the winter season (9.01 days) and spring season (9.0

days). The bud developmental stages of Kuliana lime were categorized in to nine arbitrary stages from stage-1 to stage-9 as described by Kumatkar *et al*. (2016).

The spring season recorded the maximum (93.15%) and in winter season minimum (92.55%) number of axillary flower buds. In the winter season the terminal bud percentage was more (7.47%) and less (6.84%) in spring season. All the three seasons have similar influence in production of the terminal and axillary buds and in Kuliana lime and the flowering mostly observed in the axillary buds. Similar findings were obtained by Hittalamani *et al*., 1977 who reported that *Citrus aurantifolia* Swingle mainly bore flowers in lateral and axillary shoot.

Rainy season recorded the maximum (84.99%) staminate flower followed by the winter season (82.49%) and the minimum (81.52%) was in the spring season. Hermaphrodite flower in spring season recorded the maximum (18.45%) followed by the winter season (15.2%) and the minimum (15%) were observed in the rainy season.

Viable pollen in staminate flower during the spring season (77.42%) was superior to the winter season (75.64%) and the lowest was found in the rainy season (70.09%). Highest percent of viable pollen in the hermaphrodite flower was obtained in rainy season (75.17%) which is at par with the spring season (74.21%) and the lowest was in the winter season (70.22%).

The anthesis in Kuliana lime took place from 8 a.m. to 2 p.m. in rainy and spring season and 10 a.m. to 2 p.m. in winter season. The peak period of anthesis was recorded at 10 am to 12 noon in rainy season and spring season, whereas 12 noon to 2 p.m. was recorded in winter season. The anther dehiscence in Kuliana lime was recorded ten to fifteen minutes after the anthesis. The splitting of anther starts longitudinally releasing light yellow coloured pollen. During rainy season and spring season the anther dehiscence starts from 8 a.m. and continue till 2 p.m. but in winter season it starts 10 a.m. onwards and continued till 2 p.m. Kumatkar *et al.* (2016) reported the peak period of anthesis and anther dehiscence 10 a.m. to 12 noon in Sweet orange. Warmer temperature of the climate favours the anthesis and anther dehiscence. Similar results were also reported in Naval orange by Bellows and Morse (1986).

The stigma became receptive one day prior to anthesis (88-96%) and the receptivity lasted for one day after anthesis in Kuliana lime. Stigma receptivity was 100 percent on the day of anthesis and reduces to 80% on one day after anthesis but there was drastic reduction thereafter. Rajput and Haribabu (1985) reported that receptivity period of stigma was found on the day of anthesis, followed by the day succeeding and preceding the anthesis. Kumatkar *et al*. (2016) observed the maximum fruit set in Sweet orange was on the day of anthesis (73.7 to 76.8%) and a sharp decline thereafter. Pio *et al*. (2004) reported at balloon stage 80-100% and on the day of anthesis 100% receptivity of the stigma in orange.

The highest percentage of fruit set was observed in the natural open pollination (96%) followed by hand pollination (92%), insect and wind pollination (76%) and self-pollination (36%). Similar finding was reported by Kumatkar *et al*. (2016).

During the rainy season there was the highest (6.38) average number of flower per node followed by the spring season (5.9) and winter season (5.24). The average number of flower per shoot was also recorded to be highest in the rainy season (28.43) followed by the spring season (27.96) and the winter season (27.85).

5.3 Yield and yield attributing characters of Kuliana lime

Rainy season flowering recorded the highest average length (4.68 cm) and diameter (4.39 cm) of fruit. The lowest average length (4.43 cm) and diameter of fruit was observed in winter season flowering in Kuliana lime. The abundant soil moisture in the rainy season helps in enlargement of the fruit in the length and diameter. The similar result was noticed by Cooper *et al*. (1963). Maximum (32.11 g) fruit weight of Kuliana lime was observed in spring season the lowest (19.40g) was recorded in the winter season.

Rainy season recorded the highest (29.68 cc) mean fruit volume which is statistically higher than the spring season (24.85cc) and winter season (20.92 cc) was the lowest. Maximum (1.30 g per cc) fruit specific gravity was obtained in the spring season which is statistically superior over the rainy season (0.97 g per cc) and the winter season (0.93 g per cc). This may be as a result of increased in fruit weight and reduction of fruit volume during the spring season than the rainy season flowering.

Spring season recorded the maximum (9.20) number of seed per fruit which was statistically superior over the winter season (5.38) and the rainy season (5.34). Maximum (0.55g) weight of seeds per fruit was recorded in the winter season which was statistically superior over that of the spring season (0.52g) and the rainy season (0.36g). The maximum seed weight of winter season fruit may be due to the more growth of seed in winter season the total number of days taken for fruit maturity was more.

Rind thickness was maximum (1.30 mm) in the spring season, followed by the winter season (1.07mm) and the rainy season recorded lowest (1.03mm). Prasad (1989) reported that, the peel thickness in acid lime ranges from 0.89 mm to 2.13 mm. During the period of high humidity the rind thickness of citrus fruit was less (Cooper *et al*., 1963; Hayes, 1975; Rajput and Babu, 1985)

Number of segments per fruit varies from 10.32 in rainy season to 10.72 in winter season, but there was no significant variation among the seasons for number of segments per fruit. Loussert (1992) reported the numbers of segments varies from 8-11. Vand and Abdullah (2012) recorded 6-15 segments in thorn less Rodon lime. The spring season recorded the maximum (17.52 g) pulp weight per fruit followed by rainy season (12.22 g) and the lowest (9.34 g) pulp weight per fruit was in the winter season.

Spring season flowering was noted for maximum (6.77 °Brix) TSS in fruit juice and the lowest (5.66 °Brix) was in the rainy season crop. The high level of rain fall and soil moisture in the fruit growth and maturation phase caused a decrease in the TSS as the start of new vegetative growth utilized a part of reserved carbohydrates and thus the TSS of fruit might be decreased. In cool temperature the concentration of soluble solids of the juice was more (Cooper *et al*., 1963)

In rainy season flowering maximum (16.52 ml) volume of juice per fruit was observed followed by the spring season (13.66 ml) and the lowest value (9.60 ml) was obtained in the winter season crop. Higher atmospheric humidity increases the juice content of the fruit (Rajput and Babu, 1985). During the spring season the maximum (54.5) percentage of juice per fruit was recorded and was statistically at par with that

of the rainy season (52.99%). The winter season recorded the lowest (45.59%) of juice per fruit.

Acidity of fruit juice was recorded maximum (7.44%) in the rainy season flowering and the minimum (6.19%) was recorded in the spring season. When there was increase in temperature during the fruit maturation stage then, rapid loss of acid in the fruit was observed due to utilization of the acid in the metabolic process. Similar findings were reported by Cooper *et al.* (1963) who reported the most rapid rate of acid loss occurred in Valencia orange fruits grown at Weslaco, where high temperature in the late spring and early and late summer prevail. The slowest rate of acid loss occurred in fruit grown at River side with more relative humidity and cool climate all-round the year.

Spring season flowering recorded the maximum (0.25%) reducing sugar, (0.22%) non-reducing sugar and (0.47%) total sugar but the rainy season was the lowest in (0.19%) reducing sugar, (0.14%) non-reducing sugar and (0.33%) total sugar content in Kuliana lime.

The ascorbic acid estimate record maximum (32.88 mg per 100 ml of juice) in the spring season flowering followed by the winter season (32.06 mg per 100 ml of juice) and the lowest (31.67 mg per 100 ml of juice) was recorded in the rainy season. The increase in ascorbic acid was associated with rapid increase in total sugar as the fruit synthesizes ascorbic acid hexose sugar precursors. Similar results were produced by (Mapson, 1970). The higher the intensity of sunlight during the growing season, the greater the ascorbic acid content in plant tissues (Sinclair, 1984). Ascorbic acid content in fruit can be increased with less frequent irrigation. Ascorbic acid is synthesized from sugar supplied through photosynthesis in plants (Lee and Kader, 2000). During the spring season the amount of total chlorophyll content in the leaves of Kuliana lime were maximum than the other seasons, hence the production of greater amount photosynthates which directly associated with the production of higher amount of ascorbic acid.

The maximum (91.6%) fruit set was recorded in spring season and lowest (78.46%) was in the rainy season in Kuliana lime plant. The highest (25.18%) fruit retention was recorded by the spring season and the lowest (19.69%) in winter season.

Low fruit set in rainy season may be attributed to the higher temperature during the time of bloom (May-June). Young and newly set fruit let dry up and shedding of fruit at different stage occurred due to high temperature (Rajput and Babu, 1985).

Spring season noted for maximum mean number of fruit per plant (132.80) and followed by the winter season (101.60), the lowest in rainy season (99.20). Maximum number of fruit per plant in spring season may be due to higher fruit set and fruit retention in Kuliana lime.

The maximum yield per plant was observed in the spring season (4.25 Kg per plant) which was significantly superior to that of the rainy season (2.78 Kg per plant). The lowest yield per plant was recorded by the winter season (1.935 Kg per plant). The productivity of any crop depends on the process of photosynthesis, which in turn depends on the chlorophyll content of the leaves. During the spring season the chlorophyll content of leaves were more hence it may have helped in more production of photosynthates and yield. The maximum yield in spring season may be due to more fruit set, fruit retention, number of fruit per tree and the weight of fruit during spring season.

Winter season recorded the highest average number of days taken for fruit maturity (122.10 days) which was statistically superior over the rainy season (114.16 days) and the spring season (113.44 days). 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.

SUMMARY AND CONCLUSION

The present investigation entitled **"Effect of seasons on growth and development of Kuliana lime (*Citrus aurantifolia*)"** was carried out at Horticultural Research Station, Department of Fruit Science and Horticulture Technology, Orissa University of Agriculture and Technology, Bhubaneswar during May 2016-17 on 4 years old Kuliana lime plants.

The experiment was conducted in three seasons namely rainy, winter and spring season replicated 10 times. Biometrical observations on vegetative growth dynamics, reproductive behavior and physiochemical characters of fruit were recorded time to time. The data were analyzed in Random Effect Model under PROC MIXED in Statistical Analysis System (SAS) and presented in tabular form and also in graphical manner (where ever necessary).

- The vegetative attributes of cv. Kuliana lime viz. plant height, girth, canopy volume, shoot length and diameter, inter node length, fresh weight and dry weight of the shoot, number of leaves per shoot, number of spines per shoot and fresh weight and dry weight of the leaf recoded maximum growth during the rainy season and the minimum in winter season.
- The canopy spread (E-W and N-S), number of new growth flush, chlorophyll content of leaves were maximum during the spring season and they were directly associated with increase in yield.
- The maximum percentage of old vegetative shoots were converted to reproductive shoots and duration of flowering was maximum in spring season. Whereas the days to anthesis was more during rainy season and less in spring.
- There was no significant variation in the percentages of axillary buds and terminal buds among the three seasons as Kuliana lime is mostly an axillary bearer.
- Rainy season recorded the maximum percentage of staminate flowers while spring season have more percentage of hermaphrodite flowers.
- Peak period of anthesis in Kuliana lime was 10 a.m. to 12 noon in rainy and spring season while 12 a.m. to 2 p.m. in winter season. Anther dehiscence

starts 15 to 30 minutes after anthesis. Maximum pollen viability was observed in spring season. Natural open pollination recorded maximum fruit set.

- Fruit length and diameter, fruit volume and amount of juice per fruit were highest in the rainy season flowering.
- The winter season flowering recorded more days for maturation of fruit and with maximum weight of seed per fruit.
- Maximum fruit weight, specific gravity, number of seeds per fruit, rind thickness, rag weight, TSS (°Brix), juice per fruit (%), sugar content (%), ascorbic acid content, fruit set (%), fruit retention (%) and yield (Kg per plant) were recorded in the spring season flowering.

CONCLUSION

From the experiment conducted it can be concluded that spring season flowering was superior than the other with respect to canopy spread, new growth flush, chlorophyll content of leaves, conversion of one season old shoot to reproductive shoot, duration of flowering, production of hermaphrodite flower, fruit retention, ascorbic acid content and total sugar. To achieve good yield in Kuliana lime bahar treatment must be imposed to encourage spring season flowering with adequate irrigation facility. Crop improvement work can also be taken up during spring season flowering to achieve success and production of more number of seeds. Hence the retention of spring season flowers by manipulation of cultural practices may be advised for the growers of Kuliana lime.

CHARACTERISATION OF KULIANA LIME

The cultivar Kuliana lime was planted in Horticultural Research Station, Department of Fruit Science and Horticulture Technology, O.U.A.T., Bhubaneswar during 2011-12 at a spacing of 4×4 m through air layering or gootee.

Vegetative growth dynamics of Kuliana lime

The average tree height of a 5 year plant was 2.76 m and the cultivar shows the behavior of both single stem as well as multi stem with an average trunk girth of 17.10 cm with a canopy spread of 2.35-2.74 m and 2.97-3.56 m in N-S and E-W direction respectively. The tree has a spreading growth habit with a spheroid shape. The cultivar produce the new season shoot from the distal part of the previous seasons growth and in some cases there was continuation of growth of one season old shoot.

Leaves were compound (trifoliate), without stipule, semipersistent, brevipetiolate (petiole shorter than leaf lamina), crenate leaf margin, cordiform in wing with an average length and diameter of 7.24 cm and 4.22 cm respectively. The numbers of thorns and leaves were same and in some cases one or two more thorns were also noticed in the new shoots.

Reproductive behavior

Two types of flower were observed in this variety viz. hermaphrodite and staminate flower. The flower were characterized with 5 sepals, 4 or 5 petals, one superior ovary and 20-22 number of stamens. The flowers were produced mostly in leaf axils singly or in cluster with an average of 5 numbers of flower buds per inflorescence. Flowering was observed in spring season (January-March), Rainy season (June-July) and during winter season (September-October). The flower bud and petals were white in colour. During rainy and spring season the peak period of flowering was from 10 a.m. to 12 noon where as at winter season from 12 noon to 2 p.m. and anther dehiscence starts after 15-30 minutes from anthesis.

Yield and yield attributing characters

The fruit of Kuliana lime cv. were spheroid in shape, convex base, mammiform apex, smooth surface and green in skin colour with an average length, diameter, weight and volume of 4.43-4.68 cm, 4.13-4.39 cm, 19.4-28.95 g and 20.92-29.68 cc respectively. Generally the plant bears 3-4 fruits per cluster. The mesocarp was white in colour. The pulp was firm and yellow in colour. Juice content varies from 45.59 -54.5% and greenish yellow in colour. Seed was creem in colour, ovoid in shape, 1.12 cm in length, 0.59 cm in width and 0.08 g weight. The TSS and acidity and ascorbic acid content of the fruit were 5.66-6.77 °Brix, 6.19-7.44% and 31.67-32.87 respectively. During spring, rainy and winter season flowering the fruits were harvested on May-July, October-November are January-March. The spring season was the best among the three seasons in terms of production and quality attributes.

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