EVALUATION OF PROMISING STRAWBERRY (*Fragaria x ananassa* Duch.) VARIETIES FOR WAYANAD

by

Muhammed Aslam

(2014-12-127)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Evaluation of promising strawberry (*Fragaria x ananassa* Duch.) varieties for Wayanad"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, associateship, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara,
Date: 26/08/17

MUHAMMED ASLAM
(2014-12-127)

CERTIFICATE

Certified that this thesis entitled **"Evaluation of promising strawberry (*Fragaria x ananassa* Duch.) varieties for Wayanad"** is a record of research work done independently by **Mr. Muhammed Aslam (2014-12-127)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

Vellanikkara,
Date: 26/08/2017

Dr. K. Ajith Kumar

(Chairperson,Advisory committee)
Professor (Horticulture)
Department of Fruit Science
College of Horticulture
Kerala Agricultural University
Vellanikkara, Thrissur

CERTIFICATE

We, the undersigned members of advisory committee of **Mr. Muhammed Aslam (2014-12-127)** a candidate for the degree of **Master of Science in Horticulture** with major in **Fruit Science**, agree that the thesis entitled **"Evaluation of promising strawberry (*Fragaria x ananassa* Duch.) varieties for Wayanad"** may be submitted by **Mr. Muhammed Aslam (2014-12-127)**, in partial fulfilment of the requirement for the degree.

Dr. K. Ajith Kumar
(Chairperson, Advisory Committee)
Professor (Horticulture)
Dept.of Fruit Science
College of Horticulture, Vellanikkara

Dr. A. Suma
(Member, Advisory Committee)
Professor and Head
Dept. of Fruit Science
College of Horticulture, Vellanikkara

Dr. P. Rajendran
(Member, Advisory Committee)
Associate Director of Research
Regional Agricultural Research Station
Ambalavayal, Wayanad

Dr. Jiji Joseph
(Member, Advisory Committee)
Professor and Head (Plant Breeding and Genetics)
Dept. of Plant Breeding and Genetics
College of Horticulture, Vellanikkara

20/8/17.
EXTERNAL EXAMINER
(Dr. J. RAJANGAM)

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Introduction

1. INTRODUCTION

Strawberry (*Fragaria* x *ananassa* Duch.) is one of the most delicious, refreshing and nutritious soft fruits of the world. Strawberry, a member of the family Rosaceae is native to North America (Galletta *et al.,* 1990). Strawberry is the most widely distributed fruit crop due to its heterozygosity, genotypic diversity and broad range of environmental adaptations. Being the rich source of vitamins and minerals coupled with delicate flavour, strawberry has now become an important table-fruit of millions of people around the globe.

Strawberry is a herbaceous perennial and short day plant having short stem known as crown. The crown produces trifoliate leaves at close interval along stem axis but single leaf before the emergence of flower and bear flowers at terminal position on stem axis. The edible portion includes the ripened receptacle and achenes (true fruits and seed) and usually propagated through runners. Now a days, propagation by tissue culture has been accepted and used widely in strawberry industry.

Strawberry is highly nutritious which contain fair amount of iron (0.14mg/100g of fruit), hence the fruits are beneficial to anemic patients. It also contains anti-cancer compound called ellagic acid thus reducing the risk of developing cancer by 5 – 50 per cent (Wange and Kzlogoz, 1998). Besides vitamin C (30-120 mg/100g of fruit) it is also a rich source of vitamin A (60 IU/100g of fruit) and has abundance of minerals like potassium, calcium, phosphorus. Higher pectin (0.55 per cent) in the form of calcium pectate, which serves as an excellent ingredient for jelly-making. The ripe strawberries attain attractive red colour on maturity and has a pleasant and refreshing aroma. The mature fruit contains about 5.0 per cent total sugars, 0.9 to 1.85 per cent acids. The major sugars found in strawberry are fructose and glucose and is a rich source of anthocyanin.

Commercial strawberry cultivation in the USA has been started in the beginning of the 18th century and within 25 years it gained significant

momentum.USA produces 30.4 per cent of the total world production of strawberries (FAO, 2014). Strawberry is also grown in Israel, Japan, Turkey, Australia and New Zealand. In India, strawberry was first introduced by NBPGR Regional Research Station, Shimla (Himachal Pradesh) in the early sixties. The major strawberry growing areas in India are Jammu and Kashmir, Himachal Pradesh, Maharashtra, Uttarakhand, Haryana, Uttar Pradesh, Punjab and some parts of Karnataka, Tamil Nadu and high ranges of Kerala.

Though some work on strawberry cultivation is done in temperate and subtropical conditions of the country by various workers (Beniwal *et al.,* 1989; Ashrey and Singh, 2004; Ram *et al.,* 2005), still the work on identification of suitable high yielding varieties of strawberry for different agro-climatic conditions of Kerala remains scanty in literature. With the introduction of new cultivars, it was therefore felt imperative to evaluate for its feasibility and record pomological descriptions of strawberry cultivars for their proper identification and highlighting useful characters, which could be exploited for bringing about improvement in strawberry production in the state. Keeping these points in view the present investigation work entitled "Evaluation of promising strawberry (*Fragaria x ananassa* Duch.) varieties for Wayanad" was undertaken with the objective to evaluate the performance of strawberry varieties in high ranges of Kerala under two growing systems.

Review of Literature

2. REVIEW OF LITERATURE

In this chapter relevant literature based on the objectives of the study are reviewed and presented in the order of variety, nutrients, time of planting, mulching, spacing, protected cultivation, quality and postharvest aspects. The influence of crop and environmental factors and pest and disease incidence are also reviewed.

2.1. Growth characters

The plant height, number of leaves and plant spread are the vegetative growth characters of strawberry. The vegetative growth of the crop is influenced by variety, nutrients, time of planting and mulching. Studies on the response of crop to different growth attributes are reviewed and discussed here under.

2.1.1. Plant height

2.1.1.1 Variety

The effects of varying plant densities on the growth and yield of strawberry cultivars Senga Sengana and Chandler were studied in Srinagar, Jammu and Kashmir. The cultivar, Senga Sengana was superior in terms of plant height (7.24 cm) (Ahmad, 2009).

Rao and Lal (2010) evaluated 17 strawberry genotypes under Garhwal agro climatic conditions for observing their effect on growth, yield and quality. The tallest plant was registered in Chandler (23.22 cm) than Gorella (22.53 cm), Pajaro (21.23 cm) and Confictura (20.74 cm).

Hossan *et al.* (2013) evaluated three strawberry germplasm *viz.*, SG-1, RABI-3 and SG-3 for growth and yield characters. The maximum plant height of 28.0 cm was recorded in SG-1.

Rahman *et al.* (2014) evaluated four planting time of five promising strawberry genotypes *viz.*, Sweet Charlie, Festival, Camarosa, FA 008 and

BARI Strawberry-1 for observing their effects on growth, yield and quality under sub tropical climatic conditions of Bangladesh. The tallest plant was recorded in Camarosa (28.50 cm) followed by Festival (24.33 cm) and the shortest in BARI Strawberry-1 (18.42 cm).

2.1.1.2 Nutrients

2.1.1.2.1 Organic nutrients

Umar *et al.* (2008b) observed that strawberry plants attained the height of 21.24 cm with 28.16 cm plant spread and fruit weight (15.87 g) with the application of 25 per cent nitrogen through farmyard manure augmented with *Azotobacter* and was at par with the plants supplied with urea in combination with *Azotobacter.*

Mishra and Tripathi (2011) reported that in strawberry *cv.* Chandler, Azotobacter and phosphorous solubilizing bacteria each at 6 kg ha^{-1} significantly increased plant height.

Azotobacter at 7 kg ha^{-1} + vermicompost at 30 t ha^{-1} significantly increased plant height (19.45 cm and 17.65 cm) during 2009-10 and 2010-11 respectively in strawberry *cv.* Chandler (Gupta and Tripathi, 2012).

Khalid *et al.* (2013) reported that treatment combinations of soil + silt + farmyard manure (FYM) induced positive influence on plant height (15.21 cm). Studies also revealed that FYM and vermicompost based organic amendments enhanced vegetative growth.

Application of integrated sources of nutrients Azotobacter (50%) + Azospirillum (50%) + NPK (50%) + FYM significantly increased vegetative growth of strawberry *cv.* Chandler (Lata *et al.*, 2013).

Pandit *et al.* (2013) observed 34.37 per cent increase in plant height (22.17 cm) with the application of VAM @ 12 kg ha^{-1} when compared to control in strawberry.

2.1.1.2.2 Inorganic nutrients

Rana and Chandel (2003) reported a maximum plant height of 24.51cm in strawberry when nitrogen was applied @ 100 Kg ha^{-1} combined with the inoculation of *Azotobacter*.

Yadav *et al.* (2010) observed positive influence of inorganic fertilizers on plant height in strawberry. Experiment with different doses of nitrogen and potassium revealed that a fertilizer dose of nitrogen up to 150 kg ha^{-1} and potassium up to 150 kg ha^{-1} significantly increased the plant height (27.25 cm) of strawberry *cv.* Confitura (Ahmad *et al.*, 2011).

2.1.1.3 Time of planting

Rahman M.M (2014) evaluated four planting time of five promising strawberry genotypes *viz.*, Sweet Charlie, Festival, Camarosa, FA 008 and BARI Strawberry-1 for observing their effects on growth, yield and quality under sub tropical climatic conditions of Bangladesh. The tallest plant was recorded in Camarosa (28.50 cm) followed by Festival (24.33 cm) and the shortest in BARI Strawberry-1 (18.42 cm).

Strawberry *cv.* Confitura, planted in November and mulched with black polyethylene exhibited the best growth characters (Wani *et al.*, 2007).

Rajbir *et al.* (2007) reported that mid-September planting was best for attaining maximum plant height (11.2 cm) in strawberry.

Amarjeet *et al.* (2009) observed that planting on second week of October found to be the most efficacious in improving vegetative growth in strawberry *cv.* Chandler.

Experiments were conducted on strawberry having four planting time (one month interval) with five promising strawberry genotypes *viz.*, Sweet Charlie, Festival, Camarosa, FA 008 and BARI strawberry-1 for observing their effects on growth, yield and quality under sub tropical climatic conditions of Bangladesh. The tallest plant of 27.67 cm was obtained in September planting followed by October planting (25.00 cm) and the shortest (16.87 cm) in December planting (Rahman *et al.*, 2014).

Kurian. A (2015) reported that last week of September planting was best for gaining maximum plant height (81.7 cm) in strawberry *cv.* Winter Dawn in agroclimatic condition of Wayanad.

2.1.1.4 Mulching

Studies conducted with different mulches such as black polyethylene, sugarcane trash, paddy straw, saw dust, dry grasses and un-mulched control on the growth, flowering, yield and quality of strawberry *cv.* Sweet Charlie at Kanpur, Uttar Pradesh revealed that plants mulched with black polyethylene mulch resulted in maximum plant height (Angrej and Gaur, 2007).

Rajbir *et al.* (2007) observed that plants mulched with black polyethylene recorded the highest plant height than those mulched either with clear polyethylene or paddy straw.

Sharma (2009) conducted an experiment to study the effects of mulch (polyethylene, *Eupatorium* dry plants or rice straw) on the performance of strawberry *cv.* Tiogo. Significantly improved crown height (11.1 cm) was recorded with plants mulched with black polyethylene.

Kumar *et al.* (2012) studied the impact of different mulching materials on growth, yield and quality of strawberry. The maximum plant height (21.10 cm) was recorded for strawberry *cv.* Sweet Charlie mulched with clear polyethylene mulch.

Studies conducted by Bakshi *et al.* (2014) to evaluate the effect of different mulching materials on growth, yield and quality of strawberry *cv.* Chandler. The treatments comprised of paddy straw, wheat straw, dry grass, transparent polyethylene, black polyethylene and no mulch (control). The black polyethylene mulch gave the best results in terms of reducing weed population (1.00 m^{-2}) and increasing plant height (21.67 cm).

Experiment to study the effect of mulching on economic yield of strawberry *cv.* Chandler under Alfisols of Nagaland reveals that maximum plant height was observed with black polyethylene mulch (Rhakho *et al.*, 2014, Singh *et al.*, 2006).

2.1.2 Number of leaves

2.1.2.1 Variety

Rao and Lal (2010) evaluated 17 strawberry genotypes under Garhwal agro climatic conditions for observing their effect on growth, yield and quality. The maximum number of leaves was recorded in Chandler (16.66).

Hossan *et al.* (2013) evaluated three strawberry germplasm *viz.*, SG-1, RABI-3 and SG-3 for growth and yield characters. Tha maximum number of leaves 11.0 per plant was recorded in SG-1.

Rahman *et al.* (2014) conducted an experiment on strawberry with four planting time and five promising strawberry genotypes *viz.* Sweet Charlie, Festival, Camarosa, FA 008 and BARI strawberry-1 for observing their effects on growth, yield and quality under sub tropical climatic conditions of Bangladesh. Maximum number of leaves per plant was observed in genotype Festival (39.5) followed by Camarosa (37.58) and the lowest in FA 008 (30.67).

2.1.2.2 Nutrients

2.1.2.2.1 Organic nutrients

Combined application of *Acetobacter* at 7 kg ha^{-1} + vermicompost at 30 t ha^{-1} significantly increased number of leaves per plant in strawberry *cv.* Chandler (Gupta and Tripathi., 2012)

Pandit *et al.* (2013) observed that application of VAM @ 12 kg ha^{-1} recorded a 39.03 per cent increase in number of leaves (19.47) over the control in strawberry.

2.1.2.2.2 Inorganic nutrients

Urea application at 75 g m^{-2} resulted in the highest number of leaves and runners per plant in strawberry *cv.* Chandler (Singh *et al.*, 2001)

Rana and Chandel (2003) observed that maximum number of leaves (26.20) was observed with *Azotobacter* inoculation combined with 100 N ha^{-1}.

Strawberry *cv.* Sweet Charlie were applied with 0, 50, 100, 150 or 200 kg N ha^{-1} in field condition, the number of leaves per plant and plant height were increased with inceasing rates of N (Ram and Gaur, 2003).

Experiment conducted to study the effect of different doses of nitrogen and potassium on the vegetative growth of strawberry *cv.* Confitura revealed that maximum number of leaves per plant (9.83) was recorded with nitrogen up to 150 kg ha^{-1} and potassium up to 150 kg ha^{-1} (Ahmad *et al.*, 2011).

2.1.2.3 Time of planting

Rahman *et al.* (2014) observed that the number of leaves per plant was maximum in September planting (46.13) followed by October planting (36.93) and the minimum was in December planting (24.60).

2.1.2.4 Mulching

Angrej and Gaur (2007) reported that the mulching increased the vegetative growth. Plants mulched with black polyethylene mulch recorded maximum number of leaves per plant.

Kumar *et al.* (2012) reported that clear polyethylene mulch gave the best results in terms of leaves per plant (11.77) in strawberry *cv.* Sweet Charlie.

Studies were carried out to evaluate the effect of different mulching materials on growth, yield and quality of strawberry *cv.* Chandler. The treatments comprised of paddy straw, wheat straw, dry grass, transparent polyethylene, black polyethylene and no mulch (control). The black polyethylene mulch gave the best results in terms of reducing weed population (1.00 m^{-2}) and increasing number of leaves $plant^{-1}$ (18.33) (Bakshi *et al.*, 2014).

Experiment to study the effect of mulching on economic yield of strawberry *cv.* Chandler under Alfisols of Nagaland revealed that maximum number of leaves was recorded with black polyethylene mulch (Das *et al.*, 2007, Ravi *et al.*, 2010, Rhakho *et al.*, 2014).

Kurian *et al.* (2015a) reported that mulching increased vegetative growth. Plants mulched with black polyethylene mulch recorded maximum number of leaves per plant (25.73) in strawberry cv. Winter Dawn in agroclimatic condition of Wayanad.

2.1.3 Plant spread

2.1.3.1 Variety

Ahmad (2009) investigated the effects of plant density (30×40×30 cm or single row planting, 30×50×60 cm or double row planting, and 30×60×90 cm or triple row planting, resulting in 47619, 60606 and 66666 plants ha^{-1}, respectively)

on the growth and yield of strawberry cultivars Senga Sengana and Chandler. Senga Sengana was superior in terms of plant spread (13.82 cm).

Kumar *et al.* (2011) carried out the varietal screening of strawberry under organic production system for fruit quality, flowering and yield in mid-hills of Sikkim Himalayas and found that the cultivars Shasta and Etna had maximum number of runners per plant (14), which was significantly more than other cultivars, while the cultivars Ofra, Chandler and Selva produced fewer runners per plant.

Ankita and Chandel (2014) evaluated 13 strawberry genotypes under the mid-hill conditions of Himachal Pradesh. The maximum plant spread was recorded in Confictura (51.0 cm).

2.1.3.2 Nutrients

2.1.3.2.1 Organic nutrients

Umar *et al.* (2008a) observed that strawberry plants attained 28.16 cm plant spread with the application of 25 per cent nitrogen through FYM augmented with *Acetobacter* and was at par with the plants supplied with urea in combination with *Acetobacter*.

Khalid *et al.* (2013) reported that treatment combinations soil + silt + farmyard manure (FYM) induced positive influence on plant spread (20.37 cm). It was also found that FYM and vermicompost based organic amendments enhanced vegetative growth.

2.1.3.2.2 Inorganic nutrients

Santos and Chandler (2009) studied the strawberry varieties such as Festival and Winter Dawn to different nitrogen (N) rates and found that linearly increased canopy diameters of both cultivars.

Yadav *et al.* (2010) observed positive influence of inorganic fertilizers on plant spread (34.52 cm) in strawberry.

Experiment conducted to study the effect of different doses of nitrogen and potassium on the vegetative growth of strawberry *cv.* Confitura revealed that maximum plant spread was recorded with nitrogen up to 150 kg ha^{-1} and potassium up to 150 kg ha^{-1} (Ahmad *et al.*, 2011).

2.1.3.3 Time of planting

Rajbir *et al.* (2007) reported that maximum crown spread (24.1 cm) was resulted when strawberry planted during mid-September. It was concluded that strawberry could be planted in mid-September under semi-arid regions of India for early fruiting and higher yield of better quality fruits.

2.1.3.4 Mulching

Angrej and Gaur (2007) conducted experiments on different mulches on the growth, flowering, yield and quality of strawberry *cv.* Sweet Charlie. The mulch types used were black polyethylene, sugarcane trash, paddy straw, saw dust, dry grasses and un-mulched control. Mulching increased the vegetative growth and plants mulched with black polyethylene mulch recorded maximum plant spread.

Rajbir *et al.* (2007) reported that maximum crown spread (24.1 cm) was observed when strawberry planted during mid-September and mulched with black polyethylene.

Black polyethylene has established its superiority with regard to maximum crown spread followed by white polyethylene and paddy straw mulch in strawberry (Katiyar *et al.*, 2009).

Kumar *et al.*, (2012) conducted experiment on the impact of different mulching materials on growth, yield and quality of strawberry. Ten treatments

consisted of no mulch, wheat straw, paddy straw, cut grass, green polyethylene, red polyethylene, pine needles, black polyethylene, clear polyethylene and coconut husk. Mulching with clear polyethylene gave the best results in terms of plant spread (28.99 cm) of strawberry cultivar Sweet Charlie.

Biswajit *et al.*, (2013) in an experiment conducted on growing strawberry under polyhouse environment having three planting dates (mid September, mid October and mid November), and three types of mulches (black and clear polyethylene and grass straw (*Cymbopogon maritini*) and without mulch as control) observed an improvement in plant growth of runners planted in mid September and beds mulched with black polyethylene. Clear polyethylene encouraged weed growth (355.3-362.8 weeds bed^{-1}).

Bakshi *et al.* (2014) evaluated the effect of different mulching materials on growth, yield and quality of strawberry cv. Chandler. The treatments comprised of paddy straw, wheat straw, dry grass, transparent polyethylene, black polyethylene and no mulch (control). It was observed that black polyethylene mulch gave the best results in terms of reducing weed population (1.00 m^{-2}) and increasing plant spread (31.24 cm).

2.2 Flowering attributes

2.2.1 Days to first flowering

2.2.1.1 Variety

Rahman *et al.* (2014) evaluated strawberry at four planting time (one month interval) and five promising strawberry genotypes (Sweet Charlie, Festival, Camarosa, FA 008 and BARI strawberry-1) for observing their effects on growth, yield and quality under sub tropical climatic conditions of Bangladesh. The genotype Camarosa took the longest period 89.00 days to reach the first flowering

stage followed by Festival (86.67 days) and FA 008 took the shortest period (80.00 days) for flowering which is closely followed by BARI Strawberry-1 (80.08 days).

Ankita and Chandel (2014) evaluated 13 strawberry genotypes under the midhill conditions of Himachal Pradesh. Winter Dawn was earliest (118 days) to flower than Chandler (119.34 days).

Ahsan *et al.* (2014) reported that the RABI-03 was early to flower (69.00 days) followed by Camarosa (62.70 days), whereas Festival was late to flower (60.50 days).

2.2.1.2 Nutrients

2.2.1.2.1 Organic nutrients

Azotobacter at 6 kg ha^{-1} + vermicompost at 30 t ha^{-1} significantly reduced number of days to first flowering (56.15 days and 54.15 days respectively) during two seasons in strawberry cv. Chandler (Gupta and Tripathi, 2012).

2.2.1.3 Time of planting

Rajbir *et al.* (2007) reported that in strawberry Chandler irrespective of mulching, plants took only 77.3 days to flowering in mid-September planting and 92.4 days in mid-November planting.

Rahman *et al.* (2014) reported that strawberry when planted in October took the shortest period (70.80 days) for first flowering while December planting took the longest period for first flowering (93.13 days).

2.2.1.4 Mulching

Studies in strawberry cultivars, Darrow, Earliglow and Sparkle revealed that plants under mulch flowered up to 13 days earlier and the fruit was ready to harvest 10 days earlier (Pollard *et al.*, 1989).

Abbotty and Gough (1992) investigated various mulching materials (polyethylene, polyester or oats) as alternative to straw mulch and reported that plants flowered and fruited earlier than other plants when polyethylene film was used as a mulch in strawberry cultivars, Holiday, Honoeoye, Canoga, Apollo, Scott, Garnet, Surecrop and Guardian.

Singh and Asrey (2005) conducted experiment in Punjab, India to determine the optimum planting time and suitable mulching material for greater productivity of strawberry in the semiarid region of north Indian plains which revealed that mid-September planting and black polyethylene mulch resulted in better plant growth and earlier flowering (80.2 days).

Rajbir *et al.* (2007) observed that plants mulched with black polyethylene took less number of days to flowering (80.2 days) than those mulched either with clear polyethylene (83.4 days) or paddy straw (87.8 days).

Kurian *et al.* (2015a) reported that mulching increased vegetative growth. Plants mulched with black polyethylene mulch recorded minimum days to flowering (40.00) in strawberry cv. Winter Dawn in agroclimatic condition of Wayanad.

2.2.2 Number of flowers per plant

2.2.2.2 Nutrients

2.2.2.2.1 Organic nutrients

Yusuf *et al.* (2003) reported the highest number of flowers per plant (14.63) in strawberry in the field applied with 150 kg N ha^{-1}, 100 kg P ha^{-1} and 20 t FYM ha^{-1}.

Azotobacter at 6 kg ha^{-1} + vermicompost at 30 t ha^{-1} significantly increased number of flowers per plant during two seasons in strawberry cv. Chandler (Gupta and Tripathi, 2012).

2.2.2.2.2 Inorganic nutrients

Yadav *et al.* (2010) observed maximum number of flowers (29.60 $plant^{-1}$) under the treatments in which *Azotobacter* inoculated with 50 per cent N substitution by vermicompost and remaining 50 per cent through inorganic fertilizer in two equal splits at establishment and before flowering stage.

2.2.2.3 Mulching

Studies conducted by Angrej and Gaur (2007) in strawberry *cv.* Sweet Charlie reported that mulching increased the flowering of plants. Plants mulched with black polyethylene mulch resulted in maximum number of flowers per plant.

Studies conducted on the impact of different mulching materials on growth, yield and quality of strawberry revealed that the number of flower per plant (22.76) increased with clear polyethylene mulch in strawberry *cv.* Sweet Charlie (Kumar *et al.*, 2012).

In an experiment to evaluate the effect of different mulching materials on growth, yield and quality of strawberry *cv.* Chandler, it was observed that the number of flowers per spike (28.33) increased with black polyethylene mulch (Bakshi *et al.*, 2014).

Studies conducted by Kurian *et al.* (2015b) in strawberry *cv.* Winter Dawn reported that mulching increased the flowering of plants. Plants mulched with black polyethylene mulch resulted in maximum number of flowers per plant (24) in agroclimatic condition of Wayanad.

2.2.3 Number of clusters per plant

2.2.3.1 Variety

Experiments were conducted to identify suitable environment for high production of good quality fruits with less diseases in strawberry varieties Ofra and Chandler. Higher number of clusters per plant was observed in Chandler (12.45) than Ofra (10.78) (Ashok *et al.*, 2011).

2.3 Response of crop to plant growth regulators

Ethephon (500 ppm) spray at flower initiation is effective for smothering flowering in day-neutral strawberry *cv.* Tristar, Hecker, Brighton (Choma and Himelrick, 1982).

NAA at 0.05 and 0.10 mg litre^{-1} in a lanolin emulsion to emasculated flowers resulted in 100 per cent parthenocarpic fruit development (Beech, 1983).

NAA (400 ppm) applied one week after full bloom has been effective for higher yield, higher acidity and lower sugar: acid ratio (Techawongstein, 1989).

Tricontanol at 5 ppm before flower emergence increased leaf area, leaf number and runner production in Tioga strawberry (Kumar *et al.*, 1996).

Plants treated with 0.1 per cent hydrogen cynamide or 3 per cent potassium nitrate can break dormancy of strawberry plants (Maroto *et al.*, 1998).

Xiao *et al.* (1998) reported that spraying NAA (100 ppm) + 0.3 per cent boric acid during early flowering stage reduced abnormal fruit development, and subsequently increased yields.

GA_3 at 50 ppm sprayed after flowering increased the yield up to 31-41per cent (Chadha, 2001).

Maleic hydrazide (0.1-0.3 per cent) sprayed after flowering increase yield up to 31-41 per cent. Morphectin (50 ppm) improves the fruit size of strawberry (Chadha, 2001).

2.4 Response of crop to environmental factors

2.4.1 Temperature

Roberts and Kenworthy (1956) have found ambient temperature range between 20 ^{0}C and 26 ^{0}C for proper growth of strawberry.

Temperature below 15.6 ^{0}C inhibits pollen germination and pollen tube growth, resulting in mis-shapen fruits (Garren, 1980).

Floral induction in short duration cultivars is under facultative control, meaning that when temperatures are above about 15 ^{0}C they form flower buds under short day conditions, but under cooler temperatures, they form flower buds regardless of photoperiod (Guttridge, 1985).

The strawberry is mainly grown in temperate climates because its optimum growth temperature ranges from 10 ^{0}C to 26 ^{0}C (Strik, 1985).

Strawberry plants are highly sensitive to variation in environmental conditions. Factors such as water availability, day and night time temperatures, and day light intensities affect fruit size (Avidov, 1986).

Exposure to high temperature ($\geq$35^{0}C) results in reduced plant growth (Renquist *et al.*, 1982) and lower yields (Hellman and Travis, 1988).

Westwood (1993) reported that bee activity decreases below 10 ^{0}C resulted in decreased pollination and mis-shapen fruits.

Shiow and Mary (2000) reported that in strawberry *cv.* Earliglow and Kent the optimum day/night temperatures for leaf and petiole growth was 25/12 ^{0}C,

while for roots and fruits, it was 18/12 ^{0}C. For the growth of whole plant, 25/12 ^{0} C was the optimum temperatures. As the day/night temperature increased, malic acid content increased and citric acid content decreased

The optimum temperature for short day floral initiation is 15-18 ^{0}C while below 10 ^{0}C and above 25 ^{0}C short day induction is rather ineffective (Manakasem and Goodwin, 2001).

The effects of photoperiod, day temperature and night temperature and their interactions on flower and inflorescence emergence were investigated by exposing 4 week old runner plants of strawberry cultivars, Korona and Elsanta during a period of 3 weeks. A daily photoperiod of 12 h or 13 h resulted in the number of plants with emerged flowers. A day temperature of 18 ^{0}C and a night temperature of 12 ^{0}C were optimal for plants to emerge flowers and resulted in the shortest time to flowering. The number of flowers on the inflorescence increased with decreasing day temperature and when photoperiod was raised from 12 h to 15 h (Michel *et al.*, 2006).

Successful flower induction required a day temperature of 12 ^{0}C, 15 ^{0}C or 18 ^{0}C and was irrespective of age of the plant. At 24 ^{0}C and 30 ^{0}C, plants remained vegetative. High temperature (21°C) promotes runnering in both short day and long day condition (Michel *et al.*, 2006; Heide and Sonsteby, 2007).

Singh *et al.* (2012) reported that among different planting time at day 10 in July, August, September, October and November under low tunnels skinned with 75 per cent and 50 per cent shade net, UVS polyethylene (200µm) and in open field, UVS polyethylene caused the minimum temperature during the whole growing period favourable for the growth, development and quality improvement in strawberry.

Experiment carried out in strawberry *cv.* Camarosa in the province of Huelva, Spain revealed that between early production and temperature (R^2=0.86)

and between early production and solar radiation (R^2=0.73) there was a linear relationship (Palencia *et al.*, 2013).

2.4.2. Humidity

Strawberry plants were treated with conditions of low night humidity (50-55 per cent) and high night humidity (90-95 per cent) for 40 days. It was found that the growth of strawberry plants is not affected by high humidity because of their root pressure, which supplies calcium to both the inner leaves and to the pre-emergence leaves of strawberries. Strawberry plants did not show any increase in total dry weight and leaf area in response to high night humidity (Choi *et al.*, 1997).

Studies on the effects of different humidity levels on strawberry cv. Elsanta revealed that an increase in the relative humidity in the greenhouses enhanced vegetative growth. To achieve maximum yield, good fruit size and fruit set a relative humidity of 65 per cent to 75 per cent was considered optimum. Extreme high humidity had detrimental effects on fruit firmness and shelf life (Lieten, 2002).

Experiment conducted to study the influence of microclimate changes caused by low tunnels and effect of planting time on strawberry revealed that that UVS polyethylene covering resulted in a 2-6 per cent higher relative humidity than control during whole growing period (Singh *et al.*, 2012).

2.4.3. Light intensity

Plants of the strawberry varieties Kogyoku and Red Star were illuminated with light intensities ranging from 2 to 100 lux to supplement the natural day length, giving 24 h of continuous illumination. The study reveals that flower bud differentiation was inhibited at a supplementary light intensity above 20 lux in Red Star and above 10-20 lux in Kogyoku. Vegetative growth increased when the supplementary light intensity was above 10 lux (Ueno, 2013).

2.4.4. Photoperiod

After prolonged short day exposure, plants attain a semi-dormant state, in which emerging leaves remain small, and petioles short, and the rate of leaf production decreases (Jonkers 1965).

Duration of dark period rather than the light period is the factor, which controls floral initiation in strawberry. After the induction of flowering, short day promotes flower initiation, but delays differentiation of flower organs in strawberry (Hartmann, 1947).

Yanagi and Oda (1993) reported that stolon formation, petiole length, leaf area and yield increases with increasing photoperiod.

Runnering is clearly promoted by long photoperiod (>16 = 14 h) and high temperature (>20 – 17 °C), in short day cultivars of strawberry (Darrow 1936; Durner *et al.*, 1984; Guttridge 1985; Le Mière *et al.*, 1996).

In short day conditions, axillary buds differentiate to rosette-like structures called branch crowns, whereas in long-day conditions (LD) they form runners, branches with 2 long internodes followed by a daughter plant (Timo, 2009).

Konsin *et al.* (2001) observed that in strawberry *cv.* Korona a 15 h photoperiod initiates the formation of branch crowns from the axillary buds of the main crown. A shorter photoperiod (12 h) was even more effective, whereas in long day (18 h), no branch crowns were formed. The extension of short day treatment increased the number of branch crowns, providing more meristems for floral development.

2.4.5. Response of crop to protected cultivation

Shading may, affect growth and yield, if not followed properly (Garrison *et al.*, 1991).

Studies on growth and fruiting responses of strawberry plants grown on rockwool to shading reveals that unshaded plants produced 26 per cent more leaves than those grown under shaded conditions. Shading reduces number of flowers per plant by 15 per cent than those grown under unshaded condition. Shading reduces number of fruits per inflorescence by 20 per cent than those under unshaded condition (Yahya and Atherton, 1995).

In an experiment conducted to study the comparison between strawberry growing inside and outside the plastic house in *cv.* Yael in the Northeast of Thailand. It was observed that inside the plastic house, the productivity (number of fruits) per plant was 4.6, while outside the plastic house the productivity per plant was 6.1 due to the heat accumulation inside the plastic house. The temperature inside the plastic house was higher than outside (2 °C) affecting the growth of a flower bud that is in a direct effect to reduce the amount of the strawberry production (Tongtraibhop *et al.*, 2009).

Studies were conducted to identify suitable environment for high production of good quality fruits in strawberry *cvs.* Ofra and Chandler. Both the varieties were grown under low cost polyhouse, plastic tunnel and open conditions. The highest number of flower clusters per plant was observed in open conditions (11.84) which was on par with plants under plastic tunnel (11.74) and lowest in polyhouse conditions (11.27). Fruit yield response of plants under plastic tunnel (39.6 t ha^{-1}) was significantly more than the response of other growth conditions and minimum (31.4 t ha^{-1}) in plants under open conditions. Maximum TSS was obtained for plants under plastic tunnel (6.6 per cent) which was at par with fruits in polyhouse (6.45 per cent) and minimum was in fruits under open condition (6.25 per cent) (Ashok *et al.*, 2011).

Experiments were conducted to study the influence of microclimate changes caused by low tunnels and effect of planting time on early production and extension of cropping season of strawberry. Fruit number per plant was highest at 50 per cent shade while planting in open field produced the lowest. Fifty percent

shade produced fruits 38 and 33 days earlier than normal planting time especially when planting was done in the month of July and August respectively. Extension of harvesting was observed in ultra violet sheet protected system which was caused by a higher temperature of 7.0±2.0 ^{0}C-16.0±2.0 ^{0}C inside the tunnel during the cold winter (Singh *et al.*, 2012).

Studies conducted to evaluate the performance of strawberry *cv.* Winter Dawn in different growing conditions revealed that in high ranges strawberry plants grown in open field exhibited maximum yield per plant (110.07 g) (Kurian. A, 2015).

2.5 Yield characters

2.5.1 Number of days to first harvest

2.5.1.1 Variety

Studies on the effect of two day/night temperature regimes on fruit set and flower growth in two strawberry cultivars, Nyoho and Toyonoka recorded significantly lower number of days to fruit ripening at 30/25 ^{0}C than at 23/18 ^{0}C in both cultivars, but no significant differences in cultivar response were observed (Ledesma *et al.*, 2008).

2.5.1.2 Time of planting

Planting time had a positive effect on early harvesting as well as extension of the harvesting period (Pollard and Chundari, 1989; Singh *et al.*, 2012)

2.5.2 Number of fruits per plant

2.5.2.1 Variety

Poor fruit development in some varieties may be due to the fact that they produce either pistillate flowers only, flowers with few stamens, and stamens that fail to produce sufficient pollen for fertilization (Sharma, 2002).

Studies conducted by Pradeepkumar *et al.* (2002) on the performance of strawberry varieties Sujatha, Labella and Chandler in Wayanad districts of Kerala revealed that cv. Chandler is the best in case of number of fruits per plant (17.9).

Pramanick *et al.* (2002) noticed that the strawberry cv. Shimla Delicious exhibited highest number of fruits per plant (30), while Etna and Belrubi gave the highest yield of 2.43 t/ha and 2.13 t/ha, respectively.

Among the varieties Senga Sengana and Chandler which were studied in Jammu and Kashmir, Senga Sengana was found to be superior in number of fruits per plant (28.32) (Ahmad, 2009).

Rao and Lal (2010) reported that among the 17 strawberry genotypes evaluated for their effects in growth and yield characters under Garhwal agro-climatic conditions revealed that Belrubi (16.8) and Gorella (15.10) have the maximum number of fruits per plant.

Rahman *et al.* (2014) reported that among the five promising strawberry genotypes *viz.*, Sweet Charlie, Festival, Camarosa, FA 008 and BARI strawberry-1 for observing their effects on growth, yield and quality under sub tropical climatic conditions of Bangladesh during the two winter seasons, they found that the genotype Sweet Charlie produced the maximum number of fruits (28.75) while FA 008 produced minimum fruits (19.25).

2.5.2.2 Nutrients

2.5.2.2.1 Organic nutrients

Yusuf *et al.* (2003) reported that application of 150 kg N ha^{-1}, 100 kg P ha^{-1} and 20 t FYM ha^{-1} resulted in the highest number of fruits per plant (6.40).

Mishra and Tripathi (2011) observed that combined application of *Azectobacter* and Phosphorous solubilizing bacteria (each at 6 Kg ha^{-1}) significantly increased the number of flowers (67.27) per plant.

Gupta and Tripathi (2012) reported that maximum number of fruits set (39.21 and 36.19, respectively) per plant in two seasons was observed in *Azectobacter* at 6 kg ha^{-1} + vermicompost at 30 t ha^{-1} applied in strawberry *cv.* Chandler.

2.5.2.2.2 Inorganic nutrients

Singh *et al.* (2001) found urea at 30 g m^{-2} resulted in the highest number of fruits per plant. Application of urea higher than 30 g m^{-2} reduced fruit number.

In strawberry *cv.* Sweet Charley, number of fruits harvested per plant increased with increasing rates of N up to 150 kg ha^{-1} and decreased thereafter. Fruit set was highest with the application of 200 kg N ha^{-1} (Ram and Gaur, 2003).

Yadav *et al.* (2010) observed that the number of berries (22.27 $plant^{-1}$) were maximum in *Azectobacter* inoculated with 50 per cent N substitution by vermicompost and remaining 50 per cent through inorganic fertilizer in two equal splits applied at time of planting and before flowering stage.

Experiment conducted to study the effect of different doses of nitrogen and potassium on the vegetative growth of strawberry *cv.* Confitura revealed that single fertilizer application of nitrogen and potassium was beneficial for maximum number of fruits per plant (13.72) and marketable fruit yield (Ahmad *et al.*, 2011).

2.5.2.3 Time of planting

In strawberry, planting under ultra violet stabilizing polyethylene in the month of October and November was recorded the highest number of fruits per plant. During winter season, ultraviolet sheet polyethylene increased the temperature in average 2 to 6 ^{0} C higher than in open, which may have resulted in an increased fruit number (Singh *et al.*, 2012)

Rahman *et al.* (2014) observed that in sub-tropical climatic conditions of Bangladesh, strawberry plants produced maximum number of fruits per plant (31.30) in October planting and the minimal fruits in December planting (15.80).

Kurian *et al.* (2015a) reported that last week of September planting was best for gaining maximum number of fruits per plant (8.97) in strawberry *cv.* Winter Dawn in agro climatic conditions of Wayanad, Kerala

2.5.2.4 Mulching

Angrej and Gaur (2007) observed that the mulching increased the flowering of strawberry cv. Sweet Charlie. Plants mulched with black polyethylene mulch resulted in maximum number of fruits per plant.

Maximum number of fruits was observed with black polyethylene mulch followed by transparent polyethylene and paddy straw mulch (Kour and Singh, 2009).

Kumar *et al.* (2012) found that clear polyethylene mulch gave the best results in terms of fruit per plant (18.10) of strawberry cv. Sweet Charlie.

Studies conducted by Kurian *et al.* (2015a) in strawberry *cv.* Winter Dawn reported that mulching increased the number of fruits per plant. Plants mulched with black polyethylene mulch resulted in maximum number of fruits per plant (8.97) in agroclimatic condition of Wayanad.

2.5.3 Yield

2.5.3.1 Variety

Studies conducted by Pradeepkumar *et al.* (2002) on the performance of strawberry varieties Sujatha, Labella and Chandler in Wayanad districts of Kerala revealed that *cv.* Chandler is the best in case of fruit yield per plant (79.3 g).

Experiment to study the performance of cultivars in Florida observed that *cv.* Winter Dawn had the best performance producing more than 34 ton/ acre.

There were no differences in the total yields of Carmine, Albion, Festival, Camarosa, and 00-51 which ranged between 20.7 and 24.8 ton/acre (Bielinski *et al.*, 2007).

Ahmad (2009) conducted experiments on the growth and yield of strawberry cultivars Sanga Sengana and Chandler under different plant density (30×40×30 cm, 30×50×60 cm and 30×60×90 cm). The cultivar Sanga Sangana was superior in terms of yield (204.33 g plant^{-1} or 11.84 t ha^{-1}), whereas Chandler was superior with regard to fruit weight (8.35 g), fruit length (2.83 cm) and fruit width (2.52 cm).

Rao and Lal (2010) reported that among the 17 strawberry genotypes evaluated for their effects in growth and yield characters under Garhwal agro-climatic conditions revealed that genotypes Chandler (190.70 g) and Senga Sengana (165.80 g) have maximum yield per plant.

Emdad *et al.* (2013) observed that crown height, number of flowers per plant and length of fruit had the positive effect on yield per plant in strawberry *cvs.* FA 01, FA 02, FA 03, FA 04, FA 05 and FA 06.

Rahman *et al.* (2014) reported that in strawberry genotype Festival gave the highest yield per plant (421.79 g) which was on par with Sweet Charlie (415.20 g). Lowest yield was recorded in genotype FA 008.

2.5.3.2 Nutrients

2.5.3.2.1 Organic nutrients

Studies were conducted on strawberry *cv.* Chandler to determine the effect of nitrogen (0, 60, 80 and 100 kg N ha^{-1}) and biofertilizers (*Acetobacter*, *Azospirillum* and *Acetobacter* + *Azospirillum*) on strawberry production. The maximum yield (79.12 q ha^{-1}) was recorded with *Acetobacter* inoculation combined with 60 kg N ha^{-1} (Rana and Chandel, 2003).

In strawberry *cv.* Tuft, application of 150 kg N ha^{-1}, 100 kg P ha^{-1} and 20 t FYM ha^{-1} resulted in the highest fruit weight of 5.84 g and yield 7 t ha^{-1} (Yusuf *et al.*, 2003).

Umar *et al.* (2008a) observed that strawberry plants attained the fruit weight (15.87 g) with the application of 25 percent nitrogen through FYM augmented with *Acetobacter* and was at par with the plants supplied with urea in combination with *Acetobacter.*

The physico-chemical characteristics of strawberry fruits were significantly influenced with integrated use of poultry manure, urea and *Acetobacter* registering maximum yield of 371.23 q ha^{-1}. Plants applied with urea + *Acetobacter* did not differ significantly in yield obtained for plants receiving 25 per cent nitrogen in the form of poultry manure + 75 per cent through urea + *Acetobacter* and 50 per cent nitrogen through poultry manure + 50 per cent through urea augmented with *Acetobacter* (Umar *et al.*, 2008b).

In strawberry *cv.* Chandler highest yield of 372.89 g $plant^{-1}$ was obtained with the application of 100 per cent N in the form of urea along with *Acetobacter* (Iqbal *et al.*, 2009).

Mishra and Tripathi (2011) reported that maximum duration of harvesting (70.90 days) with significantly more yield (322.17 g $plant^{-1}$) were observed in *Acetobacter* and phosphorous solubilizing bacteria (each at 6 kg ha^{-1}) fertilized plants.

Gupta and Tripathi (2012) observed that application of *Acetobacter* at 6 kg ha^{-1} + vermicompost at 30 t ha^{-1} resulted in significantly higher yield in strawberry *cv.* Chandler.

Pandit *et al.* (2013) observed that application of VAM at the rate of 12 kg ha^{-1} showed a significant increase in yield (30.14 t ha^{-1}) which was 41.63 per cent higher over the control in strawberry.

2.5.3.2.2 Inorganic nutrients

In strawberry cv. Deutsch Evern and Muncheberger Fruhe, the application of N favoured yield and fruit number per plant. Manuring with P slightly increased yield and fruit number. No effect of K manuring on yield and fruit number was observed (Stolle, 1955).

In strawberry *cv.* Chandler under greenhouse conditions, application of urea at 30 g m^{-2} resulted in the highest fruit weight and crop yield. Application of urea higher than 30 g m^{-2} reduced yield (Singh *et al.*, 2001).

In strawberry *cv.* Sweet Charley total yield increased with increasing rates of N up to 150 kg ha^{-1} and decreased thereafter (Ram and Gaur, 2003).

High potassium concentration in the nutrient solution reduced fruit yield and quality and that calcium supplied on shoots by $CaCl_2$ reduced fruit production in strawberry (Andriolo *et al.*, 2010).

Yadav *et al.* (2010) found that maximum fruit yield (101.99 q ha^{-1}) were recorded in *Acetobacter* inoculated with 50 per cent N substitution by vermicompost and remaining 50 per cent through inorganic fertilizer in two equal splits at the time of planting and before flowering stage in strawberry.

2.5.3.3 Time of planting

Brightwell and Woodard (1959) reported that under conditions in Georgia, September planting gave the best results when irrigation was available, but in the absence of irrigation better stands were obtained from October and November planting.

Mid-September planting favoured vigorous growth, and enhanced flowering and fruiting, resulting in the greatest fruit yield, fruit weight and fruit quality in Strawberry *cv.* Chandler (Rajbir *et al.*, 2005).

Studies indicated that strawberry *cv.* Chandler could be planted in mid-September with black polyethylene mulch under semi-arid regions of India for early fruiting, higher yield and better quality fruits (Rajbir *et al.*, 2007).

In a field experiment of strawberry *cv.* Confitura planting in November and mulching with black polyethylene exhibited better yield (Wani *et al.*, 2007).

Amarjeet *et al.* (2009) observed that early planting on second week of October found to be the most efficacious in improving yield of strawberry cv. Chandler.

In strawberry *cv.* Chandler, October planting coupled with black polyethylene mulching is most favourable for successful cultivation under sub-tropical conditions of Jammu (Kher *et al.*, 2010).

Rahman *et al.* (2014) reported that in strawberry maximum yield per plant was recorded from October planting (484.60 g) and the lowest from December planting (128.44 g) under subtropical climatic conditions of Bangladesh.

Kurian *et al.* (2015a) reported that last week of September planting was best for gaining maximum yield per plant (110.7 g) in strawberry *cv.* Winter Dawn in agroclimatic conditions of Wayanad, Kerala.

2.5.3.4 Spacing

Studies were conducted on the vegetative growth, development and yield of strawberry (*cv.* Elsanta) under various crop densities consisting of plant spacing of 10, 15, 20 and 25 cm between plants (100, 44, 25 and 16 plants m^{-1}, respectively). The effects of plant density on the vegetative parameters were more pronounced during the later growth periods, when the values of these parameters were greater at lower plant densities. The highest density resulted in the lowest yield per plant and the highest yield per unit area. The highest number of marketable fruits per plant was recorded for plants grown under low plant densities (Pérez de *et al.*, 2005).

Maximum fruit weight was obtained with double row of planting (30 x 50 x 60 cm with in plants, rows and between beds) followed by single row of planting (30 x 40 x 30 cm) and lowest in triple row planting (30 x 60 x 90 cm) (Fiedler and Liebelt, 1988; Ahmad, 2009).

Ahmad (2009) reported that among the different plant densities 30×40×30 cm or single row planting, 30×50×60 cm or double row planting, and 30×60×90 cm or triple row planting, double row planting resulted in the highest yield of 195.36 g per plant.

2.5.3.5 Mulching

An opaque plastic mulch suppressed weeds, conserved soil moisture, increased soil temperatures in cool weather and reduced them in warm weather and increased yields in strawberry (Thompson, 1959).

The early and total yields of strawberries were significantly higher from plastic-mulched plots than from plots mulched with paper or pine straw or without mulch in strawberry (Locascio and Thompson, 1960).

Among the mulching materials compared, the black polyethylene mulch resulted in the most vigorous growth and the highest yields in strawberry (Sharma and Khokhar, 2006).

Studies were conducted in strawberry *cv.* Florida 90 mulched with white polyethylene strips, black polyethylene strips for each plant, and coffee parchment. The yields of ripe fruit and the number of healthy fruits were highest with black plastic strips and lowest with white plastic (Castellanos and Leal, 1970).

Badiyala and Agarwal (1981) studied the effect of mulches on strawberry production using polyethlyene, pine needles and without mulch. The study reveals that polyethylene and pine needle mulches increased the yield by 68 percent and 33 percent, respectively, over the non-mulched control.

Bhattacharya and Madhava Rao (1985) reported that application of mulch increased the yield of strawberry due to favourable hydrothermal regime of soil.

Abbotty and Gough (1992) reported better moisture conservation and higher soil temperature by the use of black polyethylene mulch increased the yield compared to other mulches.

Studies have conducted in strawberry *cv.* Tioga mulched with transparent polyethylene film, black polyethylene film, pine needles, cut grass, or cut *Eupatorium sp.* Nutrient uptake, root growth, water use efficiency and yield were highest in black polyethylene mulch (Gupta and Acharya, 1993).

Trials carried out in strawberry *cv.* Oso Grande revealed that black polythene mulch produced the highest yield, followed by those mulched with transparent polythene and *Saccharum* residues (Hassan *et al.*, 2000).

Kikas (2000) reported that the average production of berries per plant in the black plastic and bed carpet treatments for all cultivars was significantly higher than in the control and the black plastic mulch gave the best results for strawberry *cv.* Senga Sengana.

Rajbir *et al.* (2005) reported that that among the black polyethylene, clear polyethylene and rice straw mulching materials, black polyethylene resulted in superior growth, fruit weight, yield and quality.

A field trial was conducted on strawberry *cv.* Chandler to evaluate the effect of various mulches on growth, flowering, fruiting, yield and quality in Uttar Pradesh. Mulching with black polyethylene was found to be the superior in growth, flowering, fruiting, yield and quality of strawberry cv. Chandler under Lucknow conditions (Ram *et al.*, 2005).

Mulching also improved plant growth, berry weight, fruit yield and quality in strawberry. Among the mulching materials, black polyethylene is the most widely used (Singh *et al.*, 2006).

The effect of different mulches on the growth, flowering, yield and quality of strawberry *cv.* Sweet Charlie was studied at Kanpur, Uttar Pradesh. Among the different mulch materials black polyethylene, sugarcane trash, paddy straw, saw dust, dry grasses and un-mulched control, plants mulched with black polyethylene mulch showed maximum fruit yield (Angrej and Gaur, 2007).

Sharma *et al.* (2008) reported that erection of row covers and mulching with black polyethylene in winter is highly useful for better growth and production of strawberry under a sub-tropical climate.

Studies were carried out to evaluate the effect of different mulching treatments on growth, yield and quality of strawberry *cv.* Chandler. The maximum fruit yield was observed with black polyethylene followed by transparent polyethylene and paddy straw (Kour and Singh, 2009).

Fruit yield of strawberry was significantly higher in plants mulched with black polyethylene (26.2 q ha^{-1}) as compared to plants mulched with paddy straw, *Eupatorium* and no mulch (Sharma, 2009).

Interactive effects of planting time and mulching on strawberry *cv.* Chandler showed that fruit weight per plant (12.6 g) and fruit yield (172.4 g $plant^{-1}$) was higher in plants mulched with black polyethylene (Kher *et al.*, 2010).

Kumar *et al.* (2012) reported that among different mulching materials, clear polyethylene gave the best results in terms of yield (20.44 t ha^{-1}) of strawberry *cv.* Sweet Charlie.

Biswajit *et al.* (2013) observed that in strawberry, runners planted in mid-September and beds mulched with black polyethylene improved fruit quality with comparatively better fruit yield per plant (159.0 g). Clear polyethylene encouraged weed growth.

Experiment to study the effect of mulching on economic yield of strawberry *cv.* Chandler under Alfisols of Nagaland reveals that maximum fruit

yield was recorded with paddy straw mulch (226.25 q ha-1) followed by black mulch (217 q ha-1) (Rhakho *et al.*, 2014).

Kurian *et al.* (2015a) reported that among the black polyethylene and clear polyethylene mulching materials, black polyethylene resulted in superior growth, fruit weight, yield and quality in strawberry.

2.6 Quality

Srivastava and Agarwal (1982) reported that hay mulch increased the ascorbic acid content of strawberry compared to other mulches.

In strawberry *cv.* Sweet Charlie the ascorbic acid content and total acidity of fruits increased with increasing rates of N up to 150 kg ha^{-1} and decreased thereafter (Ram and Gaur, 2003).

Rana and Chandel (2003) reported that in strawberry *cv.* Chandler maximum TSS (8.78° Brix) content was recorded with the application of *Acetobacter* combined with 80 kg N ha^{-1}.

Chemical analysis of 13 strawberry varieties revealed that the chemical composition of strawberry fruits significantly varied among the genotype of the plant and on the stage of maturity of fruits. The content of TSS is the function of several factors of which total sugars and organic acids constitute the major part. TSS increases during the late stages of ripening. The content of total acids decreased with maturity (Sturm *et al.*, 2003).

Rajbir *et al.* (2007) observed that the fruit having higher TSS (9.41 per cent), acidity (1.17 per cent) and higher ascorbic acid content (46.4 mg 100^{-1} g pulp) when planted during mid-September and mulched with black polyethylene. Studies indicated that strawberry could be planted in mid-September with black polyethylene mulch under semi-arid regions of India for better quality fruits.

Strawberry *cv.* Confitura planted in November and mulched with black polyethylene exhibited the best quality (Wani *et al.*, 2007).

Ahmad (2009) reported that among the different plant density of 30×40×30 cm or single row planting, 30×50×60 cm or double row planting, and 30×60×90 cm or triple row planting, double row planting resulted in the highest vitamin C content (62.51 mg 100^{-1} g of pulp).

Experiment to study the effect of plant density on growth and yield of strawberry *cv.* Sanga Sangana and Chandler revealed that cv. Chandler recorded maximum TSS, ascorbic acid and low acidity than Sangasangana (Ahmad 2009).

Amarjeet *et al.* (2009) observed that early planting on second week of October proved to be the most efficacious in improving the fruit quality.

Iqbal *et al.* (2009) reported that in strawberry cv. Chandler, the fruit quality *viz.* total soluble solids, total sugars, ascorbic acid and anthocyanin content was highest in fruits obtained from plants supplied with 25 per cent N through FYM + 75 per cent N in the form of urea + *Acetobacter* recording 6.81 ^{0}Brix, 4.73 per cent, 73.71 mg 100^{-1} g fresh berries and 0.191 OD respectively.

Katiyar *et al.* (2009) reported that the black polyethylene has established its superiority with regard to maximum quality parameters followed by white polyethylene and paddy straw.

Studies were carried out to evaluate the effect of different mulching treatments on growth, yield and quality of strawberry cv. Chandler. The six mulching treatments employed were black polyethylene, transparent polyethylene, paddy straw, saw dust, dry grasses and unmulched control. Highest TSS, sugar content and ascorbic acid content were also observed with black polyethylene but the effect was non-significant (Kour and Singh, 2009).

Experiment conducted to identify the suitable environment for high production of good quality fruits using two strawberry *cv.* Ofra and Chandler under low cost polyhouse, plastic tunnel and open condition revealed that maximum TSS, lower acidity and total sugars were observed in Chandler under plastic tunnel conditions (Kumar *et al.*, 2011).

Mishra and Tripathi (2011) reported that combined application of *Acetobacter* and phosphorus solubilizing bacteria (each at 6 kg ha^{-1}) significantly increased the TSS (10.30 °Brix), total sugars (9.54 per cent) and ascorbic acid (57.55 mg/100 g edible material) contents.

Singh *et al.* (2012) reported that the total sugar content in *cv.* Chandler (8.16 %) was higher than Pajaro (6.53 %), which was statistically at par with Gorella and Confictura.

Gupta and Tripathi (2012) reported that combined application of *Acetobacter* at 7 kg ha^{-1} + vermicompost at 30 t ha^{-1} in two seasons produced berries with maximum TSS (10.31 ^{0}Brix and 9.29 °Brix), total sugars (9.73 per cent and 8.74 per cent), ascorbic acid (56.52 mg/100 g edible pulp and 54.53 mg/100 g edible pulp) with minimum titratable acidity (0.52 per cent and 0.47 per cent) contents in comparison to untreated plants.

Kumar *et al.* (2012) reported that clear polyethylene gave the best results in terms of specific gravity (1.18), juice content (94.35 per cent), total soluble solid (9.00 per cent), total sugar (8.59 per cent), vitamin C (62.65 mg 100^{-1} ml juice) and acidity (69.00 per cent) of strawberry *cv.* Sweet Charlie.

Singh *et al.* (2012) observed that among different shade nets covering low tunnels such as low tunnels skinned with 75 per cent and 50 per cent shade net, ultra violet sheet (uvs) polyethylene (200 µm) and in open field, ascorbic acid content and anthocyanin was highest in UVS polyethylene covered low tunnel.

Experiment conducted to study the effect of integrated nutrient supply on yield, quality and fertility status of soil under rainfed conditions indicated that inoculation of bioagents with organic manure improved the quality of strawberry (Singh *et al.*, 2012).

Gunduz and Ozdemir (2014) conducted experiments by growing strawberries in three growing conditions *viz.*, greenhouse, plastic tunnel and open-

field. They observed that the growing conditions were only significant for total phenolic content, fructose and total sugar content.

Rahman *et al.* (2014) observed that the fruits of Camarosa has the highest TSS content (8.41 per cent) while highest ascorbic acid content was recorded in Sweet Charlie (79.13 mg 100^{-1} g). Among the four planting times, TSS and Ascorbic acid were highest in September planting.

Kurian *et al.* (2015a) reported that last week of September planting with black polyethylene gave the best results in terms of TSS (9.84 °Brix), total sugar (5.36 per cent) and acidity (0.24 per cent) of strawberry *cv.* Winter Dawn.

2.7 Postharvest study

Alley (1971) reported that sodium dehydroacetate (0.5 per cent) retarded ripening of strawberry and extended its shelf life in strawberry cultivars *viz.*, Midway, Surecrop, Sunrise and Catskill.

The best way to slow spoilage is to quickly remove field heat and to maintain berries to 0 ^{0}C as possible (Hardenburg *et al.*, 1986; Perez *et al.*, 1999; Kader, 2002).

Studies on controlled and modified atmosphere storage of strawberry *cv.* Pajaro revealed that a combination of 10 per cent CO_2 and 2 per cent O_2 resulted in a firmer texture and delayed ripening with no off-flavor development (Larsen and Watkins, 1995).

Strawberries fumigated with acetic acid at 5.4 mg L^{-1} were free of decay stored for 14 days at 5 °C in cultivar California (Moyls *et al.*, 1996).

Asghari *et al.* (2009) reported that cumin essential oil will act as an antifungal and increase the shelf life of strawberry.

Shifeng *et al.* (2010) reported that an ultrasonic treatment of 250 Watt for a time period of 9.8 minutes was found to be effective in inhibiting decay

incidence and preserving quality in strawberries upto 8 days in strawberry *cv.* Fengxiang.

Asghari *et al.* (2013) reported that both nitric oxide and putrescine effectively maintained fruit firmness, soluble solids content, vitamin C, red colour, total phenols, total acidity, and overall quality. Postharvest treatment of strawberries with 5 $\mu mol\ l^{-1}$ nitric oxide effectively controlled decay organisms and retained fruit quality during 15 days of storage at 2.5 °C. Putrescine effectively enhanced the effects of nitric oxide in maintaining fruit quality indices.

Romanazzi *et al.* (2013) reported that strawberries immersed in chitosan for 10 seconds after harvest resulted in effective control of gray mold and Rhizopus rot (storage decay) in strawberry cv. Camarosa.

2.8 Physiological disorder

Sharma *et al.* (2004) conducted a study on mulching influences plant growth and albinism disorder in strawberry under sub tropical climate of New Delhi revealed that among cultivars, Etna had the highest incidence of albinism (50.6 per cent), followed by Chandler (44.6 per cent) and Sweet Charlie had the least incidence of albinism (22.5 per cent). Irrespective of cultivars, albinism incidence was the highest, when plants were mulched with black polyethylene (38.6 per cent) and was the lowest when the plants were mulched with paddy straw (22.5 per cent).

Rajbir *et al.* (2007) reported that plants produced fruit with a slightly higher incidence of albinism (10.3 per cent), but comparatively lower incidence of botrytis rot (5.2 per cent) when planted during mid-September and mulched with black polyethylene.

2.9 Pest and diseases

In Europe, root weevils such as *Otiorhynchus rugosostriatus* and *O. sulcatus* are reported as the two potentially more dangerous species (Servadei *et al.*, 1972).

Soil disinfestations and soil solarization are effective for control of Verticillium Wilt in strawberry (Wilhelm and Paulus, 1980)

Kikas (2000) reported that the black plastic treatment had a significantly higher percentage of berries damage by seed beetles (*Harpalus* and *Pterostichus* spp.) and a lower percentage of berries damaged by plant bugs (*Lygus* spp.).

Soil solarization with transparent polyethylene mulch (25 μm) for 40 days during June-July is effective for the control of collar and root rot of strawberry (Raj and Sharma, 2005)

Materials and Methods

3. MATERIALS AND METHODS

The investigation envisages to evaluate the promising strawberry varieties (*Frageria* x *ananassa* Duch.) for Wayanad. The details of material used and methodology adopted during the course of the investigation are described in this chapter under the following headings.

3.1. Experimental site

The experiments were conducted over a period of one season from October 2016 to March 2017 in two growing systems *viz*., open and polyhouse conditions at, RARS Ambalavayal, Wayanad, Kerala.

3.1.1. Locations

Regional Agricultural Research Station, Ambalavayal, Wayanad is located at 76.12 ^{0}E latitude, 11.37 ^{0} N longitude and at an altitude of 1000 m above mean sea level.

3.1.2. Soil

The important physical and chemical properties of soil in the experimental site are summarized in Table 1.

Table 1. Soil characteristics of experimental field

Soil characters	Compositions
1. Physical properties	
a) Mechanical composition	
1. Sand	64.5%
2. Silt	12.5%
3. Clay	23%
b) Texture	Sandy clay loam
2. Chemical properties :	
Constituents	
Available nitrogen (kg ha^{-1})	107.00
Available Phosphorous (kg ha^{-1})	11.20
Available Potash (kg ha^{-1})	249.30
Organic carbon (%)	1.50
Electrical conductivity (mmhos cm^{-1})	0.14
pH	5.26
Calcium (mg kg^{-1})	304.00
Magnesium (mg kg^{-1})	100.10
Iron (mg kg^{-1})	42.70
Manganese (mg kg^{-1})	100.10
Copper (mg kg^{-1})	1.55

3.1.3. Climate

The climate of the experimental site was mild sub-tropical climate. The weather conditions prevailed during the cropping period are presented in Appendix-1

3.1.4. Seasons

The experiments were conducted during the period October 2016 to March 2017.

3.1.5. Planting time

Planting was done during last week of October 2016.

3.2. Materials

3.2.1. Varieties

Strawberry varieties *viz.,* Winter Dawn, Sweet Charlie, Eliyana, Sabrina and Crystal were used for this experiment. Winter Dawn is a cross between FL 93-103 and FL 95-316. Fruits are medium to large in size with attractive colour and aroma. It is a low chilling variety suited to subtropical climatic condition. Sweet Charlie is as the name suggests, deliciously sweet, fruits are medium in size with attractive colour and is an excellent choice for use as a short-day variety in warmer climates. It is resistant to anthracnose fruit rot. Eliyana is small low statured plant having large, flavorful fruit. Fruit that are attached to long pedicels makes it easy to harvest. It is moderately to highly resistant to a number of diseases. Sabrina is a cross between 9719 and 94020. They are self-fertile short day variety having large to medium sized conical fruit with good colour and flavour characteristics. Crystal is a day neutral cultivar, Fruits are firm, large in size, cylindrical with attractive shiny red colour and

taste. The tissue culture plants were collected from KF Bioplants Pvt. Ltd, Hadapsar, Pune.

3.2.2. Fertilizers

Farmyard manure @ 10t/ha is applied at the time of land preparation. Recommended dose of N: P: K is 75: 80:50 kg/ha. A basal dose of ½ N, ½ P and ½ K was applied as top dressing. Same dose of inorganic fertilizers was given 45days after planting.

3.2.3. Growing systems

Two systems of growing *viz.*, open (S_1) and polyhouse (S_2)

3.2.3.1. Open

Open field was selected for planting strawberries with a plot size of 2m x 1m.

3.2.3.2. Polyhouse

Polyhouse with a dimension of 21 m x 6 m x 3.5 m x 2 m size is covered with 200 micron poly film, shade net and misting system. The top and side walls are covered with 50 per cent agro shade net.

3.3. Methods

3.3.1. Design of the experiment

Design of the experiment was Randomized Block Design with ten treatments and three replications.

3.3.2. Treatments

Table 2. Details of the treatments

Treatment details		Notations
Varieties	Crystal	V_1
	Winter Dawn	V_2
	Sweet Charlie	V_3
	Sabrina	V_4
	Eliyana	V_5
Growing systems	Open	S_1
	Polyhouse	S_2

The layout of the experiment is given in Fig 1 and 2

Treatment notations	Treatment combinations
T_1	V_1S_1
T_2	V_2S_1
T_3	V_3S_1
T_4	V_4S_1
T_5	V_5S_1
T_6	V_1S_2
T_7	V_2S_2
T_8	V_3S_2
T_9	V_4S_2
T_{10}	V_5S_2

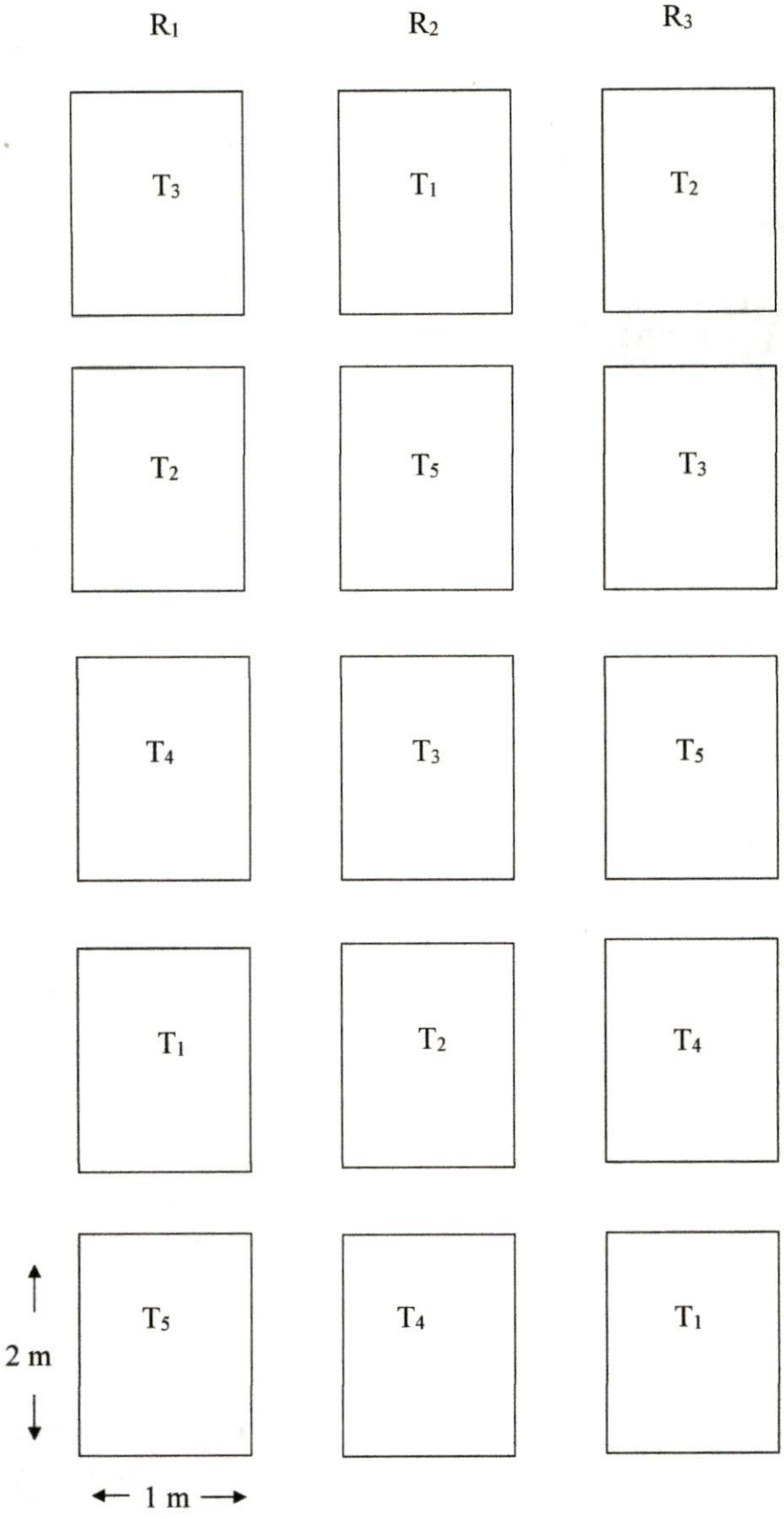


Fig. 1 Plan and layout of the experiment in open condition

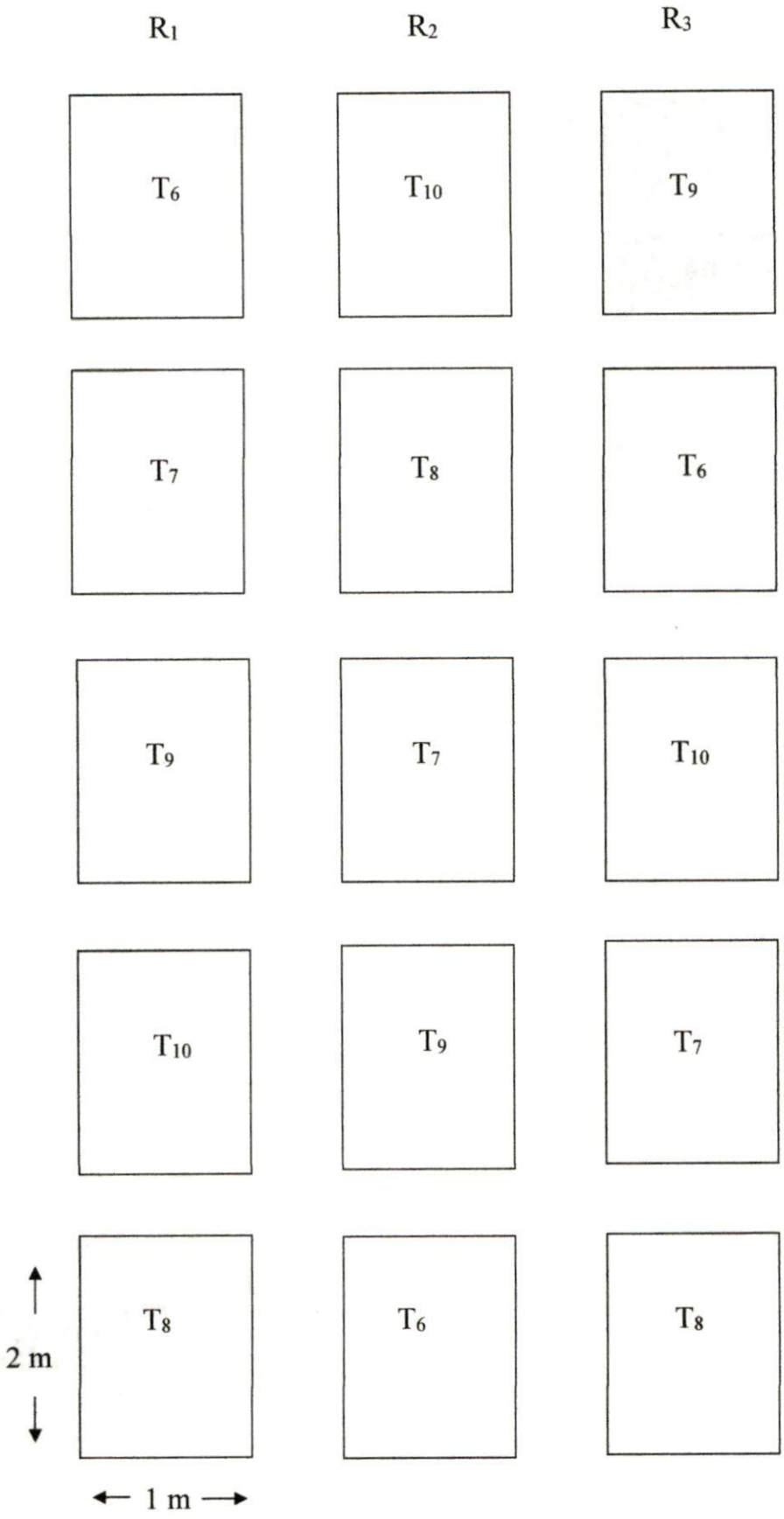


Fig. 2 Plan and layout of the experiment in polyhouse condition

3.3.3. Preparation of land

Land was raked thoroughly and was made free of weeds and stubbles. Soil fumigation with hydrogen peroxide with silver was done to make the soil pathogen-free. Then land was levelled properly and beds were taken in such a way that water can run in either direction in the furrows between the beds.

3.3.4. Fertilizer application

The full dose of FYM and half dose of N: P: K were applied at the time of bed preparation and the remaining half dose of N: P: K was applied 45days after first application.

3.3.5. Mulching

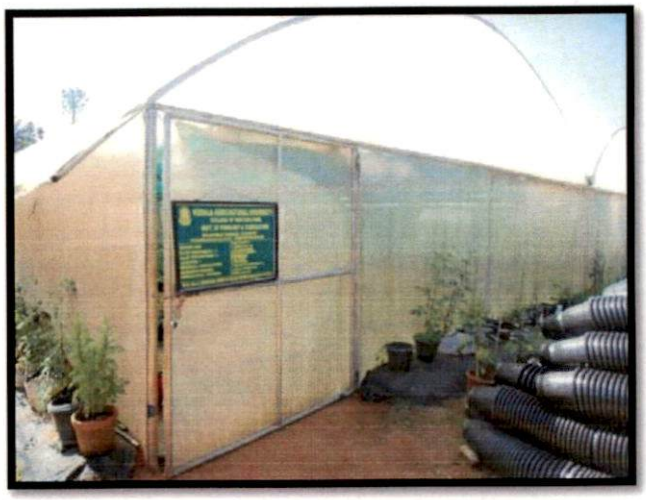
Beds were covered with silver polythene mulch in order to avoid fruits from touching the ground, conserve the soil moisture and control weeds in the plots and mulched beds are clipped with plastic coated metal clips

3.3.6. Planting

Double row hill system of planting was done on raised beds of size 2m x 1m. Between the beds, 0.5m spacing was given. In each growing system, there were about 15 raised beds or plots. Spacing given was 30 cm x 30 cm. Holes were made on the mulch depending on spacing. Planting was done during last week of October 2016. Twelve plants were planted in each plot. Planting was done by hand. One month old tissue culture plants were planted and shade was provided in open field for two weeks.

Open field (S_1)

Polyhouse (S_2)



Inside view of polyhouse

Plate 1. Different growing systems

Layout of the experiment

Planting of tissue culture strawberry plants

One month after planting

Plate 2. Layout of the experiment and planting

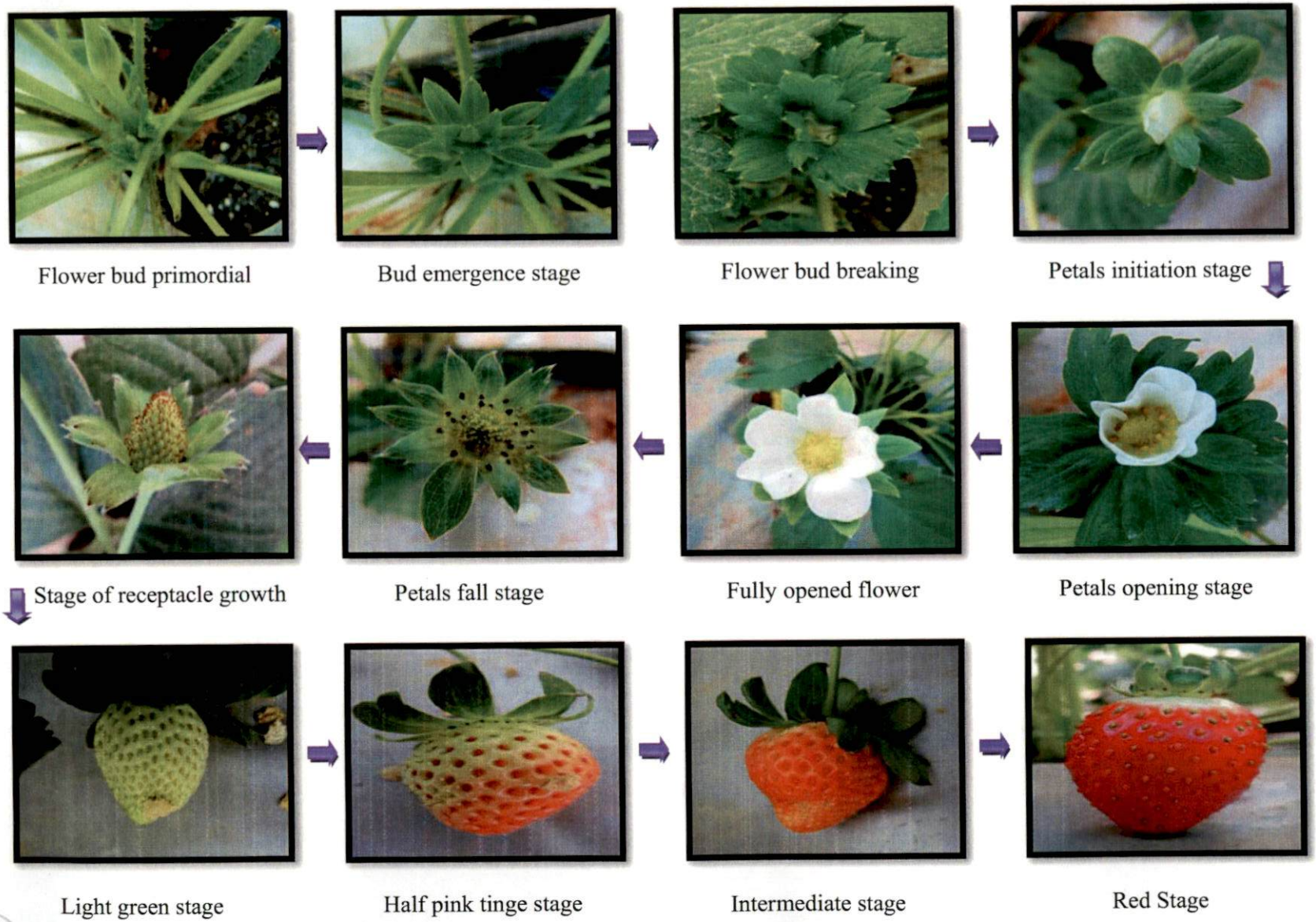
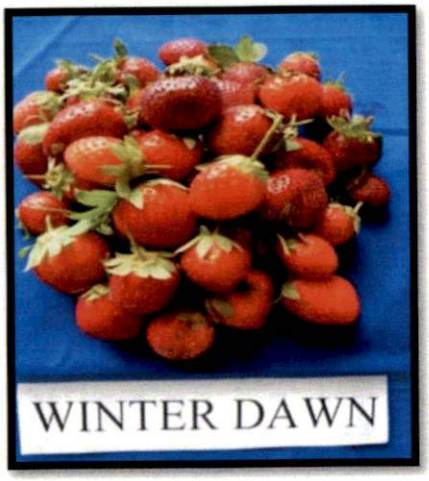
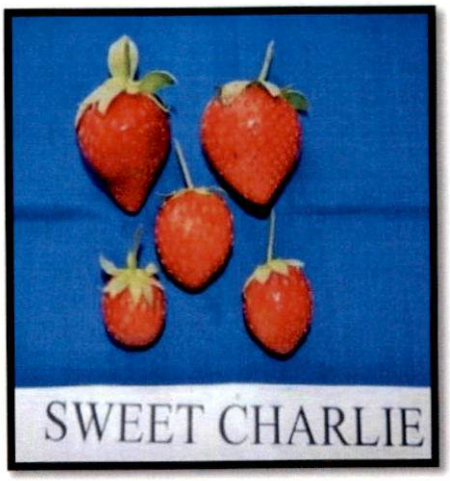
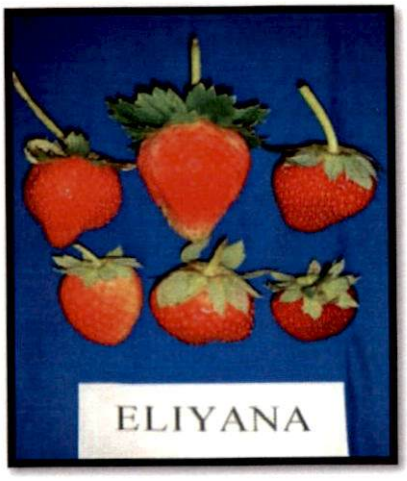


Plate 3. Different stages of flower and fruit development







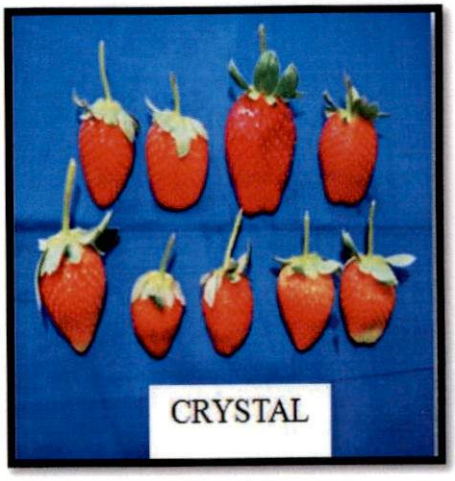
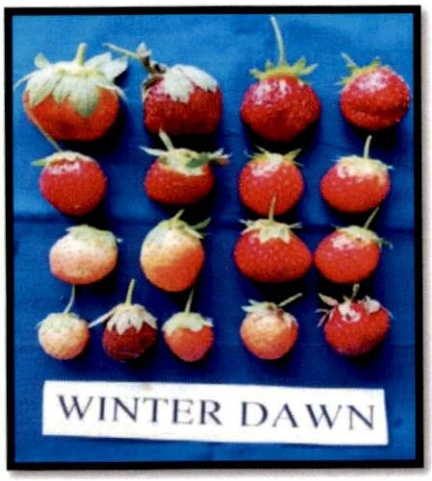
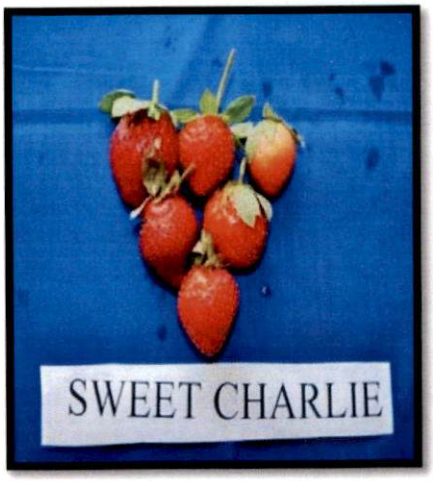
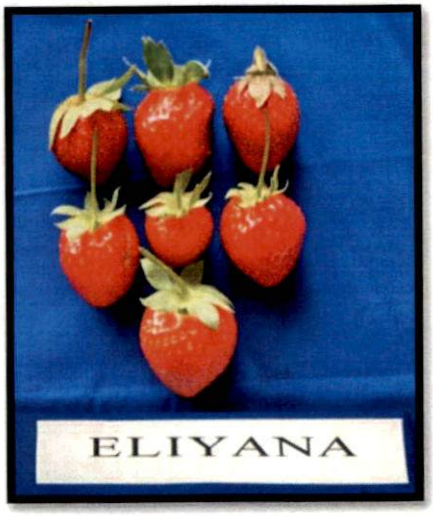


Plate 4. Strawberry fruits harvested from open condition







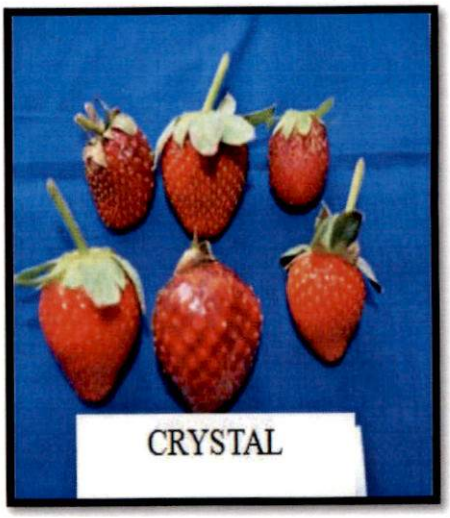
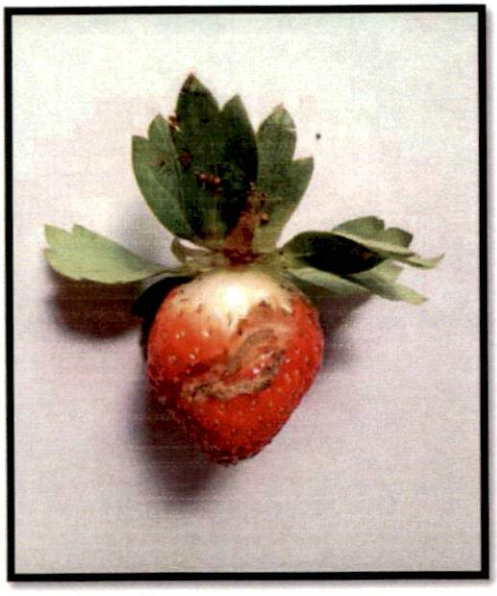


Plate 5. Strawberry fruits harvested from polyhouse condition

Termites

Larvae of armyworm



Fruit borer

Semi looper

Plate 6. Pest infestation in strawberry

Leaf blight

Powdery mildew

Plate 7. Diseases of strawberry

3.3.7. After cultivation

Weeding was done in the furrows as and when required. Raking of the soil was done every month. Irrigation was given especially during active vegetative growth and flowering. Bio control agents like *Pseudomonas fluorescens* (10 g l^{-1}) and *Trichoderma spp.* were applied at bi-weekly intervals.

3.4. Observations

Observations were recorded from individual plots. The observations on various growth parameters were taken from six sample plants selected randomly per plot at monthly intervals.

3.4.1. Observations on vegetative growth attributes

The observations on vegetative growth characters were taken from six sample plants selected randomly from the plot at monthly interval.

3.4.1.1. Height of plant

Height of the plant was measured from the ground level up to the tip of the mature leaf and expressed in centimeter (cm).

3.4.1.2. Plant spread

Spread of the plant in East-West and North-South directions were measured and the average is recorded in centimeter (cm).

3.4.1.3. Number of leaves

Number of leaves produced per plant was recorded by counting fully opened leaves from each sample plants.

3.4.2. Observations on flowering characters

The following flower characters were observed and recorded.

3.4.2.1. Days to first flowering

Number of days required for the emergence of first flower bud after planting was recorded and expressed in days.

3.4.2.2. Number of flowers per plant

Number of flowers produced per plant was counted.

3.4.2.3. Number of clusters per plant

Number of clusters arising from each plant was counted.

3.4.3. Observations on yield characters

The following yield characters were observed and recorded.

3.4.3.1. Number of fruits per plant

The total number of fruits produced per plant was counted and recorded.

3.4.3.2. Average fruit weight

Weight of each fruit was recorded separately and average weight was calculated and expressed in g.

3.4.3.3. Days to first harvest

Number of days required for the first harvest after planting was recorded and expressed in days.

3.4.3.4. Days to final harvest

Number of days taken for the final harvest was recorded and expressed in days.

3.4.3.5. Yield per plant

The yield of fruits from each plant were harvested separately and expressed in g plant^{-1}.

3.4.4. Quality attributes

Total soluble solids (TSS), Acidity, TSS/Acidity ratio and total sugars were analysed as detailed below;

3.4.4.1. Total soluble solids (TSS)

Total soluble solids content in the fruit was measured using a hand refractometer and expressed in ^{0}Brix.

3.4.4.2. Acidity

Acidity was estimated as per the procedure described by Ranganna (1997). A representative sample of 5 g was macerated and digested with boiling water and made up to 100 ml. An aliquot of the filtrate was titrated against 0.1N sodium hydroxide using phenolphthalein as indicator. End point of titration was light pink colour of solution in the beaker. The acidity was expressed in terms of the most predominant acid in the fruit *viz*., citric acid.

3.4.4.3. TSS/acidity ratio

TSS/acidity of the fruit was calculated.

3.4.4.4. Total sugars

Total sugar content in the fruit was estimated as per the procedure described by Ranganna (1997). For determination of total sugars, 2 ml of concentrated HCl was added to 50 ml of clarified solution and was kept overnight. The solution was then neutralized using NaOH and volume made up to 100 ml. The made up solution was titrated against a mixture of Fehling's A and B and total sugar content was expressed as percentage.

3.4.4.5. Sensory evaluation

3.4.4.5.1. Selection of judges

A series of sensory evaluation were carried out using hedonic scale at laboratory level to select a panel of ten judges between the age group of 18-40 years as suggested by Jellinek (1985).

3.4.4.5.2. Preparation of score card

Score card including the quality attributes like appearance, colour, flavour, texture, odour, taste, after taste and overall acceptability was prepared for sensory evaluation of strawberry fruits. Each of the above mentioned qualities were assessed by a 9 point hedonic scale. Overall acceptability was calculated separately using the average of above mentioned quality attributes. The score card used for the evaluation of fruits is given in Appendix 3.

3.4.4.5.3. Organoleptic evaluation

Organoleptic evaluation of fruits was carried out using the score card by a panel of ten selected judges. Hedonic rating scale method measures the level of liking of any product based on a test which relies on the people's ability to communicate their feelings of like or dislike. Hedonic ratings are converted to rank scores and rank analysis was done.

3.4.5. Post harvest studies

The following post harvest studies were done and recorded.

3.4.5.1. Shelf life

The shelf life was calculated as number of days from harvest till the fruits remained marketable. The fruits were rated as not marketable when more than 50 percent of the fruits in a lot showed incidence of spoilage.

3.4.6. Observations on weather parameters

Daily readings of temperature and relative humidity were recorded at 8.00 am and 2.30 pm using thermo hygrometer. Temperature is expressed in ^{0}C while relative humidity is expressed in percentage. Light intensity was recorded at 12.30 pm using luxmeter and expressed in lux. Daily rainfall was recorded and expressed in millimeters (mm).

3.4.7. Pest and diseases

The incidence of pest and diseases were observed and recorded.

3.5. Statistical analysis

The data pertaining to the growth parameters, floral characters and yield parameters were subjected to statistical analysis by applying the technique of analysis of variance (ANOVA) for Randomized Block Design (Panse and sukhatme, 1985).

Results

4. RESULTS

The results of the study pertaining to performance of strawberry varieties (*Frageria x ananassa* Duch.) under two systems of growing are presented under six captions

1. Vegetative growth attributes
2. Flowering attributes
3. Yield attributes
4. Quality attributes
5. Post harvest study
6. Pest and disease incidence

4.1 Vegetative growth attributes

Observations on growth attributes *viz.,* plant height, number of leaves and plant spread of strawberry varieties under two growing systems *viz.,* open (S_1) and polyhouse (S_2) were recorded, analyzed and the results are presented below:

4.1.1 Plant height

The data depicting the plant height of strawberry varietes under two growing systems *viz.,* open condition (S_1) and polyhouse (S_2) are presented in Table 3.

Growing system I (Open condition)

At 1 MAP, Eliyana recorded the highest plant height of 16.17 cm which was on par with Winter Dawn (15.91 cm) and Sweet Charlie (14.31 cm). Minimum plant height of 11.21 cm was recorded in Sabrina. At 2 MAP, Winter Dawn (18.12 cm) and Eliyana (17.41 cm) were on par and significantly superior to all other varieties, which was followed by Sweet Charlie (15.24 cm), Crystal (14.98 cm) and Sabrina (13.32 cm). At 3 MAP, Winter Dawn recorded the maximum plant height of 22.41 cm which was on par with Eliyana (19.32 cm) which was followed by Sweet Charlie (17.31

75

cm), Crystal (16.21 cm) and Sabrina (15.54 cm). At 4 MAP, Winter Dawn recorded significantly higher plant height of 26.87 cm which was followed by Sweet Charlie (21.56 cm), Eliyana (20.87 cm), Crystal (20.13 cm) and Sabrina (20.12 cm). At 5 MAP, Winter Dawn recorded significantly higher plant height of 30.62 cm which was followed by Sweet Charlie (26.14 cm), Crystal (25.78 cm), Sabrina (24.87 cm) and Eliyana (21.30 cm).

Growing system II (Polyhouse)

At 1 MAP, Eliyana recorded the highest plant height of 14.18 cm which was on par with Winter Dawn (13.91 cm) and Sweet Charlie (12.32 cm). Minimum plant height of 9.41 cm was recorded in Sabrina. At 2 MAP, Eliyana recorded the highest plant height of 16.31 cm which was on par with Winter Dawn (16.12) and Sweet Charlie (15.91). Minimum plant height of 11.32 cm was recorded in Sabrina. At 3 MAP, Winter Dawn recorded the highest plant height (23.45 cm) which was on par with Sabrina (19.52 cm) and Eliyana (19.31 cm). Minimum plant height of 17.32 cm was recorded in Crystal. At 4 MAP, significantly higher plant height of 27.31 cm was recorded in Winter Dawn which was followed by Sweet Charlie (23.21cm), Sabrina (22.34 cm), Crystal (22.31 cm) and Eliyana (21.45 cm). At 5 MAP, Winter Dawn registered significantly higher plant height of 32.31 cm which was followed by Sweet Charlie (27.25 cm), Crystal (26.21 cm), Sabrina (25.10 cm) and Eliyana (22.57 cm).

4.1.2 Number of leaves per plant

The data depicting the number of leaves per plant of strawberry varieties under two growing systems *viz.*, open condition (S_1) and polyhouse (S_2) are presented in Table 3.

Growing system I (Open condition)

At 1 MAP, the maximum number of leaves was noted in Winter Dawn (6.42) which was on par with Eliyana (6.14) and Sweet Charlie (5.34). Minimum number of leaves was recorded in Crystal (4.10). At 2 MAP, Winter Dawn recorded the maximum number of leaves of 11.10 which was on par with Eliyana (10.40). Minimum number of leaves was recorded in Sabrina (7.12). No significant difference in production of leaves per plant was recorded at 3 MAP. At 4 MAP, significantly higher number of leaves per plant was recorded in Winter Dawn (20.31 cm) which was followed by Crystal (18.30 cm), Sweet Charlie (18.21 cm), Eliyana (17.62 cm) and Sabrina (15.61 cm). At 5 MAP, significantly higher number of leaves per plant was recorded in Winter Dawn (26.20) which was followed by Eliyana (24.40 cm) which was on par with Sweet Charlie (23.24 cm). Minimum number of leaves per plant was recorded in Sabrina (19.12 cm).

Growing system II (Polyhouse)

At 1 MAP, Winter Dawn recorded the maximum number of leaves of 10.10 which was on par with Eliyana (9.21) which was followed by Crystal (7.21), Sweet Charlie (7.21) and Sabrina (6.21). No significant difference in production of leaves per plant was recorded at 2 MAP and 3 MAP. However, at 4 MAP, significantly higher number of leaves per plant was reported in Winter Dawn (21.21) which was followed by Sweet Charlie (19.24), Crystal (19.01), Eliyana (18.51) and Sabrina (16.16). At 5 MAP, Winter Dawn recorded maximum number of leaves per plant of 23.10 which was on par with Eliyana (22.48) and Crystal (22.35). The minimum number of leaves per plant was recorded in Sabrina (16.42).

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4.1.3 Plant spread

The data depicting the plant spread of strawberry varietes under two growing systems *viz.*, open condition (S_1) and polyhouse (S_2) are presented are presented in Table 3.

Growing system I (Open condition)

At 1 MAP, Winter Dawn recorded the maximum plant spread of 15.11 cm which was on par with Sweet Charlie (14.80 cm), Crystal (13.77 cm) and Eliyana (13.21 cm). Lowest plant spread of 10.13 cm recorded in Sabrina. At 2 MAP, the Winter Dawn recorded maximum plant spread of 18.21 cm which was on par with Crystal (17.12 cm), Sweet Charlie (16.70 cm) and Eliyana (15.26 cm). Sabrina recorded the minimum plant spread of 14.33 cm. At 3 MAP, the Winter Dawn recorded maximum plant spread of 23.49 cm which was on par with Crystal (21.42 cm), Sweet Charlie (21.31 cm) and Eliyana (18.34 cm). Minimum plant spread was observed in Sabrina (16.26 cm). At 4 MAP, Winter Dawn recorded maximum plant spread of 28.12 cm followed by Crystal (26.12 cm), Sweet Charlie (25.41 cm), Eliyana (21.52 cm) and Sabrina (19.52 cm). At 5 MAP, Winter Dawn recorded maximum plant spread of 30.11 cm which was on par with Sweet Charlie (29.60 cm) and Crystal (28.94 cm). Minimum plant spread of 24.33 cm was recorded in Sabrina.

Growing system II (Polyhouse)

At 1 MAP, Winter Dawn recorded the maximum plant spread of 16.21 cm which was on par with Sweet Charlie (15.80 cm) and Crystal (14.77 cm). However, Sabrina recorded the minimum plant spread of 12.33 cm. At 2 MAP, Winter Dawn recorded the maximum plant spread of 19.41 cm which was on par with Crystal (18.21 cm), Sweet Charlie (17.60 cm) and Eliyana (16.64 cm). Sabrina recorded the minimum plant spread of 15.33 cm. At 3 MAP, Winter Dawn recorded the maximum plant spread of 24.94 cm which was on par with Crystal (22.24 cm), Sweet Charlie

Table 3. Vegetative characters of different varieties of strawberry under open and polyhouse conditions

Varieties	Plant height (cm)									
	S_1					S_2				
	Months after planting (MAP)					Months after planting (MAP)				
	1	2	3	4	5	1	2	3	4	5
Crystal	13.34	14.98	16.21	20.13	25.78	11.24	14.21	17.32	22.31	26.21
Winter Dawn	15.91	18.12	22.41	26.87	30.62	13.91	16.12	23.45	27.31	32.31
Sweet Charlie	14.31	15.24	17.31	21.56	26.14	12.32	15.91	18.64	23.21	27.25
Sabrina	11.21	13.32	15.54	20.12	24.87	9.41	11.32	19.52	22.34	25.10
Eliyana	16.17	17.41	19.32	20.87	21.30	14.18	16.31	19.31	21.45	22.57
CD (0.05)	2.22	2.21	4.26	1.05	1.21	2.12	2.03	4.63	1.32	2.24

Varieties	Number of leaves									
	S_1					S_2				
	Months after planting (MAP)					Months after planting (MAP)				
	1	2	3	4	5	1	2	3	4	5
Crystal	4.10	8.23	12.81	18.3	22.21	7.21	8.52	14.41	19.01	22.35
Winter Dawn	6.42	11.10	15.52	20.31	26.20	10.10	9.12	16.21	21.21	23.10
Sweet Charlie	5.34	8.23	13.21	18.21	23.24	7.21	9.1	14.21	19.24	21.24
Sabrina	4.23	7.12	12.01	15.61	19.12	6.21	6.22	11.64	16.16	16.42
Eliyana	6.14	10.40	14.96	17.62	24.40	9.21	9.0	15.63	18.51	22.48
CD (0.05)	1.51	2.55	5.23	1.54	1.64	1.62	2.67	5.26	1.94	1.81

Varieties	Plant spread (cm)									
	S_1					S_2				
	Months after planting (MAP)					Months after planting (MAP)				
	1	2	3	4	5	1	2	3	4	5
Crystal	13.77	17.12	21.42	26.12	28.94	14.77	18.21	22.24	27.14	29.21
Winter Dawn	15.11	18.21	23.49	28.12	30.11	16.21	19.41	24.94	28.65	31.41
Sweet Charlie	14.80	16.70	21.31	25.41	29.60	15.80	17.60	22.13	26.41	30.60
Sabrina	10.13	14.33	16.26	19.52	24.33	12.33	15.33	17.21	20.14	26.13
Eliyana	13.21	15.26	18.34	21.52	27.23	14.01	16.64	19.34	22.61	28.12
CD (0.05)	2.26	3.64	5.21	1.62	1.86	2.13	3.56	5.84	1.45	1.93

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(22.13 cm) and Eliyana (19.34 cm). The minimum plant spread was registered in Sabrina (17.21 cm). At 4 MAP, Winter Dawn registered significantly higher plant spread of 28.65 cm which was followed by Crystal (27.14 cm), Sweet Charlie (26.41 cm), Eliyana (22.61 cm) and Sabrina (20.14 cm). At 5 MAP, Winter Dawn recorded the maximum plant spread of 31.41 cm which was on par with Sweet Charlie (30.60 cm). However, no significant difference in plant spread was observed between Sweet Charlie and Crystal (29.31 cm). Minimum plant spread was observed in Sabrina (26.13 cm).

4.2 Flowering attributes

Observations on flowering attributes *viz.*, days to first flowering, number of flowers per plant and number of clusters per plant of strawberry varieties under two growing systems *viz.*, open condition (S_1) and polyhouse (S_2) were recorded, analyzed and the results are presented below:

4.2.1 Days to first flowering

The data depicting the days to first flowering of strawberry varieties under two growing systems *viz.*, open condition (S_1) and polyhouse (S_2) are presented in Table 4.

Growing system I (Open condition)

Minimum days to first flowering was recorded in Crystal (45.21 days) which was on par with Winter Dawn (46.25 days) and Sweet Charlie (48.32 days). Maximum days taken for first flowering was observed in Sabrina (51.23 days) which was on par with Eliyana (50.25 days).

Growing system II (Polyhouse)

Minimum days to first flowering was recorded in Crystal (46.22 days) which was on par with Winter Dawn (47.21 days), Sweet Charlie (48.68 days) and Eliyana (50.65 days). Sabrina recorded maximum days (52.32) for first flowering.

4.2.2 Number of flowers per plant

The data depicting the number of flowers per plant of strawberry varieties under two growing systems *viz.*, open condition (S_1) and polyhouse (S_2) are presented are presented in Table 4.

Growing system I (Open condition)

Winter Dawn recorded maximum number of flowers per plant (20.11) which was on par with Sweet Charlie (18.70). However, no significant difference was observed in number of flowers per plant between Sweet Charlie (18.70) and Eliyana (17.01). Minimum number of flowers per plant was recorded in Sabrina (11.23).

Growing system II (Polyhouse)

Winter Dawn registered the highest number of flowers per plant (16.24) which was on par with Sweet Charlie (15.00), Eliyana (14.31) and Crystal (14.00). Minimum number of flowers per plant (10.33) was recorded in Sabrina.

4.2.3 Number of clusters per plant

Analysis of the data corresponding to the number of clusters per plant of strawberry varieties under two growing systems *viz.*, open condition (S_1) and polyhouse (S_2) are presented in Table 4.

Table 4. Flowering characters of strawberry cultivars under open and polyhouse conditions

Cultivars	Days to first flowering		Number of flowers per plant		Number of clusters per plant	
	S_1	S_2	S_1	S_2	S_1	S_2
Cristal	45.21	46.22	15.35	14.00	7.35	5.00
Winter Dawn	46.25	47.21	20.11	16.24	10.13	8.34
Sweet Charlie	48.32	48.68	18.70	15.00	9.10	7.00
Sabrina	51.23	52.32	11.23	10.33	5.23	4.31
Eliyana	50.25	50.65	17.01	14.31	8.06	6.31
CD (0.05)	4.21	5.26	2.56	2.65	1.05	1.32

Growing system I (Open condition)

Winter Dawn recorded higher number of clusters per plant (10.13) which was on par with Sweet Charlie (9.10). No significant difference was observed in number of clusters per plant in Eliyana (8.06) and Crystal (7.35). Lowest number of clusters per plant was recorded in Sabrina (5.23).

Growing system II (Polyhouse)

Winter Dawn registered significantly higher number of clusters per plant (8.34) followed by Sweet Charlie (7.00) which was on par with Eliyana (6.31). Lowest number of clusters per plant was recorded in Sabrina (4.31) which was on par with Crystal (5.0).

4.3. Yield attributes

Various observations on yield attributes *viz.*, number of fruits per plant, average fruit weight, days to first harvest, days to final harvest and yield per plant of strawberry varieties under two growing systems *viz.*, open condition (S_1) and greenhouse (S_2) were recorded, analyzed and the results are presented below:

4.3.1 Number of fruits per plant

The data depicting the number of fruits per plant of strawberry under two systems *viz.*, open condition (S_1) and polyhouse (S_2) are presented in Table 5.

Growing system I (Open condition)

Winter Dawn recorded significantly higher number of fruits per plant (12.04) which was on par with Sweet Charlie (11.53). No significant difference in number of fruit per plant was noticed among Sweet Charlie and Eliyana (9.14). The lowest number of fruits per plant was recorded in Sabrina (5.57).

Growing system II (Polyhouse)

Winter Dawn recorded the highest number of fruits per plant (9.42) which was on par with Sweet Charlie (8.17). No significant difference in number of fruits per plant was observed among Sweet Charlie (8.17) and Eliyana (6.17). The lowest number of fruits per plant was recorded in Sabrina (4.84) which was on par with Crystal (5.15) and Eliyana (6.17).

4.3.2 Average fruit weight

The data depicting the average fruit weight of strawberry under two growing systems *viz.*, open condition (S_1) and polyhouse (S_2) are presented in Table 5.

Growing system I (Open condition)

Crystal recorded significantly higher average fruit weight (11.21 g) which was on par with Sabrina (10.96 g) followed by Eliyana (9.51 g) which was on par with Winter Dawn (8.42 g). Lowest average fruit weight was recorded in Sweet Charlie (7.65 g).

Growing system II (Polyhouse)

Crystal recorded significantly higher average fruit weight of 11.01 g which was on par with Sabrina (10.52 g). However, no significant difference in average fruit weight was observed among Sabrina (10.52 g) and Eliyana (9.31 g). Lowest average fruit weight was recorded in Sweet Charlie (7.12 g) which was on par with Winter Dawn (8.11 g).

4.3.3 Days to first harvest

Data that depict the number of days to first harvest under two growing systems *viz.*, open condition (S_1) and polyhouse (S_2) are presented in Table 5.

Growing system I (Open condition)

Winter Dawn recorded the minimum days to first harvest (63.40 days) which was on par with Crystal (68.48 days) and this was followed by Sweet Charlie (69.52 days). Maximum days to first harvest was observed in Eliyana (80.39 days) which was on par with Sabrina (79.25 days).

Growing system II (Polyhouse)

Winter Dawn recorded the minimum days to first harvest (65.30 days) which was on par with Crystal (70.28 days) and Sweet Charlie (71.41 days). Maximum days to first harvest was observed in Eliyana (82.24 days) which was on par with Sabrina (81.45 days).

4.3.4. Days to final harvest

Data that depict the number of days to final harvest under two growing systems *viz.*, open condition (S_1) and polyhouse (S_2) are presented in Table 5.

Growing system I (Open condition)

Winter Dawn recorded the maximum days to final harvest (165.41 days), which was on par with Sweet Charlie (160.38 days) and Crystal (159.42 days). Minimum days to final harvest were recorded in Sabrina (154.21 days) which was on par with Eliyana (155 days).

Growing system II (Polyhouse)

Winter Dawn recorded the maximum days to final harvest (171.24 days) which was on par with Sweet Charlie (165.34 days). However, no significant difference in days to final harvest was recorded among Sweet Charlie (165.41 days) and Crystal (162.42 days). Minimum days to final harvest were recorded in Sabrina (153.65 days) which was on par with Eliyana (154.21 days).

4.3.5. Yield per plant

Data that depict the yield per plant under two growing systems *viz.,* open condition (S_1) and polyhouse (S_2) are presented in Table 5.

Growing system I (Open condition)

Winter Dawn recorded the highest yield per plant (139.51 g) which was on par with Sweet Charlie (127.43 g). However, no significant difference in yield per plant was recorded among Sweet Charlie (127.43 g) and Crystal (116.12 g). Lowest yield per plant was recorded in Sabrina (103.17 g) which was on par with Eliyana (109.16 g).

Growing system II (Polyhouse)

Winter Dawn recorded the highest yield per plant (123.36 g) which was on par with Sweet Charlie (120.25g). However, no significant difference in yield per plant was observed among Sweet Charlie (120.25 g) and Crystal (109.34 g). Lowest yield per plant was recorded in Sabrina (94.14 g) which was on par with Eliyana (104.27 g).

Significant difference was observed among cultivars with respect to the yield per plant under different growing systems. Regardless of cultivars, the plants grown under open condition had maximum yield per plant which was significantly different from the yield recorded under polyhouse condition (Table. 6)

4.4 Quality attributes

Various observations on quality characters *viz.,* total soluble salts (TSS), acidity, TSS/acidity ratio, total sugars and shelf life of strawberry varieties under two growing systems *viz.,* open condition (S_1) and polyhouse (S_2) were recorded, analyzed and the results are presented below:

Table 5. Yield and fruiting characters of strawberry cultivars under open and polyhouse conditions

Cultivars	Number of fruits per plant		Average fruit weight (g)		Days to first harvest		Days to final harvest		Yield per plant (g)	
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
Crystal	9.04	5.15	11.21	11.01	68.48	70.28	159.42	162.42	116.12	109.34
Winter Dawn	12.00	9.42	8.42	8.11	63.40	65.30	165.41	171.24	139.51	123.36
Sweet Charlie	11.50	8.17	7.65	7.12	69.52	71.41	160.38	165.34	127.43	120.25
Sabrina	5.57	4.84	10.96	10.52	79.25	81.45	154.15	153.65	103.17	94.14
Eliyana	9.14	6.17	9.51	9.31	80.39	82.24	155.00	154.21	109.16	104.27
CD (0.05)	2.45	2.32	1.32	1.25	5.21	6.24	6.32	6.21	14.65	11.43

Table 6. Effect of growing systems on yield per plant in strawberry varieties

Cultivars	Yield per plant (g)	
	S_1	S_2
Crystal	116.1	109.3
Winter Dawn	139.5	123.3
Sweet Charlie	127.4	120.2
Sabrina	103.1	94.1
Eliyana	109.1	104.2
CV	0.57	
CD (0.05) (Growing systems)	0.45	
CD (0.05) (Interaction of growing systems and cultivars)	1.01	

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4.4.1 Total Soluble Solids (TSS)

Data that depict the TSS of strawberry under two growing systems *viz.*, open condition (S_1) and polyhouse (S_2) are presented in Table 7.

Growing system I (Open condition)

Sweet Charlie recorded the highest TSS value of 10.21 ^{0}Brix which was on par with Winter Dawn (9.70 ^{0}B) and Crystal (8.43 ^{0}B). Lowest TSS of 6.21 ^{0}B was recorded in Eliyana which was on par with Sabrina (7.95 ^{0}B).

Growing system II (Polyhouse)

Sweet Charlie recorded the highest TSS value of 11.54 ^{0}Brix which is on par with Winter Dawn (10.70 ^{0}B). However, no significant difference in TSS was recorded among Winter Dawn (10.70 ^{0}B) and Sabrina (8.60 ^{0}B). Lowest TSS of 6.84 ^{0}B was recorded in Eliyana which was on par with Crystal (8.54 ^{0}B).

4.4.2 Acidity

Data that depict the acidity of strawberry under two growing systems *viz.*, open condition (S_1) and polyhouse (S_2) are presented in Table 7.

Growing system I (Open condition)

Sweet Charlie recorded the minimum acidity content (0.71 %) which was on par with Winter Dawn (0.83 %) followed by Crystal (0.94 %) and Maximum acidity was recorded in Eliyana (1.3 %) which was on par with Sabrina (0.97 %).

Growing system II (Polyhouse)

Sweet Charlie recorded the minimum acidity content (0.65 %) which was on par with Winter Dawn (0.74 %) followed by Crystal (0.8 %) and Maximum acidity was recorded in Eliyana (1.28 %) which was on par with Sabrina (0.82 %).

4.4.3 TSS/acidity

Data that depict the TSS/Acidity of strawberry varieties under two growing systems *viz.*, open condition (S_1) and polyhouse (S_2) are presented in Table 7.

Growing system I (Open condition)

It is clear from the data that Sweet Charlie recorded highest TSS/acidity ratio of 10.2 which was on par with Winter Dawn (7.4). However, no significant difference in TSS/acidity ratio was recorded among Winter Dawn (7.4) and Sabrina (7.2). Lowest TSS/acidity was observed in Eliyana (6.1) which was on par with Crystal (6.7).

Growing system II (Polyhouse)

Sweet Charlie recorded highest TSS/acidity ratio of 11.3 which was on par with Winter Dawn (8.9). However, no significant difference in TSS/acidity ratio was recorded among Winter Dawn (8.9) and Sabrina (8.1). Lowest TSS/acidity was observed in Eliyana (6.8) which was on par with Crystal (7.2).

4.4.4 Total sugars

Data that depict the total sugars in strawberry fruits under two growing systems *viz.*, open condition (S_1) and polyhouse (S_2) are presented in Table 7.

Growing system I (Open condition)

No significant difference in total sugars was recorded under open condition.

Table 7. Biochemical characters and shelf life of strawberry cultivars under open and polyhouse conditions

Cultivars	TSS (^{0}Brix)		Acidity		TSS/acidity ratio		Total sugars (%)		Shelf life (days)	
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
Crystal	8.43	8.54	0.94	0.80	6.7	7.2	5.52	6.36	3	3
Winter Dawn	9.70	10.70	0.83	0.74	7.4	8.9	5.20	5.65	3	3
Sweet Charlie	10.21	11.54	0.71	0.65	10.2	11.3	5.81	6.70	3	3
Sabrina	7.95	8.60	0.97	0.82	7.2	8.1	5.31	5.84	3	3
Eliyana	6.21	6.84	1.30	1.28	6.1	6.8	5.11	5.41	3	3
CD (0.05)	2.15	2.32	0.14	0.05	3.21	2.72	0.95	0.65	NS	NS

Growing system II (Polyhouse)

Sweet Charlie registered the highest total sugar content of 6.70 per cent which was on par with Crystal (6.36 %). However, no significant difference difference in total sugars was recorded among Crystal (6.36 %) and Sabrina (5.84 %). Lowest total sugar content was recorded in Eliyana (5.41 %) which was on par with Winter Dawn (5.65 %).

4.5 Post harvest study

4.5.1 Shelf life in days

Shelf life was influenced by the different treatments. It is evident from Table 7 that strawberry had a maximum shelf life of 3 days when stored in ambient temperature after harvest at 75 per cent ripened stage.

4.5.2 Sensory evaluation

In strawberry, colour, taste, flavor and texture contribute to the fruit quality. Hence for quality assessment, sensory evaluation was carried out on a nine point hedonic scale using score card for eight attributes namely appearance, colour, texture, flavor, odour, taste, after taste and overall acceptability. Each character was scored on the scale and the total scores calculated out of seventy. Sensory evaluation was conducted on the same day of harvest (Table 8).

Among the five varieties grown under open and polyhouse conditions, Winter Dawn under open condition (T_2) recorded maximum score for appearance and flavour and Sweet Charlie under polyhouse condition (T_8) recorded maximum score for colour, texture, odour, taste, after taste and overall acceptability.

Table 8. Sensory evaluation of strawberry fruits

Treatments	Appearence (10)	Colour (10)	Flavour (10)	Texture (10)	Odour (10)	Taste (10)	After taste (10)	Total score (70)	Acceptability (10)
T_1	8.63	8.13	8.30	8.13	8.20	8.20	8.20	57.79	8.30
T_2	8.73	8.30	8.43	8.33	8.37	8.21	7.3	58.9	8.41
T_3	8.70	8.17	8.20	8.27	8.21	9.21	8.4	59.6	8.56
T_4	8.57	8.37	8.20	8.37	8.45	6.21	8.4	52.9	8.10
T_5	8.31	8.14	8.17	8.17	7.14	8.12	6.6	56.7	8.23
T_6	7.34	8.11	8.13	8.13	8.45	7.21	7.6	51.9	8.13
T_7	8.10	8.10	8.11	8.26	8.32	7.23	8.4	52.2	8.17
T_8	8.47	9.07	8.07	9.12	8.65	9.25	8.9	61.6	9.12
T_9	7.07	6.57	6.57	7.21	6.12	8.45	8.1	48.1	7.14
T_{10}	7.00	6.90	6.90	6.31	6.12	8.63	8.4	37.4	7.16

4.5 Pest and disease incidence

During the entire period of study, there was no severe incidence of pests and diseases. In open condition, pests such as semi looper, larvae of army worm and fruit borer were noticed irrespective of varieties. Leaf blight disease was noticed in Sweet Charlie and Alternaria leaf spot was noticed in Crystal and Eliyana. In polyhouse condition, Termites were noticed irrespective of varieties. Powdery mildew was noticed in variety Sabrina.

Discussion

5. DISCUSSION

The Department of Agriculture, Government of Kerala has drawn up a pilot project to cultivate strawberry in 250 acres in Western Ghat region of Kerala especially in Wayanad and Idukki districts. Evaluation of different strawberry cultivars, for a specific region is of paramount importance for their successful cultivation. Several cultivars are available in strawberry but the photo/thermo sensitive nature of this crop warrants the testing of their cultivars/varieties for its adaptability in new areas before recommending for commercial cultivation. In this context, the present study was taken up to identify suitable varieties of strawberry for commercial cultivation in the agroclimatic condition of Wayanad.

The experiment was carried out during the year 2016 - 17 at Regional Agricultural Research Station, Ambalavayal, Wayanad under two growing systems *viz*., open condition and polyhouse, to assess the performance of different strawberry varieties for vegetative growth attributes, flower attributes, yield attributes, quality attributes, shelf life and pest and disease incidence.The results obtained on these aspects are discussed here below in this chapter.

5.1 Vegetative growth attributes

5.1.1 Plant height

In open condition, Winter Dawn recorded significantly higher plant height in all stages of growth except in 1 MAP. The maximum plant height of 30.62 cm was recorded in Winter Dawn, which was followed by Sweet Charlie (26.14 cm) at 5 MAP.

In polyhouse condition, Winter Dawn recorded significantly higher plant height in all stages of growth except, 1 MAP and 2 MAP. The maximum plant height of 32.31 cm was recorded in Winter Dawn, which was followed by Sweet Charlie (27.25 cm) at 5 MAP (Table 3 and Fig. 1a, 1b).

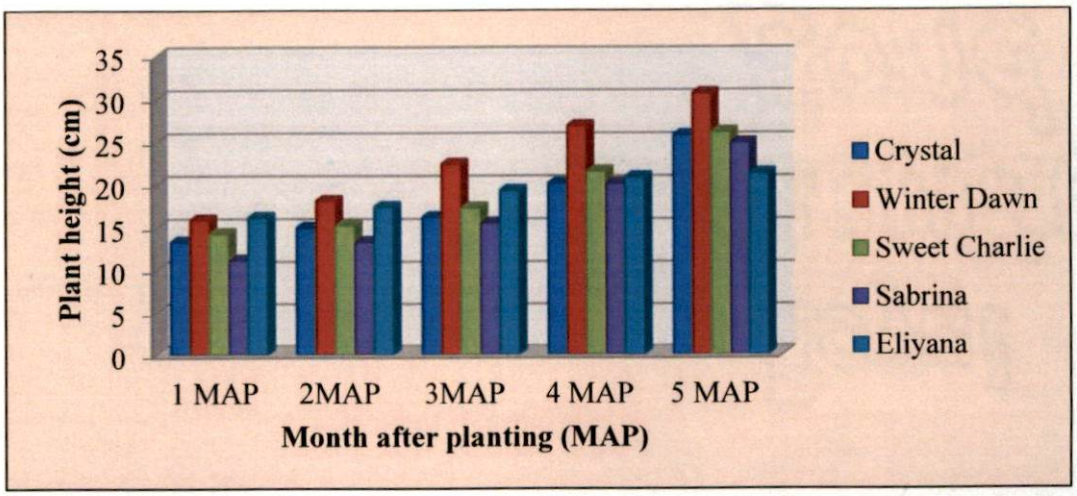

Fig 3a. Performance of strawberry varieties for plant height under open condition

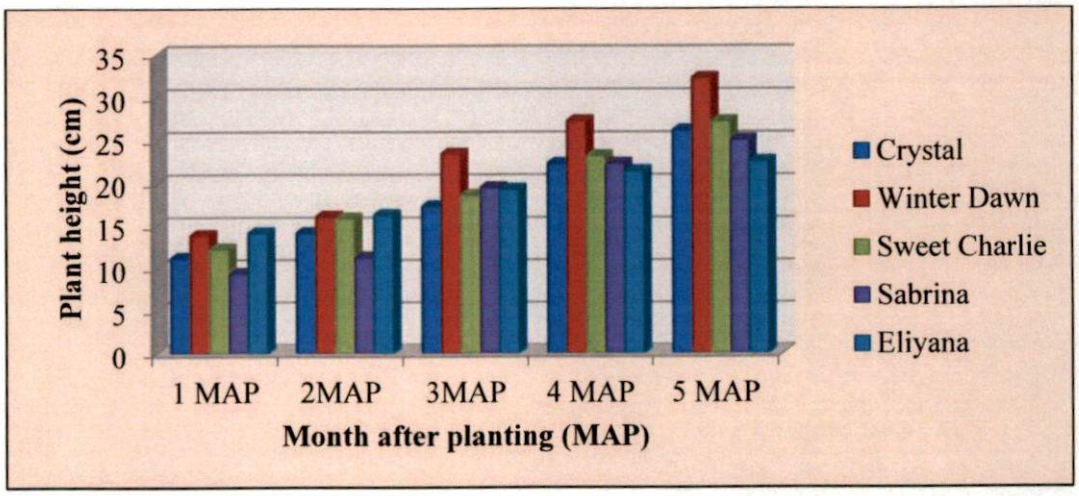

Fig 3b. Performance of strawberry varieties for plant height under polyhouse condition

The increase in plant height might be due to increased length and erect growth of leaf which is upright resulting in higher plant height controlled by genetic factor of the genotypes which differs from one another (Rao and Lal., 2010 and Hossan *et al.,* 2013).

5.1.2 Number of leaves per plant

In open condition, at 4 MAP and 5 MAP Winter Dawn recorded significantly higher number of leaves (20.31) and (26.20) respectively, which was followed by Eliyana (24.40), Crystal (23.24) and Sweet Charlie (23.24).

In polyhouse condition, Winter Dawn recorded maximum number of leaves of 23.10 which was on par with Sweet Charlie (22.48) and Crystal (22.35) at 5 MAP (Table 3 and Fig. 2a, 2b).

The increase in number of leaves may be attributed to the corresponding increase in length of epidermal and parenchyma cells, higher rate of cell division and cell elongation in sub apical meristem of strawberry shoots which might lead to production of higher number of leaves (Rao and Lal., 2010 and Hossan *et al.,* 2013).

5.1.3 Plant spread

In open condition, during later stages of growth, at 5 MAP, Winter Dawn recorded the maximum plant spread of 30.11 cm which was on par with Sweet Charlie (29.60 cm) and Crystal (28.94 cm).

In polyhouse condition, Winter Dawn recorded the maximum plant spread of 31.41 cm which was on par with Sweet Charlie (30.60 cm) at 5 MAP (Table 3 and Fig. 3a, 3b).

The favourable environmental conditions inside the polyhouse would have influenced the vegetative growth which ultimately resulted in more plant spread in Winter Dawn and Sweet Charlie. An enhanced vegetative growth under increased relative humidity was also reported in strawberry by Lieten (2002).

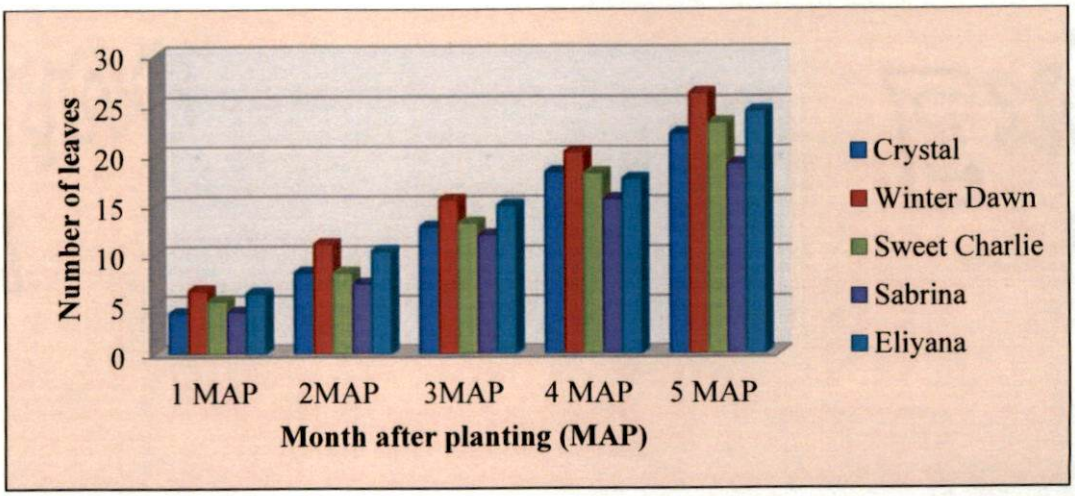

Fig 4 a. Performance of strawberry varieties for number of leaves under open condition

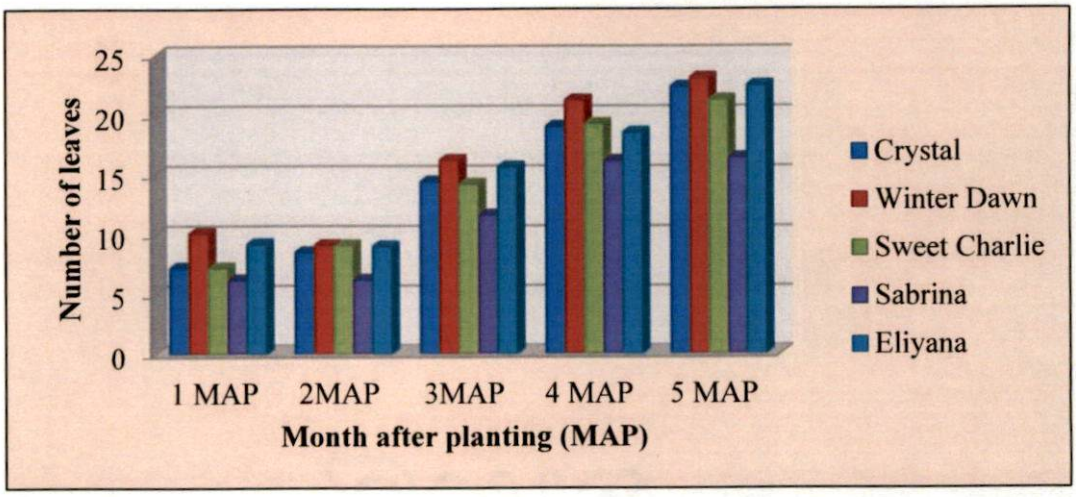

Fig 4b. Performance of strawberry varieties for number of leaves under polyhouse condition

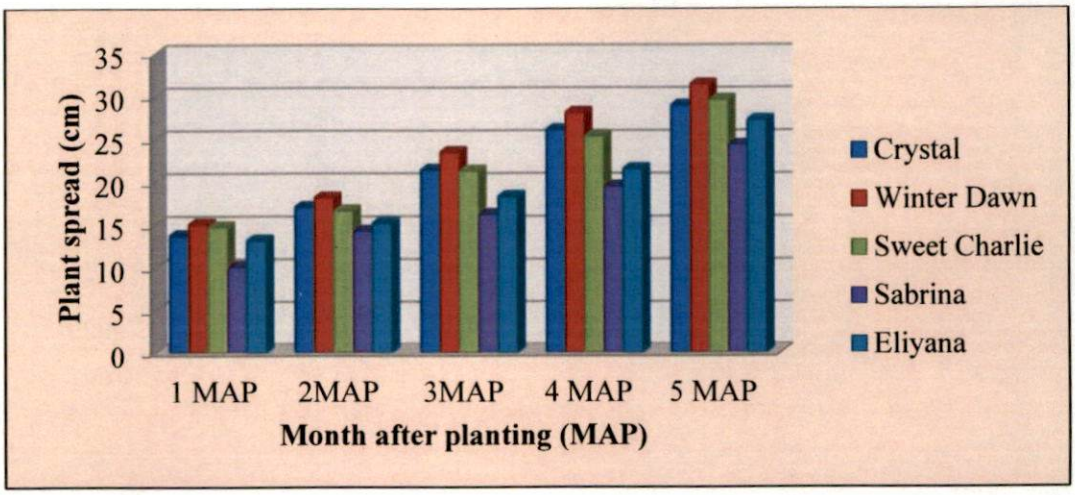

Fig 5a. Performance of strawberry varieties for plant spread under open condition

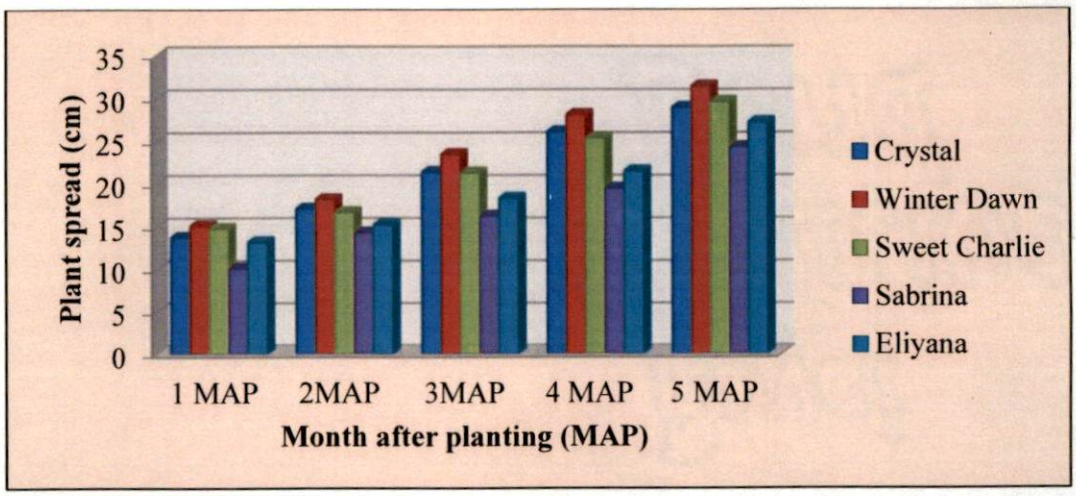

Fig 5b. Performance of strawberry varieties for plant spread under polyhouse condition

5.2 Flowering attributes

5.2.1 Days to first flowering

In open condition, minimum days to first flowering were recorded in Crystal (45.21 days) which was on par with Winter Dawn (46.25 days) and Sweet Charlie (48.32 days).

In polyhouse condition, minimum days to first flowering were recorded in Crystal (46.22 days) which was on par with Winter Dawn (47.21 days), Sweet Charlie (48.68 days) and Eliyana (50.65 days) (Table 4 and Fig. 4).

Favourable temperature and high relative humidity prevailing in agroclimatic conditions of Wayanad would have influence on variations in days to flowering in different varieties. The variations in days to flowering may also be influenced by genetic makeup of the genotypes (Ahsan *et al.*, 2014 and Ankita and Chandel., 2014).

5.2.2 Number of flowers per plant

In open condition, Winter Dawn recorded maximum number of flowers per plant (20.11) which was on par with Sweet Charlie (18.70).

In polyhouse condition, Winter Dawn registered the highest number of flowers per plant (16.24) which was on par with Sweet Charlie (15.00), Eliyana (14.31) and Crystal (14.00) (Table 4 and Fig. 5).

Higher number of leaves and maximum plant spread observed in Winter Dawn and Sweet Charlie might have influenced the production of maximum number of flowers per plant. Number of flowers per plant depended on the length of inflorescence and number of flowers per inflorescence (Uddin *et al.*, 2016).

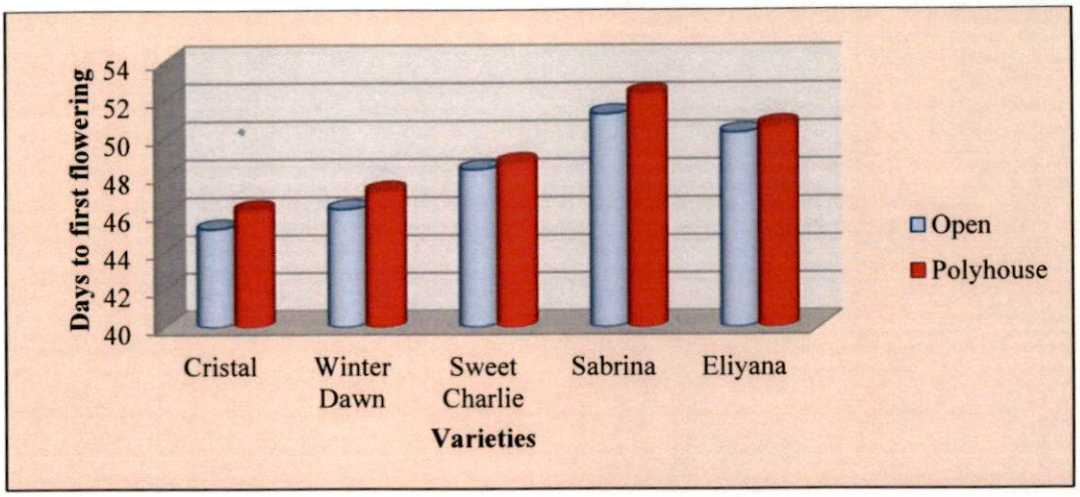

Fig 6. Performance of strawberry varieties for days to first flowering under open and polyhouse conditions

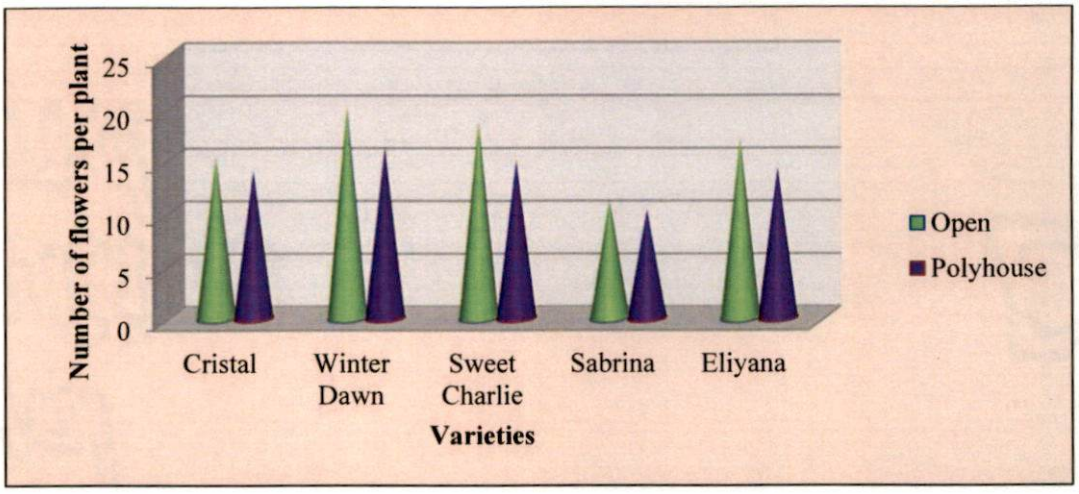

Fig 7. Performance of strawberry varieties for number of flowers under open and polyhouse conditions

5.2.3 Number of clusters per plant

In open condition, Winter Dawn recorded higher number of clusters per plant (10.13) which was on par with Sweet Charlie (9.10).

In polyhouse condition, Winter Dawn registered higher number of clusters per plant (8.34) followed by Sweet Charlie (7.00) which was on par with Eliyana (6.31) (Table 4 and Fig. 6).

It is observed that under open and polyhouse conditions, maximum number of flowers per plant was recorded in Winter Dawn. This might have be resulted in the production of more number of clusters per plant in Winter Dawn under both conditions (Uddin *et al.*, 2016).

5.3 Yield attributes

5.3.1 Number of fruits per plant

In open condition, Winter Dawn recorded significantly higher number of fruits per plant (12.04) which was on par with Sweet Charlie (11.53).

The same trend was observed in the polyhouse condition also, Winter Dawn recorded the higher number of fruits per plant (9.42) which was on par with Sweet Charlie (8.17) (Table 5 and Fig. 7).

Earlier results indicated that vegetative parameters, number of flowers per plant and number of clusters per plant were maximum in Winter Dawn which was on par with Sweet Charlie. This might be the reason for more number of fruits per plant in Winter Dawn and Sweet Charlie.

5.3.2 Yield per plant

The yield per plant was significantly influenced by the growing systems. In open condition, highest yield per plant was recorded in Winter Dawn (139.5 g) which was on par with Sweet Charlie (127.4 g).

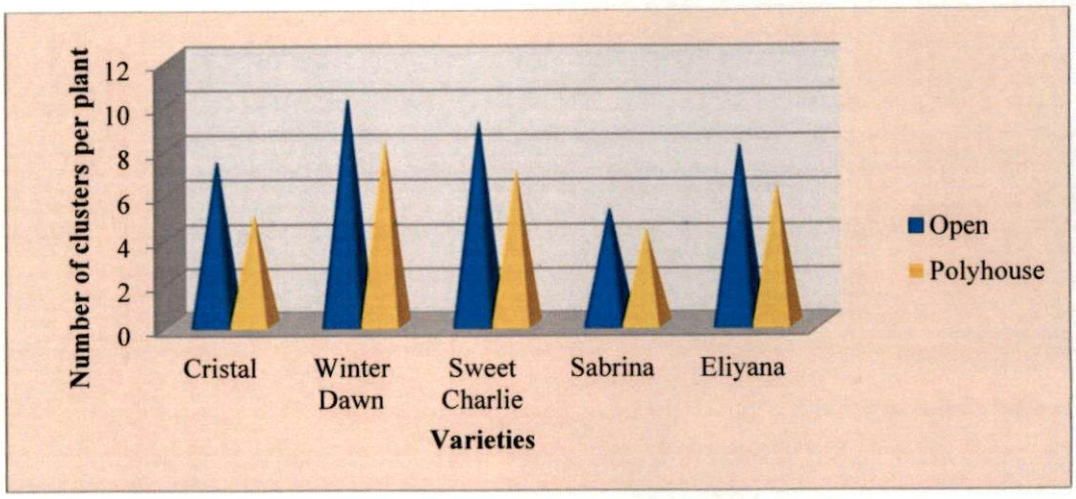

Fig 8. Performance of strawberry varieties for number of clusters per plant under open and polyhouse conditions

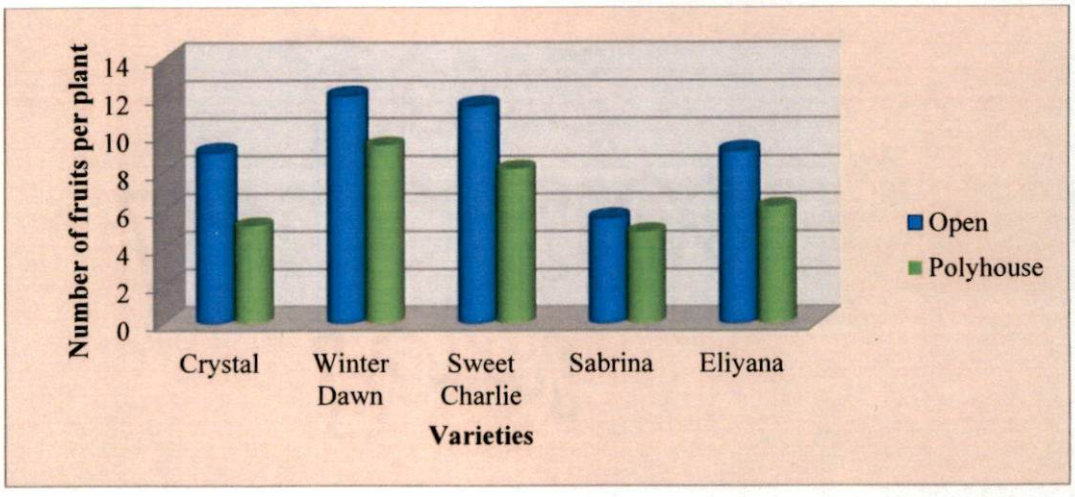

Fig 9. Performance of strawberry varieties for number of fruits per plant under open and polyhouse conditions

The same trend was observed in the polyhouse condition also. Highest yield per plant was recorded in Winter Dawn (123.3 g) which was on par with Sweet Charlie (120.2 g) (Table 5 and Fig. 11).

Earlier results indicated that number of flowers per plant, number of clusters per plant and number of fruits per plant were maximum in Winter Dawn which was on par with Sweet Charlie under both growing conditions. This may be the reason for the high yield per plant observed in Winter Dawn and Sweet Charlie under both growing conditions.

When comparing two growing conditions, plants in the open condition recorded significantly higher yield per plant than under polyhouse condition (Table 6). The results indicated that more number of leaves, flowers per plant, clusters per plant, fruits per plant and minimum days to flower were observed in plants grown under open conditions. This might have led to higher yield under open condition. Formation of more metabolites by increased number leaves and high rate of photosynthesis was reported in strawberry by Singh and Patel (2008) and Hossan *et al.* (2013). The results in the present study was parallel with the findings of Kurian *et al.* (2015a) in strawberry. Therefore it can be concluded that open condition favoured higher production of strawberry under agroclimatic condition of Wayanad.

5.3.3 Average fruit weight

In open condition, Crystal recorded significantly higher average fruit weight (11.21 g) which was on par with Sabrina (10.96 g).

The same trend was observed in polyhouse condion where Crystal recorded significantly higher average fruit weight of 11.01 g which was on par with Sabrina (10.52 g) (Table 5 and Fig. 8).

In general, the number of clusters, number of fruits and yield per plant were lowest in varieties Sabrina and Crystal. Lower fruit set and less number of fruits per plant enable maximum fruit growth (Kumar *et al.*, 2011 and Singh *et al.*,

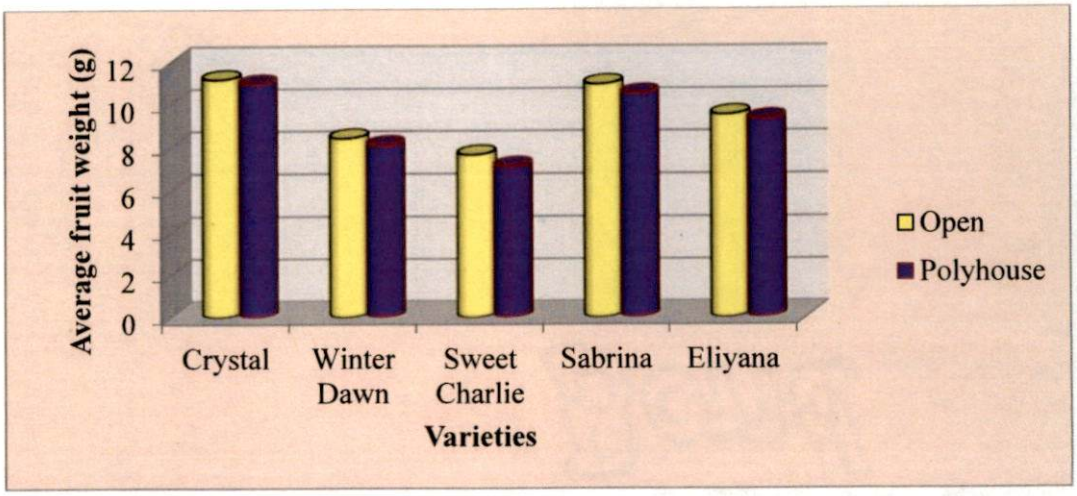

Fig 10. Performance of strawberry varieties for average fruit weight under open and polyhouse conditions

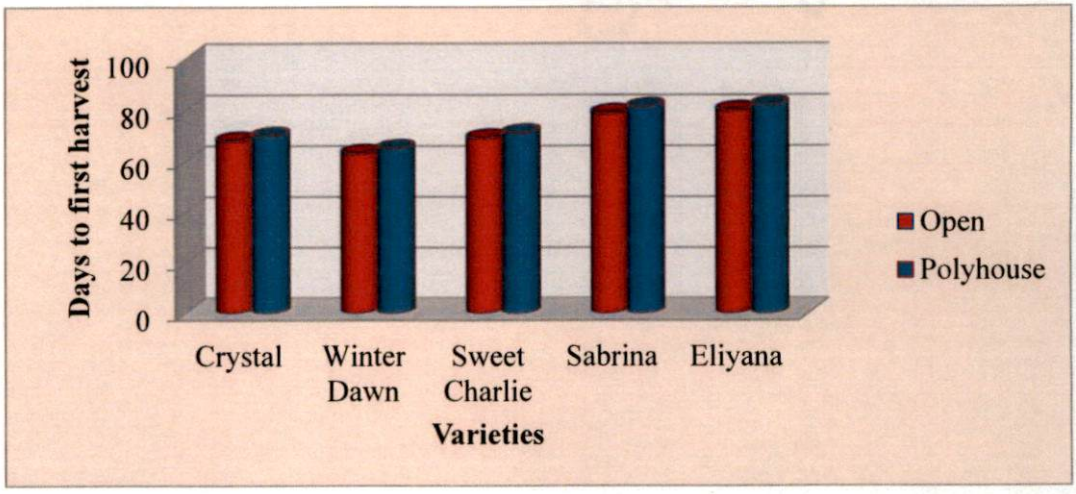

Fig 11. Performance of strawberry varieties for days to first harvest under open and polyhouse conditions

2012). This may be the reason for the increase in average fruit weight observed in Crystal and Sabrina.

5.3.4 Days to first harvest

In open condition, Winter Dawn recorded the minimum days to first harvest (63.40 days) which was on par with Crystal (68.48 days) and this was followed by Sweet Charlie (69.52 days).

In polyhouse condition, Winter Dawn recorded the minimum days to first harvest (65.30 days) which was on par with Crystal (70.28 days) and Sweet Charlie (71.41 days) (Table 5 and Fig. 9).

Number of leaves, number of flowers and clusters per plant were maximum in Winter Dawn which were grown under open condition may resulted in early harvest of strawberry. The low temperature prevailing during the flower induction period helps in the production of early and maximum production of flowers under open condition (Uddin *et al.,* 2016).

3.5 Days to final harvest

In open condition, Winter Dawn recorded the maximum days to final harvest (165.41 days) which was on par with Sweet Charlie (160.38 days) and Crystal (159.42 days).

In polyhouse condition also Winter Dawn recorded the maximum days to final harvest (171.24 days) which was on par with Sweet Charlie (165.34 days) (Table 5 and Fig. 10).

5.4 Quality attributes

5.4.1 Total soluble solids (TSS)

In open condition, Sweet Charlie recorded the highest TSS value of 10.21 ^{0}Brix which is on par with Winter Dawn (9.70 ^{0}B) and Crystal (8.43 ^{0}B).

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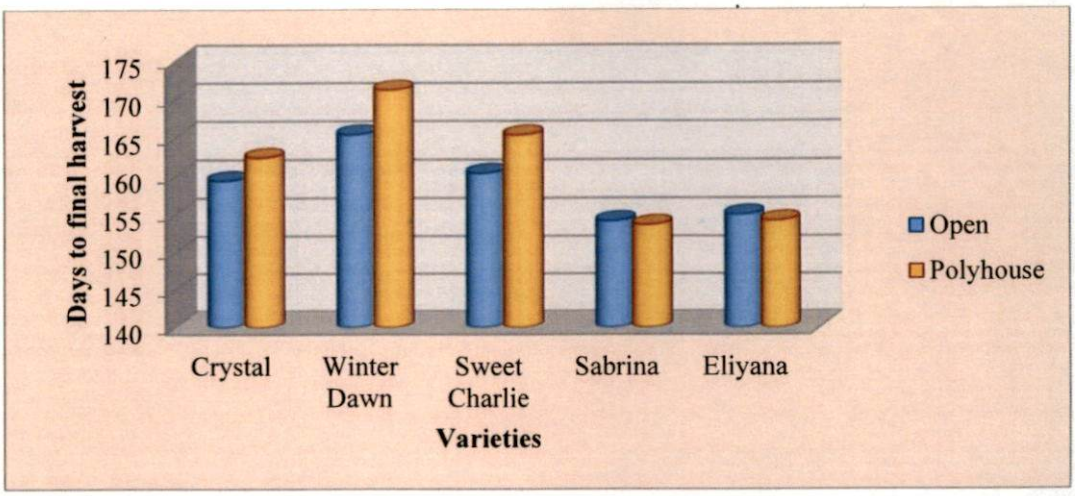

Fig 12. Performance of strawberry varieties for days to final harvest under open and polyhouse conditions

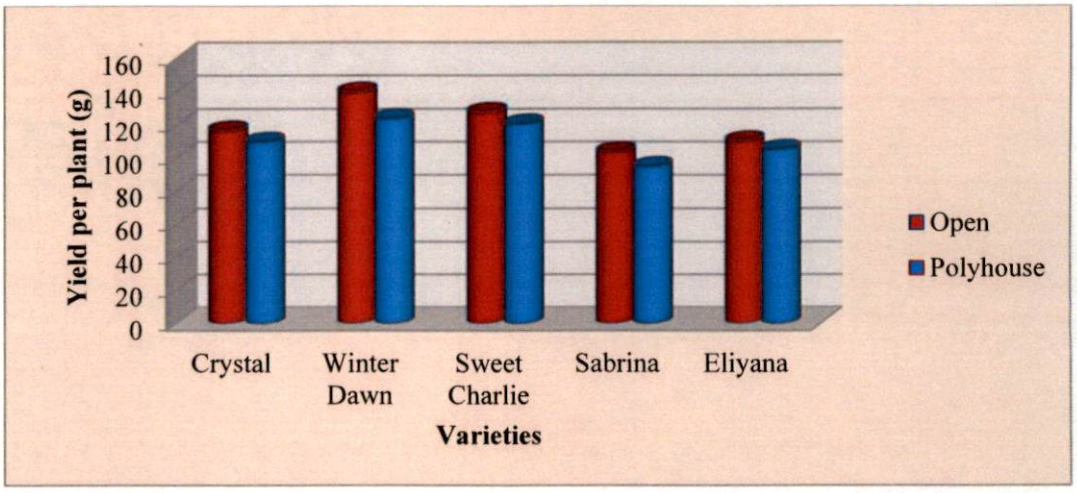

Fig 13. Performance of strawberry varieties for yield per plant under open and polyhouse conditions

In polyhouse condition also Sweet Charlie recorded the highest TSS value of 11.54 ^{0}Brix which is on par with Winter Dawn (10.70 ^{0}B) (Table 7 and Fig. 12).

The increase in the content of TSS of Sweet Charlie might be attributed to climatic conditions and genetic makeup of genotypes. The plants in polyhouse condition got maximum time for accumulation of better sugars in the fruits which might have resulted in increased TSS in plants grown under polyhouse condition. These results agree with the earlier findings of Rajbir *et al.* (2007), Sharma and Thakur (2008), Singh and Patel (2008) and Kurian *et al.* (2015b).

5.4.2 Acidity

In open condition, Sweet Charlie recorded the minimum acidity content (0.71 %) which was on par with Winter Dawn (0.83 %).

The same trend was observed in polyhouse condition also. Sweet Charlie registered the minimum acidity content (0.65 %) which was on par with Winter Dawn (0.74 %) (Table 7 and Fig. 13).

The decrease in acidity in Sweet Charlie and Winter Dawn might be due to the conversion of higher amounts of photosynthates into sugars during fruit ripening stage (Sahoo *et al.*, 2005 and Nagre *et al.*, 2005).

5.4.3 TSS/Acidity

In open condition, Sweet Charlie recorded highest TSS/acidity ratio of 10.2 which was on par with Winter Dawn (7.4).

In polyhouse condition, Sweet Charlie recorded highest TSS/acidity ratio of 11.3 which was on par with Winter Dawn (8.9) (Table 7 and Fig. 14).

Earlier results indicated that maximum TSS and lowest acidity of fruits were recorded in Sweet Charlie which was on par with Winter Dawn. This might have resulted in maximum TSS/acidity ratio in Sweet Charlie and Winter Dawn.

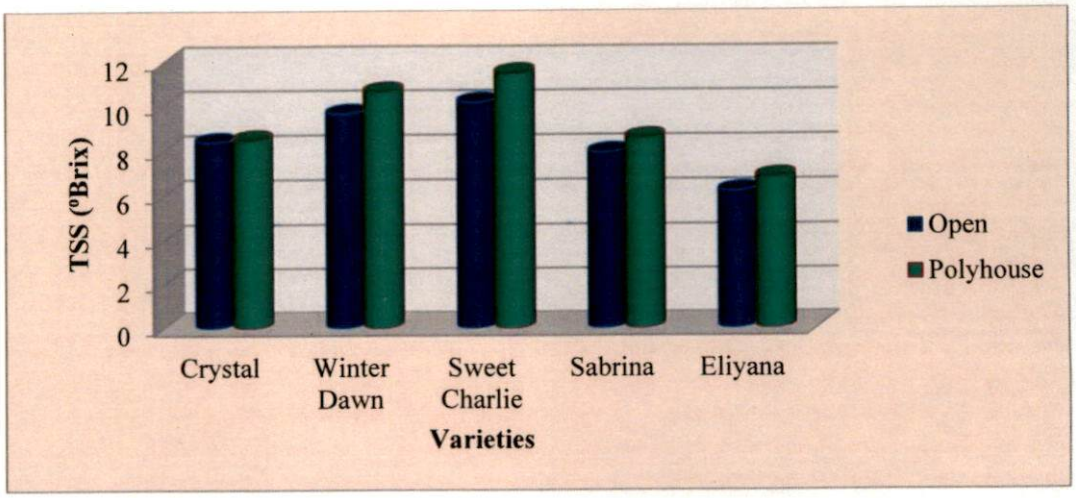

Fig 14. Performance of strawberry varieties for TSS under open and polyhouse conditions

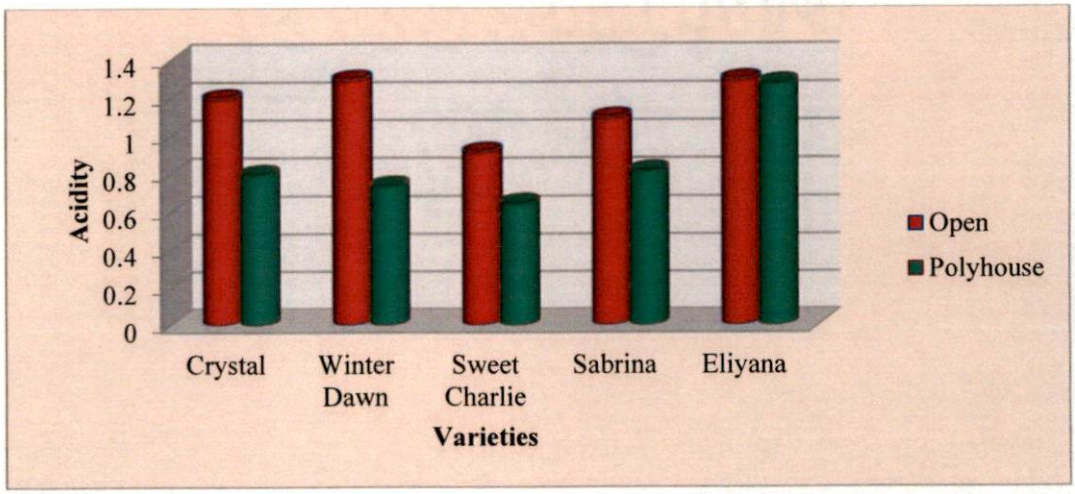

Fig 15. Performance of strawberry varieties for acidity under open and polyhouse conditions

5.4.4 Total sugars

No significant difference in total sugars was recorded under open condition.

In polyhouse condition, Sweet Charlie registered the highest total sugar content of 6.70 per cent which was on par with Crystal (6.36 %) (Table 7 and Fig. 15).

The increase in the content of sugars and TSS of fruits may be attributed to climatic conditions and genetic makeup of genotypes. The quick metabolic transformation of starch and pectin into soluble sugars and rapid translocation of sugars from leaves to the developing fruits by reducing vegetative growth of plants. The increase in content of total sugars ultimately led to higher sugar to acid ratio (Singh *et al.,* 2012 and Iqbal *et al*., 2009).

5.5 Sensory evaluation

Sensory qualities are very important from the consumer's point of view. It depends on characters like appearance, colour, taste, flavor, texture and after taste. Overall acceptability of any fruit is based on all these parameters.

In open condition Sweet Charlie recorded the highest overall sensory score (59.6) followed by Winter Dawn (58.9).

Same trend was observed in polyhouse also, Sweet Charlie recorded the highest overall sensory score of 61.6 which was followed by Winter Dawn (52.2) (Table 7). Comparing different varieties grown under open and polyhouse condition, Sweet Charlie can be considered as the best for sensory characters.

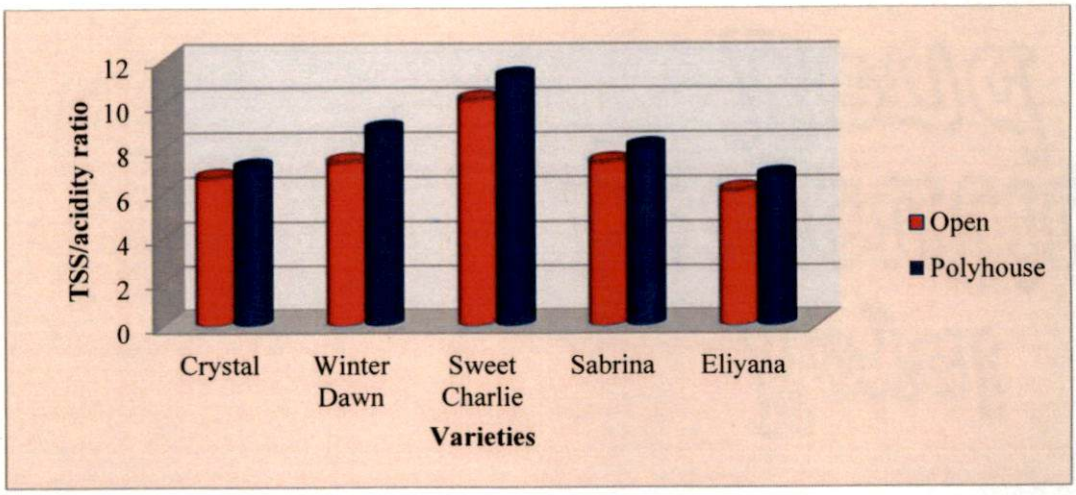

Fig 16. Performance of strawberry varieties for TSS/acidity ratio under open and polyhouse conditions

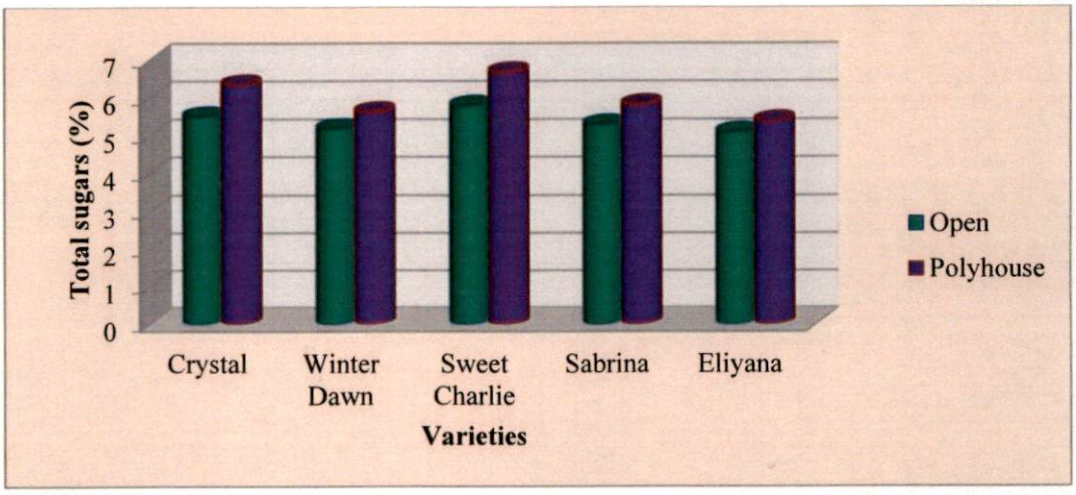

Fig 17. Performance of strawberry varieties for total sugars under open and polyhouse conditions

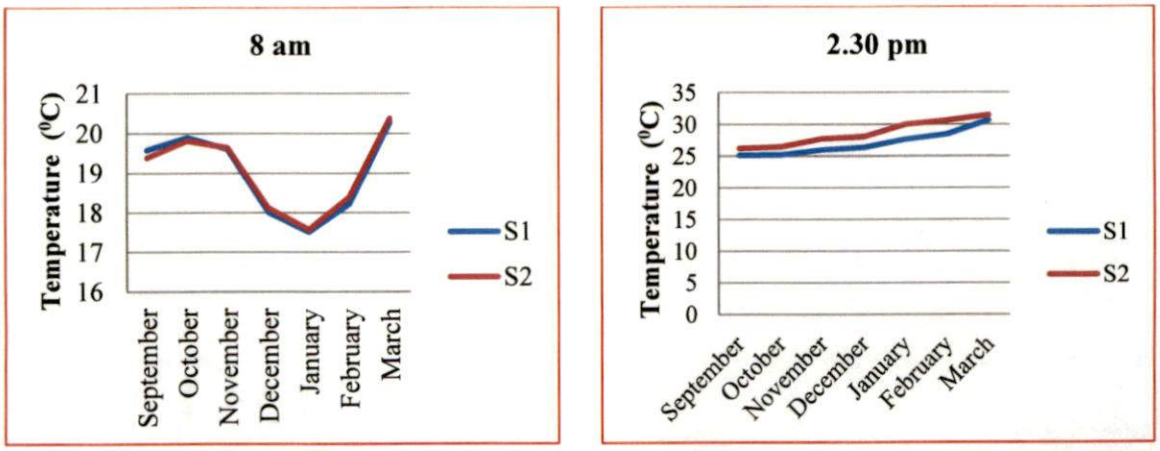

Fig 18. Monthly mean temperatures (^{0}C) in growing systems

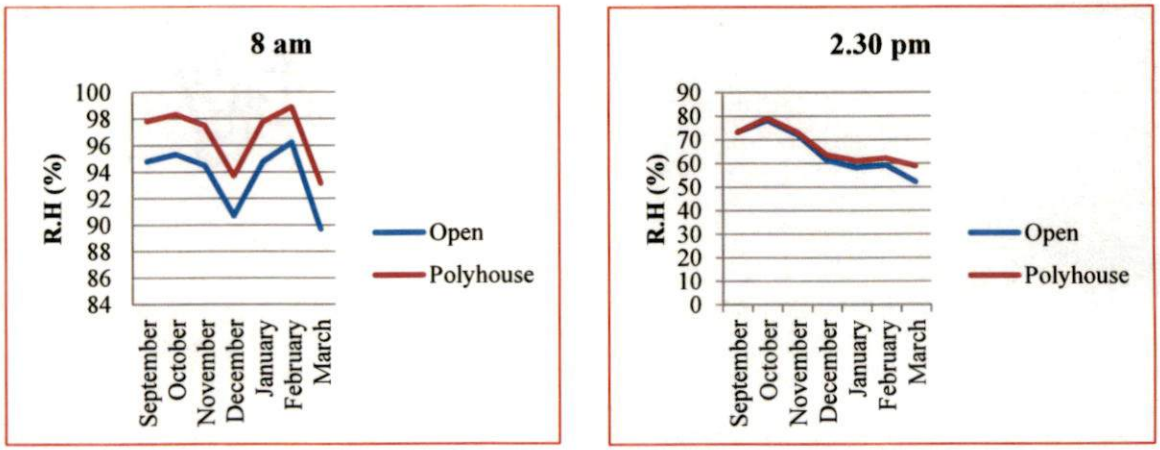

Fig 19. Monthly mean relative humidity (%) in growing systems

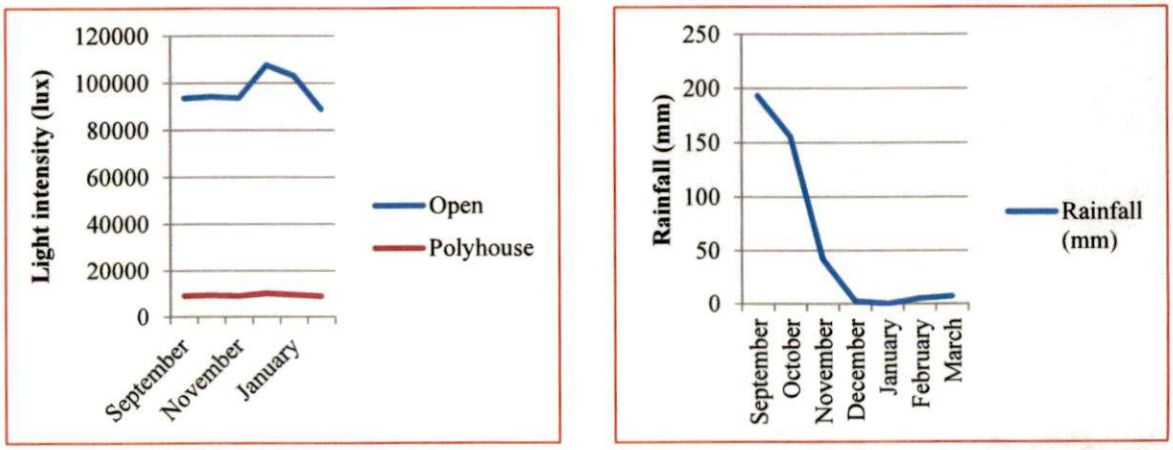

Fig 20. Light intensity (lux) in different growing systems at 12.30 pm and monthly mean rainfall (mm) during the cropping period

5.6 Pest and disease incidence

During the entire period of study, there was no severe incidence of pests and diseases. Mild incidence of pests (semi loopers and larvae of armyworm) and diseases (leaf blight in Sweet Charlie and alternaria leaf spot in Crystal and Eliyana) were observed in open condition. In polyhouse condition, termites and larvae of armyworm were recorded as pests irrespective of varieties. Alternaria leaf spot was observed in Crystal and Eliyana and powdery mildew was observed in Sabrina. Pest and diseases were controlled by adopting suitable control measures.

5.7 Benefit cost ratio

The different inputs and operations in strawberry cultivation were identified and the costs and benefits were worked out for both open and polyhouse systems. The contribution of cost incurred for construction was found to be higher for polyhouse. The yield and returns were found to be higher in open system. The analysis revealed that open system is beneficial for cultivating strawberry in the agroclimatic conditions of Wayanad district.

Summary

6. SUMMARY

The study on "Evaluation of promising strawberry (*Fragaria x ananassa* Duch.) varieties for Wayanad" was undertaken with the objective to evaluate the performance of strawberry varieties under two growing conditions in agroclimatic conditions of Wayanad, Kerala.

The study was undertaken at Regional Agricultural Research Station, Ambalavayal, Wayanad during October 2016 – March 2017. The station is situated at 76.12 ^{0} E latitude, 11.37 ^{0} N longitude and at an altitude of 1000 m above mean sea level. The climate is mild sub-tropical. One month old tissue culture plants of strawberry varieties *viz.,* Winter Dawn, Sweet Charlie, Eliyana, Sabrina and Crystal were used for the study. The varieties were planted in Randomised Block Design in open field and polyhouse conditions at a spacing of 30 cm x 30 cm. All the selected varieties were given uniform cultural practices for proper growth and development. Observations on vegetative growth attributes, flower attributes, yield attributes, quality attributes, post harvest study and pest and diseases were based on randomly selected plants in each replications. The data were statistically analysed.

The salient features of the study could be summarized as follows.

Winter Dawn recorded maximum plant height, number of leaves and plant spread in open condition which was on par with Sweet Charlie.

Winter Dawn recorded maximum plant height, number of leaves and plant spread in polyhouse condition which was on par with Sweet Charlie.

Crystal recorded minimum days to first flowering in open condition which was on par with Winter Dawn.

Crystal recorded minimum days to first flowering in polyhouse condition which was on par with Winter Dawn.

Winter Dawn recorded maximum number of flowers per plant in open condition which was on par with Sweet Charlie.

Winter Dawn registered the maximum number of flowers per plant in polyhouse condition which was on par with Sweet Charlie.

Winter Dawn recorded maximum number of clusters per plant in open condition which was on par with Sweet Charlie.

Winter Dawn registered maximum number of clusters per plant in polyhouse which was followed by Sweet Charlie.

Winter Dawn recorded significantly highest number of fruits per plant in open condition which was on par with Sweet Charlie.

Winter Dawn recorded the highest number of fruits per plant in polyhouse condition which was on par with Sweet Charlie.

Highest yield per plant was recorded in Winter Dawn under open condition which was on par with Sweet Charlie.

Highest yield per plant was recorded in Winter Dawn under polyhouse condition which was on par with Sweet Charlie.

Significantly higher average fruit weight was recorded in Crystal under open condition which was on par with Sabrina.

Crystal recorded significantly higher average fruit weight under polyhouse condition which was on par with Sabrina.

Winter Dawn recorded the minimum days to first harvest under open condition which was on par with Crystal.

Winter Dawn recorded the minimum days to first harvest under polyhouse condition which was on par with Crystal.

Winter Dawn recorded the maximum days to final harvest under open condition which was on par with Sweet Charlie.

Winter Dawn recorded the maximum days to final harvest under polyhouse which was on par with Sweet Charlie.

Sweet Charlie recorded the highest TSS under open condition which is on par with Winter Dawn.

Sweet Charlie recorded the highest TSS under polyhouse condition which is on par with Winter Dawn.

Sweet Charlie recorded the minimum acidity content under open condition which was on par with Winter Dawn.

Sweet Charlie registered the minimum acidity content under polyhouse condition which was on par with Winter Dawn.

Sweet Charlie recorded highest TSS/acidity ratio under open condition which was on par with Winter Dawn.

Sweet Charlie recorded highest TSS/acidity ratio under polyhouse which was on par with Winter Dawn.

No significant difference was observed in total sugar content of fruit in plants grown under open condition.

Sweet Charlie registered the highest total sugar content in polyhouse condition which was on par with Crystal.

Sweet Charlie recorded higher overall sensory score in open condition which was followed by Winter Dawn.

Sweet Charlie recorded higher overall sensory score in polyhouse condition which was followed by Winter Dawn.

This study was to compare different varieties of strawberry for growth, yield and quality under open and polyhouse conditions. It can be concluded that among five varieties, Winter Dawn and Sweet Charlie found to be better in yield and quality and these varieties can be recommended for commercial cultivation in agroclimatic conditions of Wayanad, Kerala.

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Appendices

Appendix-I

WEATHER DATA

Period from October 2016 to March 2017

a) Monthly mean temperature (^{0}C)

Month	Open (S_1)		Polyhouse (S_2)	
	8.00 am	2.30 pm	8.00 am	2.30 pm
September	19.58	25.09	19.38	26.19
October	19.90	25.18	19.81	26.43
November	19.60	25.95	19.64	27.72
December	18.01	26.35	18.12	28.06
January	17.51	27.63	17.57	29.95
February	18.21	28.45	18.40	30.61
March	20.28	30.66	20.38	31.46
Mean	19.01	27.04	19.04	28.63

b) Monthly mean relative humidity (%)

Month	Open (S_1)		Polyhouse (S_2)	
	8.00 am	2.30 pm	8.00 am	2.30 pm
September	94.80	73.24	97.82	73.15
October	95.32	78.16	98.32	79.16
November	94.50	72.26	97.50	73.26
December	90.71	61.39	93.71	63.61
January	94.77	58.19	97.77	61.19
February	96.23	59.19	98.87	62.19
March	89.68	52.23	93.16	58.90
Mean	93.72	64.95	96.74	67.35

c) Monthly mean light intensity (lux) and rainfall (mm)

Month	Open (S_1)	Polyhouse (S_2)	Rainfall (mm)
September	93500.30	9056.00	193.4
October	94158.06	9375.00	156
November	93603.23	9076.13	42.2
December	107597.42	10153.55	2.4
January	103014.19	9452.55	0
February	88817.42	8900.97	5.2
March	86400.32	8590.97	7.2
Mean	95298.70	9229.31	58.05

Appendix –II

Benefit Cost ratio of growing systems- 100m^2 for six months

Particulars	Open system (Rs.)	Polyhouse (Rs.)
1. Rent on land	25	25
2.Labour charges	5M + 5W =5x330 + 5x240 =1650 + 1200 = 2850	2850
3. Planting material	320 plants x Rs 12 = 3840	3840
4. Mulch	35 foot x 7 x Rs 7 = 1225	1225
5. Fertilizer (100 m^2)	200	200
6. Cow dung (100Kg)	100 Kg x Rs10 =1000	1000
7. Pseudomonas (3Kg)	3 Kg x Rs 60 =180	180
8. Plant protection chemicals	20	20
9. Irrigation charges	240	240
10. Depreciation on fixed capital (10% of cost)*	--	3229
11.Total cost	9580	12809
12. Benefit	**320 plants x 8.97 x Rs 10 =28704	320 plants x 7.82 x Rs 10 =25024
10. B/C ratio	28704/9580=3.0	25024/12809=1.95

*- After 10 years ofestablishment **-10% crop loss occur due tounpredictable reasons

Appendix- III

Score card for organoleptic evaluation

Name of the judge:

Date:

Characteristics	Scores									
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
Appearance										
Colour										
Flavour										
Texture										
Odour										
Taste										
After taste										
Overall acceptability										

9 point Hedonic scale

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Signature

List of symbols and abbreviations

Symbols	Abbreviations
%	Percent
@	At
°C	Degree centigrade
C. D.	Critical difference
cm	Centimeter
cv.	Cultivar
et al.	and other
g	Gram
i.e.	That is
kg	Kilogram
mg	Milligram
ml	Milliliter
viz.	As follows
TSS	Total soluble solids
MAP	Month after planting

EVALUATION OF PROMISING STRAWBERRY (*Fragaria x ananassa* Duch.) VARIETIES FOR WAYANAD

by
MUHAMMED ASLAM
(2014-12-127)

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Horticulture
(FRUIT SCIENCE)

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF FRUIT SCIENCE
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR – 680 656
KERALA, INDIA
2017

ABSTRACT

The experiment entitled "Evaluation of promising strawberry (*Frageria x ananassa* Duch.) varieties for Wayanad" was undertaken at Regional Agricultural Research Station, Ambalavayal, Wayanad, Kerala during the year 2016-17. Performance of five strawberry varieties *viz.,* Crystal, Winter Dawn, Sweet Charlie, Sabrina and Eliyana were evaluated under open and polyhouse conditions.

Maximum plant height (32.31 cm), number of leaves (26.20) and plant spread (31.41 cm) were recorded in variety Winter Dawn followed by Sweet Charlie under both growing systems. Number of flowers (16.24) and number of clusters per plant (10.13) was significantly higher in variety Winter Dawn followed by Sweet Charlie. Minimum days to first flowering were observed in the variety Crystal (45.21). Maximum number of fruits (12.04), yield (139.51 g) and earlier harvest of the fruits (63.40 days) were observed in variety Winter Dawn under both growing systems.

Biochemical characters *viz.,* highest TSS (11.54 ^{0}B), lowest acidity (0.65 %), TSS/acidity ratio (11.3) and total sugars (6.70 %) and overall sensory score were highest in the variety Sweet Charlie followed by Winter Dawn. However, the variety Winter Dawn had better appearance and flavour.

It can be concluded that among five varieties evaluated under two growing systems *viz.,* open condition and polyhouse, Winter Dawn and Sweet Charlie are found to be better in yield and quality. Therefore, these varieties can be recommended for commercial cultivation in agroclimatic conditions of Wayanad, Kerala.