PERFORMANCE OF STRAWBERRY (*Fragaria x ananassa* Duch.) IN DIFFERENT GROWING CONDITIONS

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DECLARATION

I, hereby declare that this thesis entitled **"Performance of strawberry (*Fragaria* x *ananassa* Duch.) in different growing conditions"** 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, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Performance of strawberry (*Fragaria x ananassa* Duch.) in different growing conditions"** is a bonafide record of research work done independently by **Ms. Anu Kurian (2012-12-105)** 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 her.

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EXTERNAL EXAMINER

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Dedicated to my family, friends and teachers

INTRODUCTION

1. INTRODUCTION

Strawberry (*Fragaria x ananassa* Duch.) is the most refreshing and delicious fruit crop which belongs to the family Rosaceae. Strawberries are native to North America. Worldwide it is the most widely distributed fruit crop due to its genetic diversity, highly heterozygous nature and broad range of environmental adaptations.

The strawberry is commercially grown on large scale in Europe and North America. USA produces 30.4 per cent of the total world production of strawberries (FAOSTAT, 2014). Among different countries, Spain, Poland, Germany and France are the major strawberry producers. The major strawberry growing states in India are Jammu and Kashmir, Himachal Pradesh, Maharastra, Uttarakhand, Haryana, Uttar pradesh and Punjab.

The strawberry is a low creeping perennial herb in which stem is compressed into a rosette crown. Strawberry inflorescences are formed terminally on the apical meristem in the crown. Fruit is technically known as an accessory fruit in that the fleshy part is derived not from the ovaries (achenes) but from receptacle. The roots of the strawberry are confined to the top six inches of the soil. Plant propagates naturally itself by the vegetative method of runner production. Vegetative and reproductive growths of strawberry are more sensitive to photoperiod and temperature. According to flowering and cropping characters, strawberries are classified into june bearing (short day plants) and ever bearing (long day plants) types.

The fresh ripe fruits of strawberry are rich source of vitamins mainly vitamin A (60 IU/100g of fruit) and vitamin C (30-120 mg/100g of fruit) and has abundance of minerals like potassium, calcium and phosphorus and has high pectin (0.55 per cent) also. The ripe strawberries attain attractive red colour on maturity and has a

pleasant and refreshing aroma. The mature fruit contains about 5 per cent total sugars, 0.9 per cent-1.85 per cent acids. The major sugars found in strawberry are fructose and glucose and is a rich source of anthocyanins also.

Fruits are mainly consumed fresh and some are processed into various value added products such as jam, jelly, chutney, squash and other food stuffs. It is used in large scale ice-cream making. The fruits are canned and shipped in frozen conditions in western countries. India exports strawberry mainly to Bangladesh, Austria, the US, Germany and Jordan (APEDA, 2013).

It is among the few fruit crops which give quicker and very high returns per unit area on the capital investment, as the crop is ready for harvesting within four months of planting. Our state is also blessed with different agro-ecological conditions suitable to various crops. The Kerala State Horticulture mission (KSHM) has drawn up a project to cultivate strawberry in 750 acres in Idukki and Wayanad districts of Kerala. The farmers were expected to earn better returns by diversifying into the high-value crop. Horticorp would procure the strawberry from farmers and Kudumbasree units would take up processing of fresh fruit. The unprocessed fruits will be sold through shopping malls under the "Safe to Eat" brand. Considering the above facts, the present study entitled "Performance of strawberry (*Fragaria x ananassa* Duch.) in different growing conditions" was undertaken with the objective to compare the performance of strawberry under three growing conditions and at two agro ecological zones of Kerala viz., Central midlands and High ranges of Kerala.

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 post harvest aspect of strawberries. The influence of crop and environmental factors and pest and disease incidence are also reviewed.

2.1. Growth attributes

The plant height, number of leaves and plant spread are the vegetative growth attributes 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 plant density 47,619, 60,606 and 66,666 plants ha^{-1} on the growth and yield of strawberry cultivars Sanga Sengana and Chandler were studied in Srinagar, Jammu and Kashmir. The cultivar, Sanga Sangana was superior in terms of plant height (7.24 cm) (Ahmad, 2009).

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.* (2008a) 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 height of the plant (19.45 cm and 17.65 cm, respectively) during 2009-10 and 2010-11 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 a 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

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

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

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).

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 higher 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 highest plant height (21.10 cm) was recorded when 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 (12.86, 14.46 and 14.8 cm at 60, 75 and 90 DAP respectively) (Rhakho *et al*., 2014, Singh *et al*., 2006).

2.1.2 Number of leaves

2.1.2.1 Variety

Rahman *et al*. (2014) conducted an experiment on strawberry having 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

Gupta and Tripathi (2012) conducted an experiment in strawberry cv. Chandler during 2009-10 and 2010-11 observed that combined application of *Azotobacter* at 7 kg ha^{-1} + vermicompost at 30 t ha^{-1} significantly increased number of leaves (63.60 and 59.60 respectively) per plant.

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 was 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).

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 Sanga Sengana and Chandler. Sanga Sangana was superior in terms of plant spread (13.82 cm).

2.1.3.2 Nutrients

2.1.3.2.1 Organic nutrients

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.

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 *Azotobacter* and was at par with the plants supplied with urea in combination with *Azotobacter*

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) 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 consisting of no mulch, wheat straw, paddy straw, cut grass, green polyethylene, red polyethylene, pine needles, black polyethylene, clear polyethylene, coconut husk. The mulch 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 poly house 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).

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 ^{cv}. 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 reveals that plants under mulch flowered up to 13 days earlier and the fruit was ready to harvest 10 days earlier (Pollard *et al*., 1989).

Abbott 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 reveals 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).

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 (67.48 and 64.51 respectively) 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).

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

GA_3 at 100 ppm and GA_3 at 75 ppm have been found to be the best treatments for production of quality runners and proper growth of plants (Kaul, 1967; Pathak and Singh, 1972; Wang, 1989; Sharma and Singh, 1990). Single application of GA_3 (50 ppm) to one year old plants promotes vegetative growth, runner development and production (Dennis and Bennett, 1969). A single spray of GA_3 at 50 ppm before flower initiation is best to suppress flowering in strawberries (Shoemaker, 1975). GA_3 at 50 ppm sprayed after flowering increased the yield up to 31-41per cent (Chadha, 2001).

Ethephon (500 ppm) spray at flower initiation is effective for smothering flowering in day-neutral strawberry cvs. 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). 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.

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).

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

Darrow and Waldo (1934) reported that a temperature averaging about 60 ^{0}F is necessary for transformation from vegetative to fruit bud formation. At temperature above 60 ^{0}F, short day period of 10 hrs or less is necessary to initiate fruit buds.

According to Roberts and Kenworthy (1956) ambient temperature range between 20 ^{0}C and 26 ^{0}C was ideal 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).

Guttridge (1985) reported that 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.

Strik (1985) observed that the optimum growth temperature for strawberry ranges from 10 ^{0}C to 26 ^{0}C.

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) resulted in reduced plant growth and lower yields (Renquist *et al*., 1982; Hellman and Travis, 1988).

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

Temperature affects the initial rate of flower production. There was a linear increase in the rate of flower initiation in both the secondary and tertiary inflorescences up to an optimum of 18.6 ^{0}C and 19.9 ^{0}C respectively and declining at higher temperatures (Le Mière *et al*., 1996).

Shiow and Mary (2000) reported that in strawberry cvs. 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 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^{0}C) promotes runnering in both short day and long day condition (Michel *et al*., 2006; Heide and Sonsteby, 2007; Verheul *et al*., 2006).

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 a linear relationship between early production and temperature (R^2=0.86) and between early production and solar radiation (R^2=0.73) (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 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 revealed 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

Darrow (1936) conducted studies on the interrelation of temperature and photoperiodism in the production of fruit buds in the strawberry by exposing nine strawberry cultivars to a combination of three photoperiods (less than 13.5, 14 and 16 h) and three temperatures (12 ^{0}C, 15.5 ^{0}C and 21 ^{0}C). Maximum flower buds occurred under the shortest photoperiods and the two lowest temperatures. The longer the photoperiod, the lower the temperature needed to maximize flower number.

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 decreased (Jonkers, 1965).

The critical photoperiod for flower induction depends mainly on temperature. Studies showed that the number of "Korona" plants that induced flowers decreased drastically at temperatures higher than 18 ^{0}C, even at photoperiods of 10 or 12 h (Heide, 1977; Verheul *et al*., 2006).

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 (Hartman, 1947; Durner and Poling, 1987).

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

Runnering is clearly promoted by long photoperiod (>14 – 16 h) and high temperature (>17 – 20 ^{0}C), in short day cultivars of strawberry (Heide 1977; Durner *et al*., 1984; Guttridge 1985; Le Mière *et al*., 1996).

Number of flowers in an inflorescence is not affected by photoperiod (Le Mière *et al*., 1996).

Sonsteby and Nes (1998) reported that a critical number of short days of 16 days is essential for flower initiation in strawberry cv. Korona.

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.

The number of days to flowering decreased with increasing photoperiod (Verheul *et al*., 2006).

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 two long internodes followed by a daughter plant (Timo, 2009).

2.4.5. Response of crop to protected cultivation

Shading may, however, 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 revealed that unshaded plants produced 26 per cent more leaves than those grown under shaded conditions. Shading reduced the number of flowers per plant by 15 per cent than those grown under unshaded condition. Shading reduced number of fruits per inflorescence by 20 per cent than those under unshaded condition (Yahya and Atherton, 1995).

Experiment conducted to study the comparison between strawberry growing inside and outside the plastic house in cv. Yael in the Northeast of Thailand. Inside the plastic house, the productivity (fruit number) 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 ^{0}C affecting the growth of a flower bud that is in a direct effect to reduce the amount of the strawberry product (Tongtraibhop *et al*., 2009).

Studies were conducted to identify suitable environment for high production of good quality fruits in strawberry cv. 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. TSS was maximum in fruits from plants under plastic tunnel (6.6 per cent) which was at par with fruits in poly house (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. 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).

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 cvs. 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

Under different time of plantings from July to November under low tunnels and open field, November planting extended the period of fruit availability to 47 days from normal period (Pollard and Cundari, 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 district of Kerala revealed that cv. Chandler was the best in case of number of fruits per plant (17.9).

Among the varieties Sanga Sengana and Chandler which were studied in Jammu and Kashmir, Sanga Sangana 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 on growth and yield characters under Garhwal agro-climatic conditions, Belrubi (16.8) and Gorella (15.10) had 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, 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 *Azotobacter* 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 maximum number of fruits (39.21 and 36.19, respectively) per plant in two seasons under the treatments with *Azotobacter* @ 6 kg ha^{-1} + vermicompost @ 30 t ha^{-1} applied in strawberry cv. Chandler.

2.5.2.2.2 Inorganic nutrients

Singh *et al*. (2001) found that 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 Charlie, 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 *Azotobacter* 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 solubilizing 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 minimum fruits in December planting (15.80).

2.5.2.4 Mulching

Angrej and Gaur (2007) observed that 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 fruits per plant (18.10) of strawberry cv. Sweet Charlie.

Black polyethylene mulch gave the maximum number of fruits per plant (12.12) in strawberry cv. Chandler (Bakshi *et al*., 2014).

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 "Winter Dawn" had the best performance producing more than 34 t $acre^{-1}$. There were no differences in the total yields of Carmine, Albion, Strawberry Festival, Camarosa and 00-51 which ranged between 20.7 and 24.8 t $acre^{-1}$ (Bielinski *et al*., 2007).

Studies were conducted by Ahmad (2009) on the growth and yield of strawberry cultivars Sanga Sengana and Chandler under different plant density. 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, 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 of strawberry had the positive effect on yield per plant.

Rahman *et al*. (2014) reported that among different strawberry genotypes evaluated, 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 FA008.

2.5.3.2 Nutrients

2.5.3.2.1 Organic nutrients

Studies were conducted in strawberry cv. Chandler to determine the effect of nitrogen (0, 60, 80 and 100 kg N ha^{-1}) and biofertilizers (*Azotobacter*, *Azospirillum* and *Azotobacter* + *Azospirillum*) on yield. The maximum yield (79.12 q ha^{-1} was recorded in *Azotobacter* 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 maximum fruit weight (15.87 g) with the application of 25 per cent nitrogen through FYM augmented with *Azotobacter* and was on par with the plants supplied with urea in combination with *Azotobacter.*

The physico-chemical characteristics of strawberry fruits were significantly influenced with integrated use of poultry manure, urea and *Azotobacter* registering maximum yield of 371.23 q ha^{-1} (Umar *et al*., 2008b).

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

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

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

Application of VAM at the rate of 12 kg ha^{-1} resulted in a significant increase in yield (30.14 t ha^{-1}) which was 41.63 per cent higher over the control in strawberry (Bakshi *et al*., 2014)

2.5.3.2.2 Inorganic nutrients

In strawberry cv. Deutsch Evern and Muncheberger Fruhe, the application of N had a positive influence on yield and fruit number per plant. Manuring with P slightly increased yield and fruit number and there was no significant effect of K manuring on yield and fruit number (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 calcium supplied on shoot 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 *Azotobacter* 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 favored vigorous growth, and enhanced flowering and fruiting, resulted 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 with strawberry cv. Confitura, planting in November, mulched with black polyethylene resulted in better yield (Wani *et al*., 2007).

Amarjeet *et al*. (2009) observed that early planting in second week of October was efficacious in improving yield of strawberry cv. Chandler.

In strawberry cv. Chandler, October planting coupled with black polyethylene mulching was observed to be 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.

2.5.3.4 Spacing

Maximum fruit weight was obtained with double row of planting (30x50x60 cm with in plants, rows and between beds) followed by single row of planting (30x40x30 cm) and lowest in triple row planting (30x60x90 cm) (Fiedler and Liebelt, 1988; Ahmad, 2009).

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 highest density resulted in the lowest yield per plant and the highest yield per unit area. The highest number of marketable fruits per plant were recorded in plants grown under low plant densities (Pérez de *et al*, 2005).

Ahmad (2009) reported that among the different 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; 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 (Shetty and Andersen, 1964; Sharma and Khokhar, 2006).

Studies have 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 polyethylene strips and lowest with white polyethylene strips (Castellanos and Leal, 1970).

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

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

Abbotty and Gough (1992) reported that 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 among the black polyethylene, clear polyethylene and rice straw mulching materials, black polyethylene resulted in superior growth, fruit weight, yield and quality.

Mulch with black polyethylene was found to be the superior on growth, flowering, fruiting, yield and quality of strawberry cv. Chandler under Lucknow conditions (Ram *et al*., 2005; 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).

Mulching with black polyethylene in winter is highly useful for better growth and production of strawberry under a sub-tropical climate (Sharma *et al*., 2008; Kour and Singh, 2009).

Interactive effects of planting time and mulching on strawberry cv. Chandler showed that fruits 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).

2.6 Quality

Srivastava and Aggarwal (1982) reported that hay mulch increase 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 ^{0}Brix) content was recorded with the application of *Azotobacter* combined with 80 kg N ha^{-1}.

Chemical analysis of 13 strawberry varieties reveals that the chemical composition of strawberry fruits significantly varied among the genotype of the plant and on the stage of maturity of fruits. TSS increases during the last stage of ripening (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.

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

Experiment to study the effect of plant density on growth and yield of strawberry in cv. Sanga Sangana and Chandler revealed that cv. Chandler recorded maximum TSS, ascorbic acid and low acidity than Sanga sangana (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 + *Azotobacter* recording 6.81 ^{0}Brix, 4.73 per cent, 73.71 mg/100 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.

Highest TSS, sugar content and ascorbic acid content were observed in strawberry cv. Chandler mulched with black polyethylene (Kour and Singh, 2009).

Kumar *et al*. (2011) reported that maximum TSS, lower acidity and total sugars was observed in Chandler under plastic tunnel compared to open condition.

Mishra and Tripathi (2011) reported that combined application of *Azoctobacter* and phosphorus solubilizing bacteria (each at 6 kg ha^{-1}) significantly increased the TSS (10.30 ^{0}Brix), total sugars (9.54 per cent) and ascorbic acid (57.55 mg/100 g) contents of strawberry fruits.

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, content of ascorbic acid and anthocyanin was highest in UVS polyethylene covered low tunnel.

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.

Bakshi *et al*. (2014) reported that black polyethylene mulch gave the best results in terms increasing total soluble solids (7.63 ^{0}B), total sugars (7.00 per cent), vitamin C (57.77 mg 100^{-1} g) and crude protein (9.64 per cent) 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.

2.7 Postharvest study

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

The best way to slow spoilage is to quickly remove field heat and to maintain berries as 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).

Post harvest dipping of strawberry fruits cv. Tudla in 1 per cent $CaCl_2$ solution at 77 ^{0}Fwas the most effective treatment for increasing the calcium content of the fruits, for controlling their postharvest decay and for maintaining their firmness and soluble solids content (Garcia *et al*. (1996a); Lara *et al*. 2004)

Garcia *et al*. (1996b) reported that the postharvest heat treatment at 44 ^{0}C or 46 ^{0}C showed best retension of firmness and maintained internal quality even after 4 days of harvest and allowed the best control of Botrytis development in strawberry cv. Tudla.

Marked reduction in decay of strawberry fruits was observed when the fruits were dipped or sprayed with 10^{-2} M Dimethoxy benzoic acid (Lattanzio *et al*., 1996).

Strawberry fruits when fumigated with acetic acid at 5.4 mg L^{-1} were free of decay and can be stored for 14 days at 5 ^{0}C (Moyls *et al*., 1996).

Holcroft and Kader (1999) reported that CO_2 enriched atmospheres were successful in controlling Botrytis rot and firmness even after 10 days at 5 ^{0}C storage in strawberry cv. Selva.

In strawberry cv. Pajaro, the CO_2 treatments enhance firmness of strawberry in a non–reversible manner even after the fruits were returned to air as long as the strawberries were held at 0 ^{0}C (Harker *et al*., 2000; Pelayo *et al*., 2003).

Lara *et al*. (2004) reported that 1 per cent $CaCl_2$ solution was effective in reinforcing fruit tissues against fungal contamination and extending the shelf life for strawberry cv. Pajaro.

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 up to 8 days in strawberry cv. Fengxiang.

Asghari *et al*. (2013) reported that postharvest treatment of strawberries with 5 µmol l^{-1} nitric oxide effectively controlled decay organisms and retained fruit quality during 15 days of storage at 2.5 ^{0}C.

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 disease

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)

The Red Spider Mite, *Tetranychus urticae* is a serious pest of strawberry. It can colonize the plants and by feeding, it can reduce plant vigour and decrease fruit size. It is endemic along Mediterranean Sea (Galazzi and Nicoli, 1996)

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.).

Leaf spot is a major disease of strawberry appears on the top side of leaves as reddish to purplish spots with grey centre. Leaf spot is favored by wet and cooler conditions. The spores are spread by wind, rain splash and overhead irrigation (www.industry.nsw.gov.au).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The investigation envisages to study the performance of strawberry (*Fragaria x ananassa* Duch.) in different growing conditions of Kerala. The materials used and methodology adopted for the studies are described in this chapter.

3.1. Experimental site

The experiments were conducted over a period of one season from September2013 to October 2013 to February 2014 to March 2014 in three growing systems *viz*., open condition, greenhouse and fan and pad system in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, Thrissur, Keralaand KrishiVigyanKendra (KVK),Ambalavayal, Wayanad, Kerala.

3.1.1. Locations

Location I (Central mid-lands) is the College of Horticulture, Vellanikkara,Thrissur, is located at $10^0$31'N latitude and $76^0$3'E longitude, at an altitude of 22.25m above mean sea level and enjoys the typical warm humid tropical climate of Kerala. Location II (High ranges) is the KrishiVigyan Kendra, Ambalavayal,Wayanad, is located at 76.12^0E latitude,11.37^0N longitude and at an altitude of 1000 m above mean sea level and enjoys mild sub-tropical climate.

3.1.2. Soil

The important physical and chemical properties of soil in the experimental sites are summarized in Table1.

Table 1. Physico-Chemical properties of soil at the experimental site

Soil characters	Location I	Location II
A.Physical properties		
Mechanical composition		
Sand	77.5%	64.5%
Silt	5.0 %	12.5%
Clay	17.5%	23.0 %
Texture	Sandy loam	Sandy clay loam
B. Chemical properties		
Available nitrogen ($kgha^{-1}$)	224.00	110.00
Available Phosphorous ($kgha^{-1}$)	7.00	8.70
Available Potash ($kgha^{-1}$)	276.00	5.00
Organic carbon (%)	1.99	.96
Electrical conductivity(mmhos cm^{-1})	0.14	.05
pH	5.70	4.95
Calcium ($mgkg^{-1}$)	15.20	211.70
Magnesium($mgkg^{-1}$)	73.10	0.80
Iron ($mgkg^{-1}$)	13.95	70.50
Manganese($mgkg^{-1}$)	48.43	0.40
Copper ($mgkg^{-1}$)	8.83	1.19
Zinc ($mgkg^{-1}$)	9.68	0.72
Boron ($mgkg^{-1}$)	0.89	.28

3.1.3. Climate

The climate of the experimental sites were tropical humid climate in Vellanikkara,Thrissur(Location I) and mild sub-tropical climate in KVK, Ambalavayal, Wayanad (Location II). The weather conditions prevailed during the cropping period is shown below in Table2. The normal weather data (average for years) are given in AppendixI.

Table 2. Mean weather conditions of two locations during the cropping period

Weather parameters	Location I	Location II
Maximum temperature (^{0}C)	32.30	27.30
Minimum temperature (^{0}C)	24.50	18.90
Relative humidity (per cent)	78.65	93.54
Rainfall (mm)	113.78	58.06

3.1.4. Seasons

The experiments were conducted during the period September 2013/October 2013 to February 2014/March 2014.

3.1.5. Planting time

Two time of planting were done at an interval of one month as follows

P_1- Last week of September 2013

P_2- Last week of October 2013

3.2. Materials

3.2.1.Variety

Strawberry variety Winter Dawn was used for this experiment. It 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 lowchilling variety suited to subtropical climatic condition. Healthy and disease free runners were procuredfrom KF Bioplants Pvt. Ltd, Hadapsar, Pune in the month of September 2013.

3.2.2. Fertilizers

Farmyard manure @ 10tha^{-1}is applied at the time of land preparation.Recommended dose of NPK was75: 80:50kg/ha (Pandey and Mishra, 1983).A basal dose of 1/2 N,1/2P and 1/2 K was applied as top dressing. Same dose of inorganic fertilizers viz., 1/2 N, 1/2P and 1/2 K was given 45days after planting.

3.2.3. Growing systems

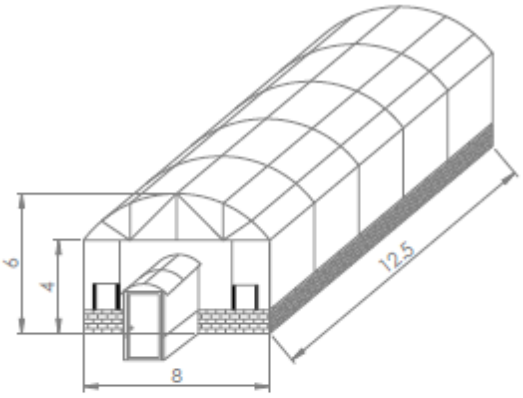
Three systems of growing viz., open condition (S_1), greenhouse (S_2) and fan and pad system (S_3).

3.2.3.1. Open condition

Open field was selected for planting strawberry runners with a plot size of 11m x 7 m.

3.2.3.2. Greenhouse

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



FAN AND PAD SYSTEM

All dimensions are in metre (m)

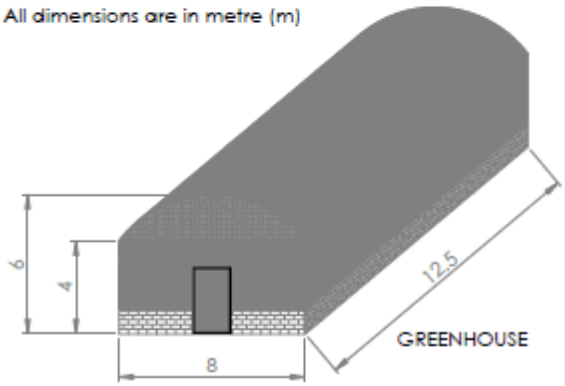


Plate 1.Systems of growing

3.2.3.3. Fan and pad system

Fan and pad system was 12.50 m x 8.00 m x 6.00 m x 4.00 msize, covering with 200 micron polyfilm and UV stabilized shade net with fan and pad for cooling system.Shade level of 50 per cent was provided in this system.

3.3. Methods

3.3.1. Design of the experiment

Design of the experiment was 3x2x2 Factorial randomized block design with three replications in each location.Treatments are arranged randomly in each growing system.

3.3.2. Treatments

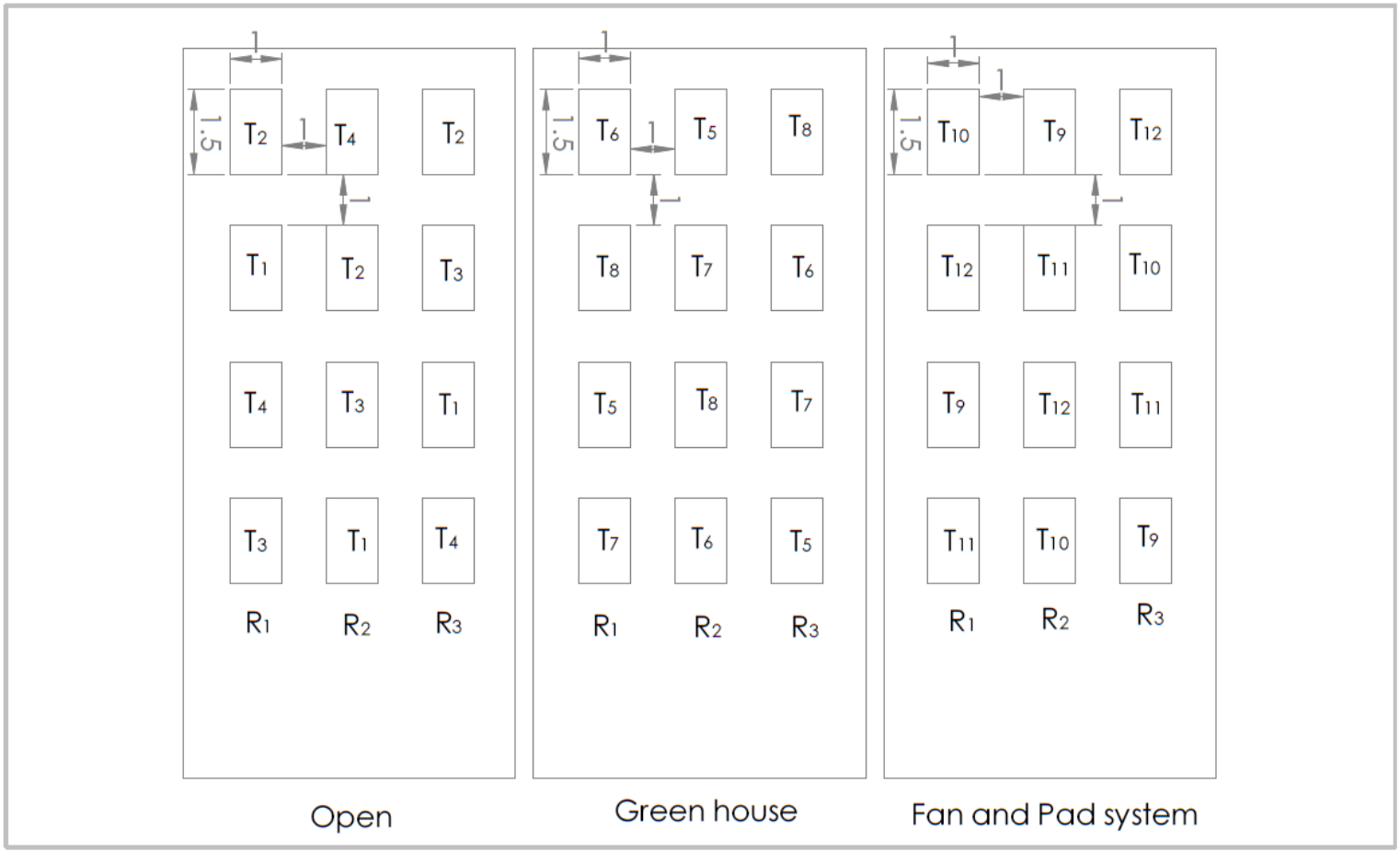
Table3. Details of the treatments

Treatments	Details	Notations
Growing systems	Open	S_1
	Greenhouse	S_2
	Fan and Pad	S_3
Time of planting	Last week of September	P_1
	Last week of October	P_2
Type of mulch	White mulch	M_1
	Black mulch	M_2

Total treatment combinations-12 Replications-3

3.3.3. Preparation of land

The land was raked thoroughly and the field was made free of weeds and stubbles. Soil fumigation with methyl bromide was done to make the soil free from



All diameters are in metre (m)

Plate 2. Layout of the experiment.

Open field (S_1)

Greenhouse (S_2)

Fan and pad system (S_3)

Plate 3. Different growing systems

Misting system inside shade net

Plants on raised beds in greenhouse

Inside view of fan and pad system

Pad for cooling inside fan and pad

White and black mulch

Plate 4. Inside view of growing system and mulches

soil borne pathogens. Manures and fertilizers were mixed in the soil and raised beds were taken in such a way that water can run in either directions in the furrows between the beds.

3.3.4. Manuring

The full dose of farmyard manure and half dose of NPK were applied at the time of bed preparation and the remaining half dose of NPK was applied45days after first application.

3.3.5. Mulching

Beds were covered with polythene mulch either white or black according to the treatment.

3.3.6. Planting

Double row hill system of planting was done on raised beds of size 1.5m x 1m x 0.3m. Between the beds, one meter spacing was given. In each growing system, there were about 12 raised beds or plots. Spacing given was 30cm x40cm.Holes were made on the mulch depend on spacing. Plots were randomly selected for planting. Half number of plots in each system was planted during last week of September. Another half number of plots were planted during last week of October. Ten plants were planted in each plot. Planting was done by hand.One month old tissue culture strawberry plants were planted in late evening hours. Shade was provided in open field for a week.

3.3.7. After cultivation

Weeding is done in the furrows as an when required. Irrigation was given especially during active vegetative growth and flowering stages.Biocontrol agents like *Pseudomonas fluorescens* ($10gl^{-1}$) and *Trichoderma*spp. ($10\ g\ l^{-1}$) were applied at 15 days intervals.

Lay out in the system

Planting strawberry

One month after planting

Plate 5. Lay out and planting

3.4. Observations

The observations on various growth parameters were taken from five sample plants selected randomly per plot at monthly intervals.

3.4.1. Observations on vegetative growth attributes

The following vegetative growth characters were observed and recorded.

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 countingfully 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 per each plant was counted.

3.4.2.3. Number of clusters per plant

Number of clusters arising in 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 per plant

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

3.4.3.3. Days to first harvest

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

3.4.3.4.Days to final harvest

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

3.4.3.5.Yield per plant

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

3.4.4.Quality attributes

Total soluble sugars (TSS), acidity, TSS/acidity ratio and total sugars were analysed.

3.4.4.1. Total soluble sugars (TSS)

Total soluble sugar 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 byRanganna (1997).A representative sample of 5 g macerated and digested with boiling water and made up to 100ml.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 estimatedas 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 nine 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 X.

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 relays 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 per cent 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 2:30pm using thermo-hygrometer. Temperature was expressed in ^{0}C while relative humidity was 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.

3.4.7.1. Isolation of the pathogen

The pathogen was isolated from naturally infected plants. The infected leaves were collected and cut into small bits with both healthy and infected portions and were surface sterilized with 0.1 per cent mercuric chloride solution for 30 seconds and then repeatedly washed in two to three charges of sterile water. These sterilized bits are then placed in potato-dextrose agar medium in sterile petridishes and incubated at room temperature. The pathogen in the infected portion grows and identified under the microscope.

3.5. Benefit cost ratio

It indicates the return on a rupee of investment. The ratio was worked out by ascertaining the current market price for the economic produce and the existing university wages to the men and women labourers employed and other costs. The ratio will serve as a measure, which would indicate whether the costs are proportionate with the returns obtained.

3.6. Statistical analysis

The data pertaining to the growth parameters and floral characters were subjected to statistical analysis by applying the technique of analysis of variance (ANOVA) for randomized block design(Panse and sukhatme,1985). The data pertaining to organoleptic evaluation were analysed using Kendall,s coefficient of concordance and Mann – Whitney test.

RESULTS

4.RESULTS

The results of the study pertaining to performance of strawberry(*Fragaria xananassa*Duch.) under three systems of growing, two time of planting and twotypes of mulching at two locations are presented under six captions *viz.,*

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

4.1 Vegetative growth attributes

Various observations on growth of strawberry under three growing systems*viz.,* open condition (S_1), greenhouse(S_2), and fan and pad system(S_3) in two time of planting *viz.,*last week of September (P_1) and last week of October (P_2),in two types of mulch *viz.,* white polyethylene mulch (M_1) and black polyethylene mulch (M_2) at two locations *viz.,*Central midland region (Location I)and High ranges (Location II) of Kerala were recorded, analyzed and the results are presented in Tables 4a to 6b.

4.1.1 Plant height

The data depicting the plant height of strawberry at two locations *viz.,*Central midlands and High ranges of Kerala are presented in Tables4a and 4b.

Table 4a. Effect of growing systems, time of planting and mulch on plant height (cm) of strawberry cv. Winter Dawn at two locations

Treatments		Location 1 (Central midlands)					Location 2 (High ranges)				
		Months after planting (MAP)					Months after planting (MAP)				
		1	2	3	4	5	1	2	3	4	5
Growing systems (S)	S_1	8.88	10.46	12.42	14.95	17.13	10.57	12.67	15.18	16.33	17.22
	S_2	7.12	8.28	9.45	10.72	11.86	11.27	13.67	16.42	17.58	18.77
	S_3	11.88	13.26	14.63	16.18	17.70	6.35	7.67	8.96	10.25	11.13
CD		1.66	1.82	1.86	1.80	1.85	1.23	1.20	1.00	1.06	1.09
Time of planting (P)	P_1	9.94	11.34	12.78	14.66	16.24	8.97	10.89	13.04	14.61	15.32
	P_2	8.64	9.99	11.55	13.24	14.89	9.82	11.78	14.00	14.83	16.09
CD		NS	NS	NS	NS	NS	NS	NS	0.03	NS	NS
Mulch (M)	M_1	9.33	10.70	12.23	13.94	15.47	9.19	11.00	13.28	14.61	15.51
	M_2	9.26	10.63	12.09	13.95	15.66	9.60	11.67	13.76	14.83	15.90
CD		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4b. Effect of P x M, S x P, S x M and S x P x M interactions on plant height (cm) of strawberry cv. Winter Dawn at two locations

Treatments		Location 1 (Central midlands)					Location 2 (High ranges)				
		Months after planting (MAP)					Months after planting (MAP)				
		1	2	3	4	5	1	2	3	4	5
P x M	P_1M_1	9.71	11.10	12.59	14.38	15.83	8.76	10.33	12.84	14.78	15.16
	P_1M_2	10.18	11.59	12.97	14.93	16.64	9.18	11.44	13.24	14.44	15.49
	P_2M_1	8.96	10.30	11.88	13.51	15.11	9.62	11.67	13.71	14.44	15.87
	P_2M_2	8.33	9.68	11.22	12.97	14.67	10.02	11.89	14.28	15.22	16.31
CD		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x P	S_1P_1	9.60	11.10	12.77	15.20	17.12	9.83	12.00	14.87	16.17	16.93
	S_1P_2	8.16	9.82	12.07	14.70	17.15	11.30	13.33	15.50	16.50	17.50
	S_2P_1	8.24	9.42	10.70	12.17	13.40	10.67	13.00	15.43	17.00	17.93
	S_2P_2	6.00	7.15	8.20	9.27	10.32	11.87	14.33	17.40	18.17	19.60
	S_3P_1	11.98	13.52	14.87	16.60	18.20	6.40	7.67	8.83	10.67	11.10
	S_3P_2	11.77	13.00	14.38	15.75	17.20	6.30	7.67	9.09	9.83	11.17
CD		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sx M	S_1M_1	8.45	9.92	11.95	14.43	16.60	10.30	12.50	14.70	15.83	16.60
	S_1M_2	9.32	11.00	12.88	15.47	17.67	10.83	12.83	15.67	16.83	17.83
	S_2M_1	6.79	7.90	9.05	10.30	11.33	11.37	13.17	16.53	17.50	18.90
	S_2M_2	7.45	8.67	9.85	11.13	12.38	11.17	14.17	16.30	17.67	18.63
	S_3M_1	12.75	14.28	15.70	17.10	18.48	5.90	7.33	8.60	10.50	11.03
	S_3M_2	11.00	12.23	13.55	15.25	16.92	6.80	8.00	9.33	10.00	11.23
CD		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SxPxM	$S_1P_1M_1$	9.17	10.63	12.37	14.73	16.67	9.67	11.67	14.33	15.67	16.40
	$S_1P_1M_2$	10.03	11.57	13.17	15.67	17.57	10.00	12.33	15.40	16.67	17.47
	$S_1P_2M_1$	7.73	9.20	11.53	14.13	16.53	10.93	13.33	15.07	16.00	16.80
	$S_1P_2M_2$	8.60	10.43	12.60	15.27	17.77	11.67	13.33	15.93	17.00	18.20
	$S_2P_1M_1$	7.69	8.67	9.83	11.27	12.33	10.67	12.00	15.60	17.33	18.13
	$S_2P_1M_2$	8.80	10.17	11.57	13.07	14.47	10.67	14.00	15.27	16.67	17.73
	$S_2P_2M_1$	5.90	7.13	8.27	9.33	10.33	12.07	14.33	17.47	17.67	19.67
	$S_2P_2M_2$	6.10	7.17	8.13	9.20	10.30	11.67	14.33	17.33	18.67	19.53
	$S_3P_1M_1$	12.27	14.00	15.57	17.13	18.50	5.93	7.33	8.60	11.33	10.93
	$S_3P_1M_2$	11.70	13.03	14.17	16.07	17.90	6.87	8.00	9.07	10.00	11.27
	$S_3P_2M_1$	13.23	14.57	15.83	17.07	18.47	5.87	7.33	8.60	9.67	11.13
	$S_3P_2M_2$	10.30	11.43	12.93	14.43	15.93	6.73	8.00	9.58	10.00	11.20
CD		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Location I (Central midlands)

In Central midland region, the response of growing systems(S) on plant height was significant. At1MAP, highest plant height of 11.88cm was recorded in S_3which was followed by S_1 (8.88 cm) and S_2(7.12 cm). At 2MAP and 3MAP also, same trend was observed as above in plant height. At 4MAP, S_3 recorded a highest plant height of 16.18cm which was on par with S_1 (14.95 cm) while at 5MAP also, S_3 recorded a highest plant height of 17.70 cm which was on par with S_1 (17.13cm).In general, lowest plant height was recorded under S_2 in all stages of growth.

Plant height did not vary significantly among different time of planting during all stages of growth.

It is concluded that the plant height was not significantly influenced by different mulch in all stages of growth.

P x M, Sx P,Sx M and S x P x M interactions had no significant effect on plant height in all stages of growth.

Location II (High ranges)

Growing systems showed significant influence on plant height in all stages of growth. At 1 MAP, the growing system S_2 recorded significantly higher plant height of 11.27cm which was on par with S_1 (10.57 cm). At 2 MAP, S_2 recorded maximum plant height of 13.67 cm which was on par with S_1 (12.67cm). At 3MAP, the growing system S_2 recorded the maximum plant height of 16.42cm which was followed by S_1 (15.18cm) and S_3 (8.96cm). At 4MAP and 5MAP also, same trend was observed as above in plant height. In general, lowest plant height was recorded under S_3 in all stages of growth.

Time of planting had significant effect on plant height only at 3MAP.At 3MAP, significantly higher plant height was recorded in T_2 (14.00cm) which was followed by T_1(13.04cm).

It is concluded that the mulch had no significant effect on plant height in all stages of growth.

P x M, S x P, S x M and S x P x M interactions had no significant effect on plant height in all stages of growth.

4.1.2 Number of leaves per plant

The data depicting the number of leavesper plant in strawberry at two locations *viz.,*Central midlands and High ranges of Kerala are presented in Tables 5a and 5b.

Location I (Central midlands)

Response of growing systems on number of leaves per plant was significant in all stages of growth. At 1MAP, S_3 recorded maximum number of leaves per plant (8.25) which was followed by S_2 (6.83) and S_1 (5.83). Same trend was observed in 2MAP also. At 3MAP, S_1 recorded the maximum number of leaves per plant (26.82) which was on par with S_3 (25.08). At 4MAP, S_1 recorded maximum number of leaves per plant 46.06 which was followed by S_3 (31.35) and S_2 (23.30). At 5 MAP also, same trend was observed as above in production of number of leaves per plant. In general, lowest number of leaves per plant was recorded under S_3 in all stages of growth except in 1 MAP.

Time of plantinghad significant effect on number of leaves per plant in all stages of growth.At 1MAP, P_1 recorded significantly higher number of leaves per plant (7.99) which was followed by P_2 (5.96). At 2MAP, P_1 recorded higher number

Table 5a. Effect of growing systems, time of planting and mulch on number of leaves of strawberry cv. Winter Dawn at two locations

Treatments		Location 1 (Central midlands)					Location 2 (High ranges)				
		Months after planting (MAP)					Months after planting (MAP)				
		1	2	3	4	5	1	2	3	4	5
Growing systems (S)	S_1	5.83	11.58	26.82	46.06	63.04	7.27	11.87	26.42	32.83	23.00
	S_2	6.83	11.55	17.70	23.30	20.05	7.82	10.77	15.95	19.07	13.15
	S_3	8.25	19.43	25.08	31.35	32.10	7.33	8.75	10.07	11.25	7.17
CD		0.81	2.86	3.62	5.66	9.30	NS	1.59	3.95	6.25	4.35
Time of planting (P)	P_1	7.99	16.94	26.18	36.73	42.47	7.92	11.69	19.09	22.11	14.20
	P_2	5.96	11.43	20.22	30.41	34.32	7.02	9.23	15.87	19.99	14.68
CD		0.66	2.33	2.96	4.62	7.59	0.67	1.30	NS	NS	NS
Mulch (M)	M_1	6.72	13.92	23.63	35.37	41.93	7.40	10.74	16.93	21.17	14.20
	M_2	7.22	14.46	22.77	31.77	34.86	7.54	10.18	18.02	20.93	14.68
CD		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 5b. Effect of P x M, SxP, Sx M and Sx P x M interactions on number of leaves of strawberry cv. Winter Dawn at two locations

Treatments		Location 1 (Central midlands)					Location 2 (High ranges)				
		Months after planting (MAP)					Months after planting (MAP)				
		1	2	3	4	5	1	2	3	4	5
P xM	P_1M_1	7.73	16.27	27.04	39.02	46.4	7.93	11.82	18.96	22.51	13.87
	P_1M_2	8.24	17.62	25.31	34.43	38.54	7.91	11.56	19.22	21.71	14.53
	P_2M_1	5.71	11.58	20.22	31.71	37.47	6.87	9.67	14.91	19.82	14.53
	P_2M_2	6.2	11.29	20.22	29.11	31.18	7.18	8.8	16.82	20.16	14.82
CD		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x P	S_1P_1	6.6	15.27	29.73	49.52	67.78	8.07	14.57	30.97	36.27	23.37
	S_1P_2	5.07	7.9	23.9	42.6	58.3	6.47	9.17	21.87	29.4	22.63
	S_2P_1	8.17	13.47	20.73	25.87	22.73	8.07	11.6	16.03	18.43	12.47
	S_2P_2	5.5	9.63	14.67	20.73	17.37	7.57	9.93	15.87	19.7	13.83
	S_3P_1	9.2	22.1	28.07	34.8	36.9	7.63	8.9	10.27	11.63	6.77
	S_3P_2	7.3	16.77	22.1	27.9	27.3	7.03	8.6	9.87	10.87	7.57
CD		NS	NS	NS	NS	NS	NS	2.24	NS	NS	NS
SxM	S_1M_1	5.47	11.8	27.8	49.67	69.1	6.9	11.73	24.13	31.8	21.47
	S_1M_2	6.2	11.37	25.83	42.45	56.98	7.63	12	28.7	33.87	24.53
	S_2M_1	6.6	10.4	17.37	23.17	22	8.1	11.7	16.37	19.9	14.17
	S_2M_2	7.07	12.7	18.03	23.43	18.1	7.53	9.83	15.53	18.23	12.13
	S_3M_1	8.1	19.57	25.73	33.27	34.7	7.2	8.8	10.3	11.8	6.97
	S_3M_2	8.4	19.3	24.43	29.43	29.5	7.47	8.7	9.83	10.7	7.37
CD		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sx P xM	$S_1P_1M_1$	5.93	14.53	29.87	53.13	74.13	7.87	14.27	30.13	36	21
	$S_1P_1M_2$	7.26	16	29.6	45.9	61.43	8.27	14.87	31.8	36.53	25.73
	$S_1P_2M_1$	5	9.07	25.73	46.2	64.07	5.93	9.2	18.13	27.6	21.93
	$S_1P_2M_2$	5.13	6.73	22.07	39	52.53	7	9.13	25.6	31.2	23.33
	$S_2P_1M_1$	7.6	11.47	20.6	25.27	23.8	8.68	12.6	16.47	19.27	14.07
	$S_2P_1M_2$	8.73	15.47	20.87	26.47	21.67	7.47	10.6	15.6	17.6	10.87
	$S_2P_2M_1$	5.6	9.33	14.13	21.07	20.2	7.53	10.8	16.27	20.53	14.27
	$S_2P_2M_2$	5.4	9.93	15.2	20.4	14.53	7.6	9.07	15.47	18.87	13.4
	$S_3P_1M_1$	9.67	22.8	30.67	38.67	41.27	7.27	8.6	10.27	12.27	6.53
	$S_3P_1M_2$	8.73	21.4	25.47	30.93	32.53	8	9.2	10.27	11	7
	$S_3P_2M_1$	6.53	16.33	20.8	27.87	28.13	7.13	9	10.33	11.33	7.4
	$S_3P_2M_2$	8.07	17.2	23.4	27.93	26.47	6.93	8.2	9.4	10.4	7.73
CD		1.62	NS	NS	NS	NS	NS	NS	NS	NS	NS

of leaves per plant (16.94) which was followed by P_2 (11.43). At 3 MAP also, P_1 recorded the higher number of leaves per plant (26.18) which was followed by P_2 (20.22). At 4 MAP and 5MAP also, P_1recorded the highest number of leaves per plant which were 36.73 and 42.47 respectively.

It is concluded that the mulch had no significant effect on number of leaves per plant in all stages of growth.

P x M, S x P and S x M interactions had no significant effect on number of leaves per plant. S x Px M interaction had significant influence on number of leaves per plant only at 1 MAP. At 1MAP, maximum number of leaves (9.67) was recorded in $S_3P_1M_1$ which was on par with $S_2P_1M_2$(8.73), $S_3P_1M_2$ (8.73) and S_3P_2M2 (8.07).The lowest number of leaves per plant was recorded under the combinations of $S_1P_2M_1$ (5.00),which was on par with $S_1P_2M_2$(5.13), $S_2P_2M_2$(5.40), $S_2P_2M_1$(5.60), $S_1P_1M_1$ (5.93), $S_3P_2M_1$ (6.53).

Location II (High ranges)

Growing systems hadsignificant effect on number of leaves per plant from 2MAP to 5MAP.At 2MAP, S_1 recorded significantly higher number of leaves per plant (11.87) which was on par with S_2 (10.77).At 3MAP, S_1 recorded maximum number of leaves (26.42) which was followed by S_2 (15.95) and S_3 (10.07).At 4 MAP, S_1recorded the maximum number of leaves (32.83) which was followed by S_2 (19.07) and S_3 (11.25).At 5 MAP also, S_1 recorded the highest number of leaves (23.00) which was followed by S_2 (13.15) and S_1 (7.17).From 2 MAP, lowest number of leaves per plant was recorded under S_3 in all stages of growth.

Time of planting had significant effect on number of leaves only at1MAP and 2MAP.At 1MAP, P_1 recorded highest number of leaves per plant (7.92) which

was followed by P_2 (7.02).At 2 MAP also, P_1 recorded the highest number of leaves per plant (11.69) which was followed by P_2 (9.23).

It is concluded that mulch had no significant effect on number of leaves during the entire period of growth.

S x Pinteractions on production of leaves per plant was significant only at 2MAP. The treatment combinations of S_1P_1 recorded significantly higher number of leaves per plant (14.57) which was followed by S_2P_1 (11.60), S_2P_2 (9.93), S_1P_2 (9.17), S_3P_1(8.90), S_3P_2(8.60).P x M, S x M and S x P x M interactions did not have significant influence on production of leaves per plant.

4.1.3 Plant spread

The data depicting the plant spread of strawberry at two locations *viz.,*Central midlands and High ranges of Kerala are presented in Tables 6a and 6b.

Location I (Central midlands)

Growing systemshad significant influence on plant spread from 1MAP to 3MAP.At 1MAP, S_3 recorded the highest plant spreadof 23.99 cm whichwas followed by S_2 (17.17 cm) and S_1 (11.98 cm).At 2MAP also,S_3 recorded the highest plant spread (36.48 cm) which was followed by S_2(24.13 cm) and S_1 (17.11 cm). At 3MAP, highest plant highest plant spread of 36.26 cm was recorded in S_3 which was followed by S_2 (26.83) and S_1 (22.34). At 4 MAP and 5 MAP, growing systems had no significant influence on plant spread.

Time of planting (P) also had a significant influence on plant spread only at 1 MAP and 2 MAP. At1 MAP, P_1 recorded the highest plant spread (18.87 cm) which was followed by P_2 (16.55 cm). At 2 MAPalso, P_1 recorded the highest plant

Table 6a. Effect of growing systems, time of planting and mulch on plant spread (cm) of strawberry cv. Winter Dawn at two locations

Treatments		Location 1 (Central midlands)					Location 2 (High ranges)				
		Months after planting (MAP)					Months after planting (MAP)				
		1	2	3	4	5	1	2	3	4	5
Growing systems (S)	S_1	11.98	17.11	22.34	28.89	35.40	15.48	19.30	23.86	26.35	27.75
	S_2	17.17	24.13	26.83	30.13	33.26	14.85	19.80	24.73	28.43	31.57
	S_3	23.99	36.48	36.26	36.02	33.73	10.30	14.41	17.91	19.85	22.00
CD		2.61	4.92	5.03	NS	NS	1.23	1.79	2.17	2.23	2.49
Time of planting (P)	P_1	18.87	28.11	30.60	33.65	35.60	13.43	17.68	22.49	24.44	26.69
	P_2	16.55	23.71	26.35	29.71	32.66	13.66	17.99	21.84	25.31	27.52
CD		2.13	4.02	NS	NS	NS	NS	NS	NS	NS	NS
Mulch (M)	M_1	17.08	25.24	27.49	30.41	33.52	14.08	18.23	22.47	24.69	26.93
	M_2	18.34	26.58	29.45	32.95	34.74	13.01	17.44	21.86	25.06	27.28
CD		NS	NS	NS	NS	NS	1.01	NS	NS	NS	NS

Table 6b. Effect of P x M, Sx P, Sx M and SxP x M interactions on plant spread (cm) of strawberry cv. Winter Dawn at two locations

Treatments		Location 1 (Central midlands)					Location 2 (High ranges)				
		Months after planting (MAP)					Months after planting (MAP)				
		1	2	3	4	5	1	2	3	4	5
P x M	P_1M_1	18.03	26.90	29.04	31.66	34.02	14.47	18.54	23.06	23.98	26.23
	P_1M_2	19.71	29.33	32.15	35.64	37.17	12.39	16.81	21.92	24.91	27.16
	P_2M_1	16.12	23.59	25.94	29.16	33.02	13.69	17.92	21.88	25.41	27.63
	P_2M_2	16.98	23.82	26.76	30.26	32.30	13.62	18.07	21.80	25.21	27.40
CD		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x P	S_1P_1	11.55	15.87	20.53	27.80	34.23	15.35	19.48	24.68	26.38	27.42
	S_1P_2	18.89	26.18	28.43	32.03	34.68	15.60	19.12	23.03	26.32	28.08
	S_2P_1	15.45	22.08	25.22	28.22	31.84	14.77	18.93	24.53	27.57	30.67
	S_2P_2	12.40	18.36	24.14	29.98	36.56	14.93	20.67	24.92	29.30	32.47
	S_3P_1	25.32	39.80	39.22	38.93	35.55	10.17	14.62	18.25	19.38	22.00
	S_3P_2	22.66	33.17	33.30	33.10	31.90	10.43	14.20	17.57	20.32	22.00
CD		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SxM	S_1M_1	11.50	15.77	20.02	25.72	31.62	15.73	18.97	23.27	25.98	27.42
	S_1M_2	12.45	18.46	24.66	32.06	39.18	15.22	19.63	24.45	26.72	28.08
	S_2M_1	15.92	23.45	26.22	30.70	35.31	16.07	21.10	26.07	28.27	31.37
	S_2M_2	18.43	24.82	27.43	29.55	31.22	13.63	18.50	23.38	28.60	31.77
	S_3M_1	23.82	36.52	36.25	34.80	33.63	10.43	14.63	18.07	19.83	22.02
	S_3M_2	24.16	36.45	36.27	37.23	33.82	10.17	14.18	17.75	19.87	21.98
CD		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SxPxM	$S_1P_1M_1$	11.17	16.13	21.03	26.17	32.27	16.00	19.43	23.60	25.30	26.33
	$S_1P_1M_2$	13.63	20.58	27.25	33.78	40.85	14.70	19.53	25.77	27.47	28.50
	$S_1P_2M_1$	11.83	15.40	19.00	25.27	30.97	15.47	18.50	22.93	26.67	28.50
	$S_1P_2M_2$	11.27	16.33	22.07	30.33	37.50	15.73	19.73	23.13	25.97	27.67
	$S_2P_1M_1$	17.03	24.10	26.10	30.70	33.63	17.10	21.53	27.47	27.70	30.60
	$S_2P_1M_2$	20.75	28.27	30.77	33.37	35.73	12.43	16.33	21.60	27.43	30.73
	$S_2P_2M_1$	14.80	22.80	26.33	30.70	36.98	15.03	20.67	24.67	28.83	32.13
	$S_2P_2M_2$	16.10	21.37	24.10	25.73	26.70	14.83	20.67	25.17	29.77	32.80
	$S_3P_1M_1$	25.90	40.47	40.00	38.10	36.17	10.30	14.67	18.10	18.93	21.77
	$S_3P_1M_2$	24.73	39.13	38.43	39.77	34.93	10.03	14.57	18.40	19.83	22.23
	$S_3P_2M_1$	21.73	32.57	32.50	31.50	31.10	10.57	14.60	18.03	20.73	22.27
	$S_3P_2M_2$	23.58	33.77	34.10	34.70	32.70	10.30	13.80	17.10	19.90	21.73
CD		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

spread (28.11 cm) which was followed by P_2 (23.71 cm). From 3 MAP to 5 MAP, plant spread was not significantly influenced by the time of planting.

It is concluded that the mulch had no significant effect on plant spread in all stages of growth.

P x M, S x P, S x M and S x P x M interactions had no significant effect on plant spread in all stages of growth.

Location II (High ranges)

Growing system had significant effect on plant spread up to 5MAP.At1MAP, S_1 recorded highest plant spread of 15.48 cm which was on par with S_2 (14.85 cm).At 2MAP, S_2 recorded the maximum plant spread of 19.80 cmwhich was on par with S_1 (19.30 cm).At 3MAP, S_2recorded maximumplant spreadof 24.73 cm which was on par with S_1 (23.86 cm). At 4MAP, S_2 recorded the highest plant spread of 28.43 cm which was on par with S_1 (26.35 cm). However at 5MAP, S_2 recorded the highest plant spread of 31.57 cm which was followed by S_1(27.75 cm) and S_3 (22.0 cm). In general, lowest plant spread was observed in S_3 in all stages of growth.

Plant spread did not vary significantly among different time of planting during all stages of growth.

Mulch had significant influence on plant spread onlyat 1MAP.At1MAP, M_1 recorded the maximum plant spread (14.08 cm) which was followed by M_2(13.01 cm).

P x M, S x P, S x M and S x P x M interactions had no significant effect on plant spread in all stages of growth.

4.2 Flowering attributes

Various observations on flowering attributes of strawberryunder three growing systems *viz.,* open condition (S_1), greenhouse (S_2), and fan and pad system (S_3) in two time of planting *viz.,* last week of September (P_1) and last week of October (P_2), in two types of mulch *viz.,* white polyethylene mulch (M_1) and black polyethylene mulch (M_2) at two locations *viz.,* Central midland region and High ranges of Kerala were recorded, analyzed and the results are presented in Tables 7a and 7b.

4.2.1 Days to first flowering

Analysis of the data corresponding to days to first flowering of strawberry at two locations *viz*.,Central midlands and High ranges of Kerala is presented in Tables 7a and 7b.

Location I (Central midlands)

Growing system has significant effect on days to first flowering.S_3took minimum duration of 55.67 days for flowering which was followed by S_2(56.92 days) and S_1 (62.83 days).

Days to flowering did not vary significantly among different time of planting.

Mulch has significant effect on days to first flowering.M_2 took minimum duration of 57.11 days for flowering, while M_1 took maximum duration of 59.83 days for first flowering.

S x M interactions on days to first flowering was significant.The S_3M_2 recorded minimum days forfirst flowering (55 days) which was on par with S_2M_2

Table7a.Effect of growing systems,time of planting and mulch on flowering attributes of strawberry cv. Winter Dawn at two locations

Treatments		Location 1(Central mid-lands)			Location 2(High ranges)		
		Days to first flowering	No. of flowers per plant	No. of clusters per plant	Days to first flowering	No. of flowers per plant	No. of clusters per plant
Growing systems (S)	S_1	62.83	7.15	3.63	40.00	20.78	17.47
	S_2	56.92	5.45	3.02	40.83	11.07	8.97
	S_3	55.67	7.97	4.17	40.00	8.69	4.29
CD		0.59	NS	NS	NS	2.61	2.67
Time of planting (P)	P_1	58.39	7.42	3.89	40.56	13.88	10.57
	P_2	58.56	6.29	3.32	40.00	13.14	9.91
CD		NS	NS	NS	NS	NS	NS
Mulch (M)	M_1	59.83	6.11	3.31	40.00	12.43	2.97
	M_2	57.11	7.60	3.90	40.56	14.60	3.72
CD		0.84	NS	NS	NS	NS	NS

(55.5 days) except S_3M_1 (56.33 days), S_2M_1 (58.33 days), S_1M_2(60.83 days) and S_1M_1 (64.83 days).

Location II (High ranges)

Growing systems had no significant effect on days to first flowering.

Days to first flowering did not vary significantly among different time of planting.

It is concluded that the mulch had no significant effect on days to first flowering.

P x M, S x P, S x M and S x P x M interactions had no significant effect on days to first flowering.

4.2.2 Number of flowers per plant

Analysis of the data corresponding to number of flowers per plant of strawberry atCentral midlands and High ranges of Kerala is presented in Tables7a and 7b.

Location I (Central midlands)

Growing systems had no significant influence on number of flowers per plant.

Number of flowers per plant did not vary significantly among different time of planting.

It is concluded that the mulch had no significant effect on number of flowers per plant.

P x M, S x P, S x M and S x P x M interactions had no significant effect on number of flowers per plant.

Location II (High ranges)

In high ranges, growing systems had significant influence on production of flowers per plant. Growing system, S_1recorded highest number of flowers per plant (20.78) which was followed by S_2 (11.07) and S_3 (8.69).

Number of flowers per plant did not vary significantly among different time of planting.

It is concluded that the mulch had no significant effect on number of flowers per plant.

SxM interactions on number of flowers per plant was significant. The interaction S_1M_2 recorded significantly highest number of flowers per plant(25.85) which was followed by S_1M_1 (15.72), S_2M_1(13.23), S_3M_2(9.05), S_2M_2(8.90), S_3M_1(8.33).P x M, S x P and S x P x M interactions did not have significant influence on number of flowers per plant.

4.2.3 Number of clusters per plant

Analysis of the data corresponding to number of clusters per plant of strawberry atCentral midlands and High ranges of Kerala is presented in Tables7a and 7b.

Location I (Central midlands)

Growing systems had no significant influence on number of clusters per plant.

Number of clusters per plant did not vary significantly among different time of planting.

It is concluded that the mulch had no significant effect on number of clusters per plant.

Vegetative growth

Flowering and fruiting stages

Mature fruits

Plate 6. Different stages of growth

Plate 7. Stages of flowering to fruiting

Table 7b.Effect of P x M, S x P, S x M and S x P x M interactions on flowering attributes of strawberry cv. Winter Dawn at two locations

Treatments		Location 1(Central midlands)			Location 2(High ranges)		
		Days to first flower	No. of flowers per plant	No. of clusters per plant	Days to first flower	No. of flowers per plant	No. of clusters per plant
P x M	P_1M_1	59.78	6.47	3.47	40.00	12.43	9.46
	P_1M_2	57.00	8.38	4.31	41.11	15.33	11.69
	P_2M_1	59.89	5.76	3.16	40.00	12.42	9.46
	P_2M_2	57.22	6.82	3.49	40.00	13.87	10.37
CD		NS	NS	NS	NS	NS	NS
S x P	S_1P_1	62.50	8.10	4.10	40.00	20.92	18.83
	S_1P_2	63.17	6.20	3.17	40.00	20.65	16.10
	S_2P_1	57.00	5.30	3.00	41.67	11.10	8.07
	S_2P_2	56.83	5.60	3.03	40.00	11.03	9.87
	S_3P_1	55.67	8.87	4.57	40.00	9.63	4.82
	S_3P_2	55.67	7.07	3.77	40.00	7.75	3.77
CD		NS	NS	NS	NS	NS	NS
S x M	S_1M_1	64.83	5.47	2.83	40.00	15.72	13.37
	S_1M_2	60.83	8.83	4.43	40.00	25.85	21.57
	S_2M_1	58.33	5.30	3.07	40.00	13.23	10.90
	S_2M_2	55.50	5.60	2.97	41.67	8.90	7.03
	S_3M_1	56.33	7.57	4.03	40.00	8.33	4.10
	S_3M_2	55.00	8.37	4.30	40.00	9.05	4.48
CD		0.84	NS	NS	NS	3.70	3.78
S x P x M	$S_1P_1M_1$	64.67	6.27	3.20	40.00	14.83	13.27
	$S_1P_1M_2$	60.33	9.93	5.00	40.00	27.00	24.40
	$S_1P_2M_1$	65.00	4.67	2.47	40.00	16.60	13.47
	$S_1P_2M_2$	61.33	7.73	3.87	40.00	24.70	18.73
	$S_2P_1M_1$	58.33	4.80	2.87	40.00	13.33	10.53
	$S_2P_1M_2$	55.67	5.80	3.13	43.33	8.87	5.60
	$S_2P_2M_1$	58.33	5.80	3.27	40.00	13.13	11.27
	$S_2P_2M_2$	55.33	5.40	2.80	40.00	8.93	8.47
	$S_3P_1M_1$	56.33	8.33	4.33	40.00	9.13	4.57
	$S_3P_1M_2$	55.00	9.40	4.80	40.00	10.13	5.07
	$S_3P_2M_1$	56.33	6.80	3.73	40.00	7.53	3.63
	$S_3P_2M_2$	55.00	7.33	3.80	40.00	7.97	3.90
CD		NS	NS	NS	NS	NS	NS

P x M, S x P, S x M and S x P x M interactions had no significant effect on number of clusters per plant.

Location II (High ranges)

Growing systems had significant influence on number of clusters per plant. Growing system, S_1 recorded the maximum number of clusters per plant (17.47) which was followed by S_2(8.97) and S_3(4.29).

Number of clusters per plant did not vary significantly among different time of planting.

It is concluded that the mulch had no significant effect on number of clusters per plant.

S x Minteraction on number of clusters per plant was significant. S_1M_2 recorded the highest number of clusters perplant (21.57) which was followed by S_1M_1(13.37), S_2M_1 (10.90), S_2M_2(7.03), S_3M_2 (4.48) and S_3M_1 (4.10).P x M, S x P and S x P x M interactions did not have significant influence on production of clusters per plant.

4.3. Yield attributes

Various observations on yield characters of under three growing systems *viz.,* open condition (S_1), greenhouse (S_2), and fan and pad system (S_3) in two time of planting *viz.,* last week of September (P_1) and last week of October (P_2), in two types of mulch *viz.,* white polyethylene mulch (M_1) and black polyethylene mulch (M_2) at two locations *viz.,*Central midland region and High ranges of Kerala were recorded, analyzed and the results arepresented in Tables 8a and 8b.

4.3.1 Number of fruits per plant

The data depicting the number of fruits per plant of strawberry at two locations *viz.,*Central midlands and High ranges of Kerala are presented in Tables8a and 8b.

Location I (Central midlands)

Growing systems had significant influenceon number of fruits per plant. S_3recorded the maximum number of fruits per plant (5.87) which was on par with S_1 (4.55).Lowest number of fruits per plant was registered in S_2 (3.31).

Number of fruits per plant varies significantly among different time of planting. T_1recorded maximum number of fruits per plant (5.43) which was followed by T_2 (3.72).

It is concluded that the mulch had no significant effect on number of fruits per plant.

P x M, S x P, S x M and S x P x M interactions had no significant effect on number of fruits per plant.

Location II (High ranges)

Growing systems had a significant effect in the number of fruits per plant. S_1recorded maximum number of fruits per plant (8.97) which was on par with S_2(7.82). Lowest number of fruits per plant was recorded in S_3 (6.33).

Number of fruits per plant did not vary significantly among different time of planting.

It is concluded that the mulch had no significant effect on number of fruits per plant.

Table 8a. Effect of growing systems,time of planting and mulch on yield attributes of strawberry cv. Winter Dawn at two locations

Treatments		Location I (Central midlands)					Location II (High ranges)				
		No. of fruits per plant	Yield per plant (g)	Average fruit weight per plant (g)	Days to first harvest	Days to final harvest	No. of fruits per plant	Yield per plant (g)	Average fruit weight per plant (g)	Days to first harvest	Days to final harvest
Growing systems (S)	S_1	4.55	32.67	7.35	132.83	163.25	8.97	80.35	8.79	81.17	153.33
	S_2	3.31	23.75	7.35	82.67	139.50	7.82	61.27	7.76	86.75	173.00
	S_3	5.87	40.90	6.67	84.50	153.00	6.33	41.52	6.56	103.17	137.42
CD		1.82	NS	NS	9.44	7.36	1.88	17.49	0.88	5.43	8.61
Time of planting (P)	P_1	5.43	38.19	6.98	99.33	154.78	7.59	58.65	7.51	88.44	148.22
	P_2	3.72	26.69	7.27	100.67	149.06	7.82	63.45	7.90	92.28	160.94
CD		1.49	NS	NS	NS	NS	NS	NS	NS	NS	7.03
Mulch (M)	M_1	4.09	27.93	6.81	104.94	150.67	7.69	57.92	7.38	91.39	158.11
	M_2	5.06	36.95	7.44	95.06	153.17	7.72	64.17	8.03	89.33	151.06
CD		NS	NS	NS	13.35	NS	NS	NS	NS	NS	NS

S x M interaction had significant influence on number of fruits per plant. S_1M_2 recorded maximum number of fruits per plant (10.53) and was on par with S_2M_1 (9.03).Lowest number of fruits per plant was recorded in S_3M_2 (6.02) which was on par with S_2M_2 (6.60), S_3M_1 (6.65), S_1M_1 (7.40). P x M, S x P and S x P x M interactions did not have significant effect on number of fruits per plant.

4.3.2 Yield per plant

The data depicting the yield per plant of strawberry at two locations *viz.,*Central midlands and High ranges of Kerala are presented in Tables8a and 8b.

Location I (Central midlands)

Growing systems hadno significant effect on yield per plant.

Yield per plant did not vary significantly among different time of planting.

It is concluded that the yield per plant was not significantly influenced by different types of mulch.

P x M, S x P, S x M and S x P x M interactions had no significant effect on yield per plant in all stages of growth.

Location II (High ranges)

Growing systems had significant effect on yield per plant.S_1recorded maximum yield per plant (80.35g) which was followed by S_2(61.27 g) and S_3(41.52g).

Yield per plant did not vary significantly among different time of planting.

It is concluded that the yield per plant was not significantly influenced by different types of mulch.

S x M interaction had significant effect on yield per plant. The interaction S_1M_2recorded the maximum yield per plant (102.17 g) which was followed by S_2M_1 (71.87 g), S_1M_1 (58.53 g), S_2M_2 (50.67 g), S_3M_1 (43.36 g) and S_3M_2 (39.69 g).P x M, S x P and S x P x M interactions did not have significant influence on yield per plant.

4.3.3 Average fruit weight per plant

The data depicting the average fruit weight per plant of strawberry at two locations *viz.,*Central midlands and High ranges of Kerala are presented in Tables8a and 8b.

Location I (Central midlands)

Growing systems had no significant effect on average fruit weight per plant.

Average fruit weight per plant did not vary significantly among different time of planting.

It is concluded that the average fruit weight per plant was not significantly influenced by different types of mulch.

P x M, S x P, S x M and S x P x M interactions had no significant effect on average fruit weight per plant in all stages of growth.

Location II (High ranges)

Growing systems had significant effect on average fruit weight per plant.S_1recorded maximum average fruit weight per plant (8.79 g) which was followed by S_2 (7.76 g) and S_3 (6.56 g).

Average fruit weight per plant did not vary significantly among different time of planting.

Table 8b. Effect of P x M, S x P, S x M and S x P x M interactions on yield attributes of strawberry cv. Winter Dawn at two locations

Treatments		Location 1 (Central midlands)					Location 2 (High ranges)				
		No. of fruits per plant	Yield per plant (g)	Average fruit weight per plant (g)	Days to first harvest	Days to final harvest	No. of fruits per plant	Yield per plant (g)	Average fruit weight per plant (g)	Days to first harvest	Days to final harvest
PxM	P_1M_1	4.56	31.78	6.98	102.00	153.78	7.39	52.76	7.09	90.67	145.22
	P_1M_2	6.30	44.59	6.98	96.67	155.78	7.80	64.54	7.93	86.22	151.22
	P_2M_1	3.62	24.09	6.65	107.89	147.56	8.00	63.08	7.67	92.11	171.00
	P_2M_2	3.82	29.30	7.90	93.44	150.56	7.63	63.81	8.13	92.44	150.89
CD		NS	NS	NS	NS	NS	NS	NS	NS	NS	9.94
S x P	S_1P_1	5.93	38.09	6.12	131.33	163.17	8.40	77.20	8.97	77.50	147.33
	S_1P_2	3.17	27.26	8.58	134.33	163.33	9.53	83.50	8.62	84.83	159.33
	S_2P_1	3.55	27.60	8.00	82.00	146.83	7.50	54.87	7.24	85.50	169.67
	S_2P_2	3.07	19.90	6.70	83.33	132.17	8.13	67.67	8.29	88.00	176.33
	S_3P_1	6.80	48.87	6.82	84.67	154.33	6.88	43.88	6.33	102.33	127.67
	S_3P_2	4.93	32.92	6.53	84.33	151.67	5.78	39.17	6.80	104.00	147.17
CD		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SxM	S_1M_1	3.53	23.27	6.58	151.33	166.50	7.40	58.53	7.84	80.17	147.67
	S_1M_2	5.57	42.08	8.12	114.33	160.00	10.53	102.17	9.75	82.17	159.00
	S_2M_1	2.73	19.05	7.32	81.83	132.50	9.03	71.87	7.80	89.67	175.17
	S_2M_2	3.88	28.45	7.38	83.50	146.50	6.60	50.67	7.73	83.83	170.83
	S_3M_1	6.00	41.48	6.54	81.67	153.00	6.65	43.36	6.51	104.33	151.50
	S_3M_2	5.73	40.31	6.81	87.33	153.00	6.02	39.69	6.62	102.00	123.33
CD		NS	NS	NS	13.35	10.41	2.66	24.62	NS	NS	12.17
SxP xM	$S_1P_1M_1$	4.13	25.60	6.33	143.67	166.00	5.53	44.33	7.97	80.67	135.67
	$S_1P_1M_2$	7.73	50.58	5.90	119.00	160.33	11.27	110.07	9.97	74.33	159.00
	$S_1P_2M_1$	2.93	20.94	6.83	159.00	167.00	9.27	72.73	7.70	79.67	159.67
	$S_1P_2M_2$	3.40	33.57	10.33	109.67	159.67	9.80	94.27	9.53	90.00	159.00
	$S_2P_1M_1$	2.67	22.15	8.41	81.00	142.33	8.87	65.33	7.24	86.67	174.00
	$S_2P_1M_2$	4.43	33.05	7.58	83.00	151.33	6.13	44.40	7.23	84.33	165.33
	$S_2P_2M_1$	2.80	15.94	6.22	82.67	122.67	9.20	78.40	8.36	92.67	176.33
	$S_2P_2M_2$	3.33	23.85	7.18	84.00	141.67	7.07	56.93	8.23	83.33	176.33
	$S_3P_1M_1$	6.87	47.59	6.19	81.33	153.00	7.77	48.61	6.06	104.67	126.00
	$S_3P_1M_2$	6.73	50.15	7.45	88.00	155.67	6.00	39.15	6.60	100.00	129.33
	$S_3P_2M_1$	5.13	35.37	6.88	82.00	153.00	5.53	38.11	6.95	104.00	177.00
	$S_3P_2M_2$	4.73	30.47	6.17	86.67	150.33	6.03	40.23	6.65	104.00	117.33
CD		NS	NS	NS	NS	NS	NS	NS	NS	NS	17.21

It is concluded that the average fruit weight per plant was not significantly influenced by different types of mulch.

P x M, S x P, S x M and S x P x M interactions had no significant effect on average fruit weight per plant in all stages of growth.

4.3.4 Days to first harvest

Data that depict the number of days to first harvest in two locations *viz*., Central midlands and High ranges are presented in Tables 8a and 8b.

Location I (Central midlands)

Growing systems had a significant influence on the number of days to first harvest.Growing system, S_2recorded minimum days to first harvest (82.67 days)which was on par withS_3 (84.5 days). S_1 recorded maximum days to first harvest(132.83 days).

Days to first harvest did not vary significantly among different time of planting.

Mulch had a significant influence on days to first harvest.M_2 took minimum days to first harvest (95.06 days) which was on par with M_1 (104.94 days).

S x M interaction had a significant influence on the number of days to first harvest.S_3M_1 took minimum days to first harvest (81.67 days) which was on par withS_2M_1 (81.83 days), S_2M_2 (83.50 days) andS_3M_2 (87.33 days). S_1M_1 (151.33days) interactions recorded significantly higher number of days to first harvest which was followed by S_1M_2 (114.33 days). P x M, S x P and S x P x M interactions had no significant influence on number of days to first harvest of the crop.

Location II (High ranges)

Growing system had significant influence on days to first harvest. Growing system, S_1 took minimum days to first harvest (81.17 days) which was followed by S_2(86.75 days) and S_3(103.17 days).

Days to first harvest did not vary significantly among different time of planting.

It is concluded that days to first harvest was not significantly influenced by type of mulch.

P x M, S x P, S x M and S x P x M interactions had no significant influence on number of days to first harvestof the crop.

4.3.5. Daysto final harvest

Data that depict the number of days to final harvest at two locations *viz.*, Central midlands and High ranges of Kerala are presented in Tables 8a and 8b.

Location I (Central midlands)

Growing systems had a significant influence on the number of days to final harvest. Growing system, S_1 recorded the maximum days to final harvest (163.25 days) which was followed by S_3 (153.0 days) and S_2(139.5 days).

Days to final harvest did not vary significantly among different time of planting.

It is concluded that days to final harvest was not significantly influenced by different types of mulch.

S x M interactions significantly influence the number of days to final harvest. Interaction S_1M_1 recorded the maximum number of days to final harvest (166.50 days) which was on par with S_1M_2 (160 days). S_3M_1 and S_3M_2 recorded 153.00 days for final harvest which was on par with S_2M_2 (146.50 days).The minimum number of days to final harvest was recorded in S_2M_1(132.50 days).P x M, S x Pand S x P x M interactions had no significant effect on number of days to final harvest.

Location II (High ranges)

Growing systems had a significant influence on the number of days to final harvest. Growing system, S_2 recorded maximum number of days to final harvest (173 days) which was followed by S_1 (153.33 days) and S_3 (137.42 days).

Time of planting had significant influence on number of days to final harvest. Treatment P_2 recorded the maximum days to final harvest (160.94 days) which was followed byT_1(148.22 days).

It is concluded that days to final harvest was not significantly influenced by different types of mulch.

P x M, S x M and S x P x Minteractions had significant influence on number of days to final harvest.P_2M_1interaction recorded significantly maximum days to final harvest (171.00 days). Minimum days to final harvest were recorded in P_1M_1(145.22 days)which was on par withP_2M_2 (150.89 days) and P_1M_2 (151.22 days).

S x M interactions was significant on days to final harvest. S_2M_1interaction recorded significantly maximum days to final harvest (175.17 days) which was on par with S_2M_2 (170.83 days). S_1M_2 interaction recorded 159 days to final harvest which was on par with S_3M_1 (151.50 days) and S_1M_1 (147.67 days). Lowest days to final harvest was recorded in S_3M_2 (123.33 days).

S x P x M interactions had significant influence on days to final harvest. Maximum days to final harvest were observed in interaction $S_3P_2M_1$ (177.00 days) which was on par with $S_2P_2M_1$ (176.33 days), $S_2P_2M_2$ (176.33 days), $S_2P_1M_1$ (174.00 days)and $S_2P_1M_2$ (165.33 days).The combination $S_3P_2M_2$recorded minimum duration of 117.33 days for final harvesting.

4.4 Quality attributes

Various observations on quality characters of strawberry fruits under three growing systems *viz.,* open condition (S_1), greenhouse (S_2), and fan and pad system (S_3) in two time of planting *viz.,* last week of September (P_1) and last week of October (P_2), in two types of mulch *viz.,* white polyethylene mulch (M_1) and black polyethylene mulch (M_2) at two locations *viz.,*Central midland region and High ranges of Kerala were recorded, analyzed and the resultsare presented in Tables 9a and 9b.

4.4.1 Total soluble solids (TSS)

Data that depict the TSS of strawberry fruits in two locations viz., Central midlands and High ranges are presented in Tables 9a and 9b.

Location I (Central midlands)

Growing systems had no significant impact on the TSS of strawberry fruits.

Time of planting (T) had significant effect on TSS of strawberry fruits. T_1 recorded maximum TSS content of 9.34^0Brix which was followed by T_2 (8.61^0Brix).

It is concluded that TSS was not significantly influenced by type of mulch.

Table 9a. Effect of growing systems, time of planting and mulch on quality attributes of strawberry cv. Winter Dawn at two locations

Treatments		Location 1 (Central midlands)					Location 2(High ranges)				
		TSS (^{0} Brix)	Acidity (per cent)	TSS/ acidity	Total sugars (per cent)	Shelf life (days)	TSS (^{0} Brix)	Acidity (per cent)	TSS/ acidity	Total sugars (per cent)	Shelf life (days)
Growing systems (S)	S_1	8.86	0.13	69.21	6.03	3	10.49	0.15	74.80	5.81	3
	S_2	8.84	0.14	65.97	4.40	3	11.07	0.13	86.46	5.88	3
	S_3	9.23	0.13	72.07	5.02	3	8.48	0.56	15.46	3	3
CD		NS	NS	NS	0.54	NS	0.58	0.04	8.83	0.11	NS
Time of planting (P)	P_1	9.34	0.14	70.93	5.04	3	10.1	0.26	59.22	5.23	3
	P_2	8.61	0.13	67.23	5.26	3	9.93	0.29	58.6	5.21	3
CD		0.54	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mulch (M)	M_1	8.83	0.13	69.01	5.17	3	9.82	0.26	58.85	5.31	3
	M_2	9.12	0.14	69.15	5.12	3	10.21	0.29	58.96	5.14	3
CD		NS	NS	NS	NS	NS	NS	NS	NS	0.09	NS

T x M interaction has significant effect on TSS. The interaction T_1M_1 recorded maximum TSS content of 9.49^{0}Brix which was on par with T_1M_2(9.20^{0}Brix) and T_2M_2 (9.03^{0}Brix). The combination T_2M_1 recorded minimum TSS content of 8.18 ^{0}Brix.

Location II (High ranges)

Growing systems (S) had significant effect on TSS.Among growing systems, S_2 recorded significantly higher TSS content 11.07^{0}Brix which was on par with S_1 (10.49^{0}Brix).

TSS did not significantly influenced by different time of planting.

It is concluded that TSS was not significantly influenced by different types of mulch.

S x Pinteraction has significant effect on TSS. The interaction S_2P_1 recorded highest TSS content of 11.47^{0}Brix which was on par with S_1P_2(10.97^{0}Brix)and S_2P_2 (10.67^{0}Brix).Lowest TSS was recorded in S_3T_2(5.03 ^{0}Brix).

S x Minteraction has significant effect on TSS. The interaction S_2M_1 recorded highest TSS content of 11.32^{0}Brix which was on par with S_2M_2(10.82^{0}Brix) and S_1M_2 (10.73^{0}Brix). Lowest TSS was recorded in S_3M_1 (7.9^{0}Brix).

4.4.2 Acidity

Data that depict the acidity of strawberryfruits in two locations viz., Central midlands and High ranges are presented in Tables 9a and 9b.

Location I (Central midlands)

Growing systems had no significant influence on the acidity of strawberry fruits.

Acidity did not significantly influenced by different time of planting.

It is concluded that acidity was not significantly influenced by type of mulch.

P x M, S x P, S x M and S x P x M interactions had no significant effect on acidity of strawberry.

Location II (High ranges)

Growing systems had significanceinfluence on the acidity of strawberry fruits.The greenhouse system (S_2)recorded minimum acidity (0.13per cent) which was followed by S_1(0.15percent).

Acidity did not significantly influenced by different time of planting.

It is concluded that acidity was not significantly influenced by different type of mulch.

P x M, S x P, S x M and S x P x M interactions had no significant effect on acidity of strawberry.

4.4.3 TSS/acidity

Data that depict the TSS/acidity of strawberryfruits at two locations *viz*., Central midlands and High ranges are presented in Tables 9a and 9b.

Location I (Central midlands)

Growing systemshad no significantinfluenceon the TSS/acidity of fruits.

TSS/acidity did not significantly influenced bydifferent time of planting.

Table 9b Effect of P x M, Sx P, Sx P and Sx P x M interactions on quality attributes of strawberry cv. Winter Dawn at two locatıons

Treatments		Location 1 (Central midlands)					Location 2(High ranges)				
		TSS (^{0} Brix)	Acidity (per cent)	TSS/ acidity	Total sugars (per cent)	Shelf life (days)	TSS (^{0} Brix)	Acidity (per cent)	TSS/ acidity	Total sugars (per cent)	Shelf life (days)
PxM	P_1M_1	9.49	0.13	74.13	4.80	3	9.84	0.24	61.13	5.36	3
	P_1M_2	9.20	0.14	67.73	5.27	3	10.36	0.30	57.31	5.11	3
	P_2M_1	8.18	0.13	63.89	5.54	3	9.80	0.28	56.58	5.26	3
	P_2M_2	9.03	0.13	70.57	4.98	3	10.06	0.28	60.61	5.17	3
CD		0.76	NS	6.20	0.63	NS	NS	NS	NS	NS	NS
SxP	S_1P_1	9.43	0.13	73.70	5.73	3	10.02	0.15	71.42	5.70	3
	S_1P_2	8.28	0.13	64.71	6.33	3	10.97	0.15	78.19	5.92	3
	S_2P_1	9.33	0.15	66.70	4.33	3	11.47	0.13	89.58	6.00	3
	S_2P_2	8.35	0.13	65.23	4.47	3	10.67	0.13	83.34	5.75	3
	S_3P_1	9.27	0.13	72.40	5.05	3	8.82	0.54	16.66	4.00	3
	S_3P_2	9.18	0.13	71.75	4.98	3	8.15	0.58	14.26	3.98	3
CD		NS	NS	NS	NS	NS	0.82	NS	NS	0.15	NS
SxM	S_1M_1	8.63	0.13	67.45	6.15	3	10.25	0.15	72.59	5.98	3
	S_1M_2	9.08	0.13	70.96	5.91	3	10.73	0.15	77.02	5.63	3
	S_2M_1	8.60	0.13	67.19	4.35	3	11.32	0.13	88.41	5.95	3
	S_2M_2	9.08	0.15	64.74	4.46	3	10.82	0.13	84.51	5.80	3
	S_3M_1	9.27	0.13	72.40	5.03	3	7.90	0.52	15.56	3.99	3
	S_3M_2	9.18	0.13	71.75	5.01	3	9.07	0.60	15.37	3.99	3
CD		NS	NS	NS	NS	NS	0.82	NS	NS	0.15	NS
SxPxM	$S_1P_1M_1$	9.83	0.13	76.82	5.50	3	9.53	0.13	74.48	5.90	3
	$S_1P_1M_2$	9.03	0.13	70.57	5.95	3	10.50	0.17	68.36	5.50	3
	$S_1P_2M_1$	7.43	0.13	58.07	6.80	3	10.97	0.17	70.70	6.07	3
	$S_1P_2M_2$	9.13	0.13	71.35	5.87	3	10.97	0.13	85.68	5.77	3
	$S_2P_1M_1$	9.37	0.13	73.18	4.09	3	11.70	0.13	91.40	6.17	3
	$S_2P_1M_2$	9.30	0.17	60.21	4.57	3	11.23	0.13	87.76	5.83	3
	$S_2P_2M_1$	7.83	0.13	61.20	4.61	3	10.93	0.13	85.42	5.73	3
	$S_2P_2M_2$	8.87	0.13	69.27	4.34	3	10.40	0.13	81.25	5.77	3
	$S_3P_1M_1$	9.27	0.13	72.40	4.83	3	8.30	0.48	17.51	4.01	3
	$S_3P_1M_2$	9.27	0.13	72.40	5.28	3	9.33	0.60	15.82	4.00	3
	$S_3P_2M_1$	9.27	0.13	72.40	5.23	3	7.50	0.56	13.62	3.97	3
	$S_3P_2M_2$	9.10	0.13	71.09	4.73	3	8.80	0.60	14.91	3.98	3
CD		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

It is concluded that TSS/acidity was not significantly influenced by different type of mulch.

Among interactions, P x M had significant effect on TSS/acidity ratio.P_1M_1 recorded the maximum TSS/acidity ratio (74.13) which was on par with P_2M_2 (70.57). P_2M_1 recorded the minimum value for TSS/acidity ratio (63.89) which was on par with P_1M_2 (67.73).

Location II (High ranges)

Growing systems have significant influence on TSS/acidity of fruits.TSS/acidity ratio was very high in S_2 (86.46) which was followed by S_1 (74.80) and S_3 (15.46).

TSS/acidity ratio of fruits was not significantly influenced by different time of planting.

It is concluded that TSS/acidity ratio of the fruits was not significantly influenced by different types of mulches.

P x M, S x P, S x M and S x P x M interactions had no significant influence on TSS/acidity ratio of strawberry fruits.

4.4.4 Total sugars

Data that depict the total sugars in strawberry fruits at two locations *viz*., Central midlands and High ranges are presented in Tables 9a and 9b.

Location I (Central midlands)

Growing systems have significant effect on total sugars content of fruits. Growing system S_1 recorded the highest total sugar content of 6.03 per cent which was followed by S_3 (5.02 per cent) and S_2 (4.40 per cent).

Time of planting did not have a significant influenceon total sugars of the fruits.

It is concluded that total sugar content of fruits was not significantly influenced by different typeof mulch.

Px Minteractions had significantinfluence on total sugar content of the fruits. P_2M_1 recorded the highest total sugar contentof 5.54per cent which was on par with P_1M_2 (5.27per cent) and P_2M_2 (4.98per cent).

Location II (High ranges)

Growing systems had a significant effect on total sugars content of fruits. The systemS_2recorded the maximum total sugar contentof 5.88per centwhich was on par with S_1 (5.81per cent).

Time of planting did not have a significant influence on total sugar content of fruits.

Mulch had significant effect on total sugar content of fruits.M_1recorded the significantly higher total sugar content of 5.31per centwhich was followed by M_2(5.14per cent).

S x P and S x Minteractions had significant influence on total sugar content of fruits.S_2P_1 recorded the highest total sugar content of 6.0per cent which was on par with S_1P_2 (5.92per cent).Lowest total sugar content of 3.98 per cent was recorded in interaction S_3P_2 which was on par with S_3P_1 (4.00 per cent). S_1M_1interaction recorded significantly higher total sugar content of 5.98per cent which was on par with S_2M_1 (5.95per cent). Lowest total sugar content of 3.99 per cent was recorded in combinations $S_3M_2$and S_3M_1 (3.99 per cent).

4.4.5 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 two. Sensory evaluation was conducted on the same day of harvest. Observations from the two locations are given in table 10 and 11.

Comparing the two locations using Mann-Whitney test (Table 12) reveals that there is significant difference in appearance and colour.Colour and appearance was found to be superior in High ranges than Central midlands.

In location I (Central midlands) among the twelve treatments, the highest score for appearance was recorded by T_1 (plants planted in September with white mulch in open system) and lowest score by T_{11} (plants planted in October with white mulch in fan and pad system).The highest score for colour was recorded by the treatment T_1 (plants planted in September in white mulch in open field). The highest score for flavor and texture were recorded by T_8 (plants planted in black mulch in October in greenhouse). The highest score for odour was recorded by T_3 and T_5.T_1 (plants planted in September in white mulch in open field) recorded the highest score for taste, aftertaste and acceptability.The highest total sensory score (49.61) was recorded by T_1 (plants planted in September in white mulch in the open field) followed by T_2 (plants planted in September in black mulch in open system).

In location II (High ranges), among the twelve treatments, T_2 (plants planted in black mulch in September in open field) recorded the highest score for appearance, flavor, odour, taste, aftertaste and acceptability while T_4 (plants planted in October in

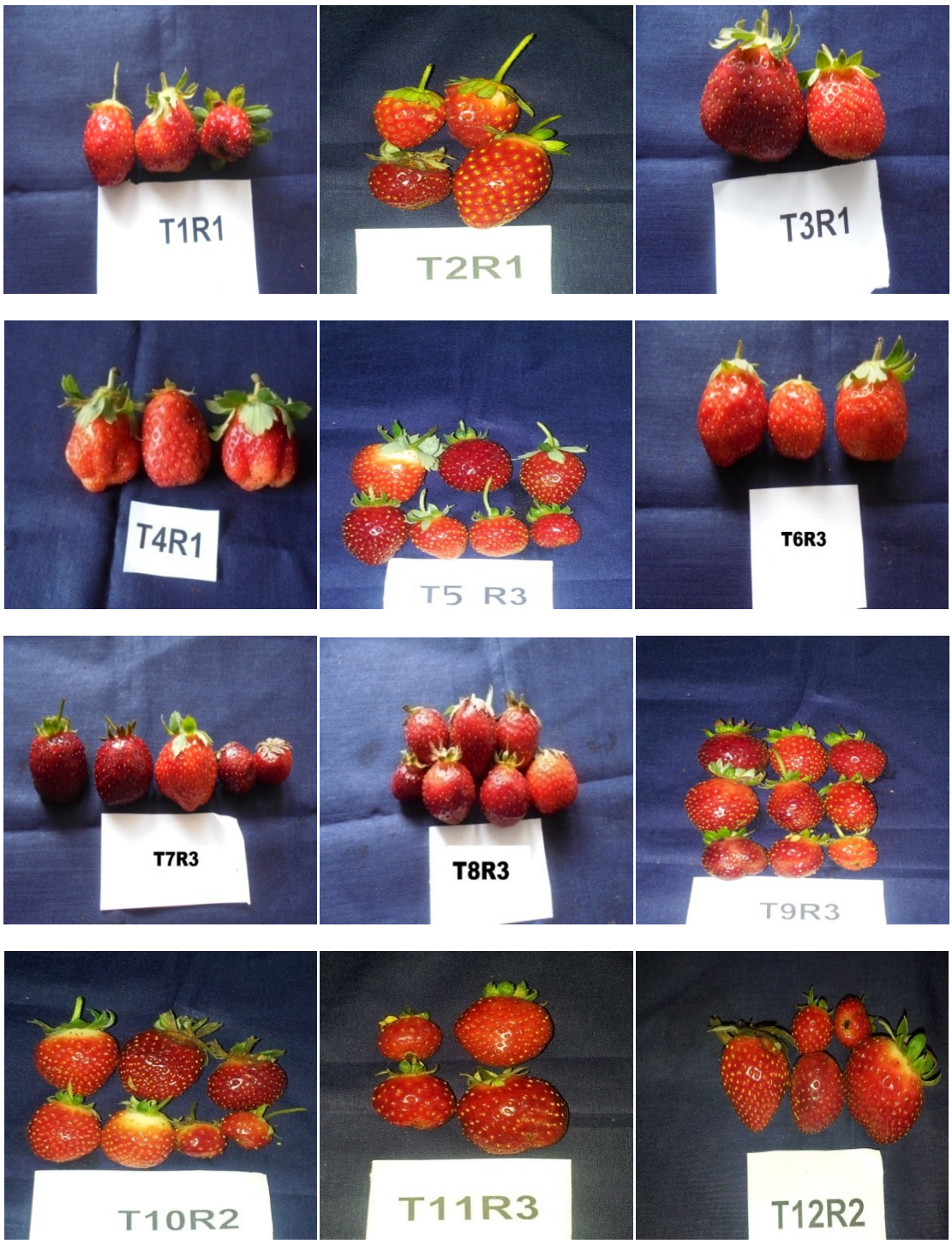


Plate 8. Strawberry fruits from Central midlands region

Table 10. Sensory evaluation of strawberry fruits from Location I (Central mid-lands)

Treatments	Appearance (10)	Colour (10)	Flavour (10)	Texture (10)	Odour (10)	Taste(10)	After taste(10)	Total score (70)	Acceptability (10)
T_1	7.27	**7.53**	6.91	7.21	7.06	**7.30**	**6.33**	**49.61**	**6.91**
T_2	7.33	7.40	6.55	6.70	7.12	6.88	6.21	48.19	6.88
T_3	7.00	6.93	6.39	7.15	**7.27**	7.00	6.27	48.01	6.79
T_4	6.73	7.10	6.91	7.09	7.09	7.27	6.18	48.37	6.64
T_5	6.97	7.40	6.67	6.64	**7.27**	6.97	6.18	48.1	6.45
T_6	7.03	7.10	6.88	7.06	7.03	6.88	6.24	48.22	6.33
T_7	6.93	6.80	6.73	7.18	7.09	6.85	6.24	47.82	6.21
T_8	6.77	7.20	**7.18**	**7.36**	6.91	6.91	6.12	48.45	6.82
T_9	7.28	7.40	6.91	7.06	6.85	7.06	6.15	48.71	6.36
T_{10}	7.20	7.50	7.12	7.15	6.94	7.21	6.24	49.36	6.70
T_{11}	7.00	6.87	6.79	7.00	6.64	6.94	6.09	47.33	6.55
T_{12}	**7.37**	7.43	6.88	7.03	6.82	7.06	6.18	48.77	6.76

Table 11. Sensory evaluation of strawberry fruits from Location II (High ranges)

Treatments	Appearance (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**	**8.37**	**8.37**	**58.9**	**8.43**
T_3	8.70	8.17	8.20	8.27	8.30	8.00	8.00	57.64	8.23
T_4	8.57	**8.37**	8.20	**8.37**	8.40	8.10	8.10	58.11	8.23
T_5	8.31	8.14	8.17	8.17	8.10	8.17	8.23	57.29	8.23
T_6	7.34	8.11	8.13	8.13	8.13	8.17	8.20	56.21	8.13
T_7	8.10	8.10	8.23	8.17	8.07	8.10	8.13	56.9	8.17
T_8	8.47	8.07	8.13	8.17	8.17	8.07	8.07	57.15	8.03
T_9	7.07	6.57	4.77	4.57	4.57	4.67	5.00	37.22	4.77
T_{10}	7.00	6.90	4.70	4.53	4.57	4.60	4.63	36.93	4.63
T_{11}	7.00	7.00	4.40	4.53	4.57	4.47	4.57	36.54	4.40
T_{12}	7.20	6.90	4.93	4.63	4.57	4.63	4.77	37.3	4.93

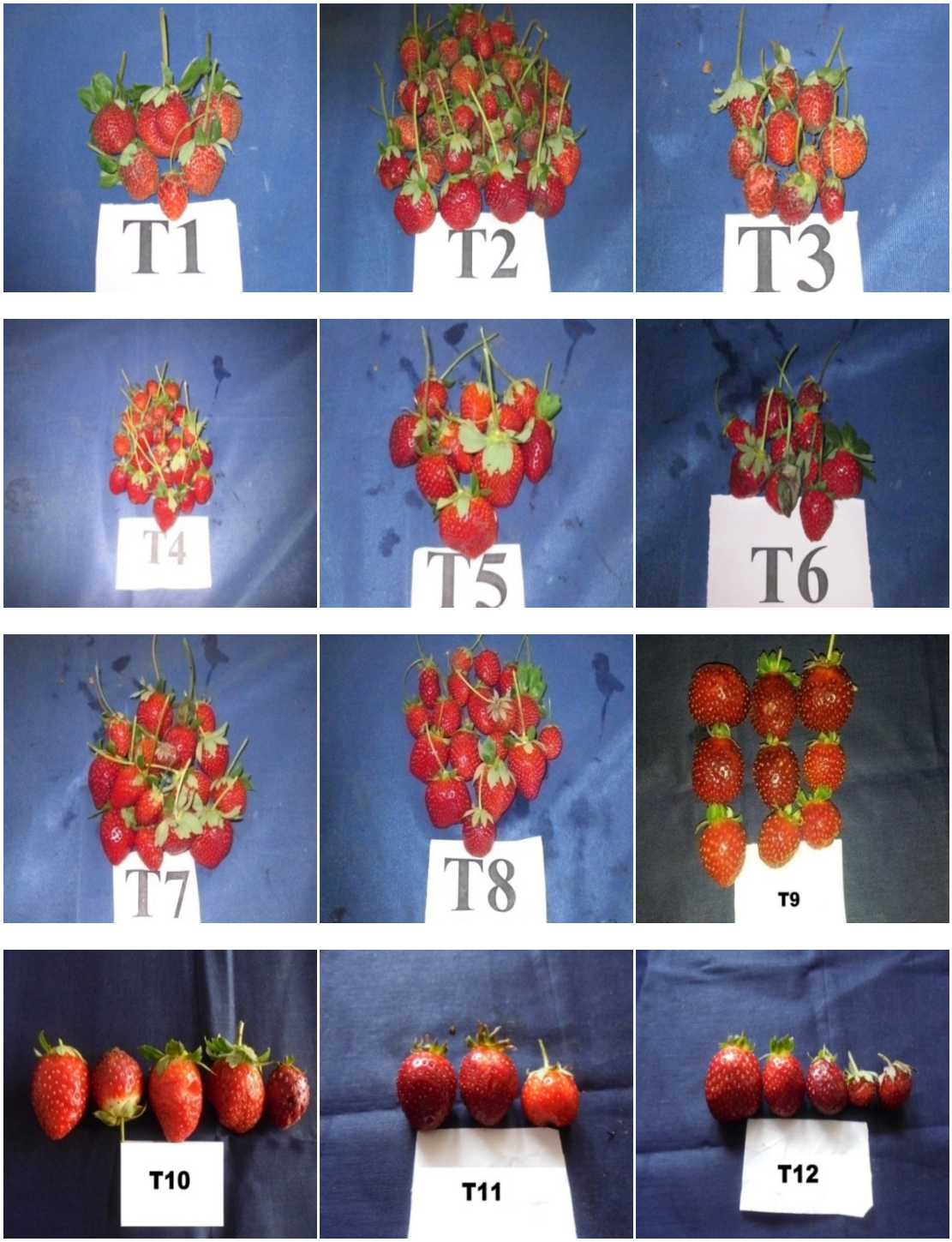


Plate 9. Strawberry fruits from High range region

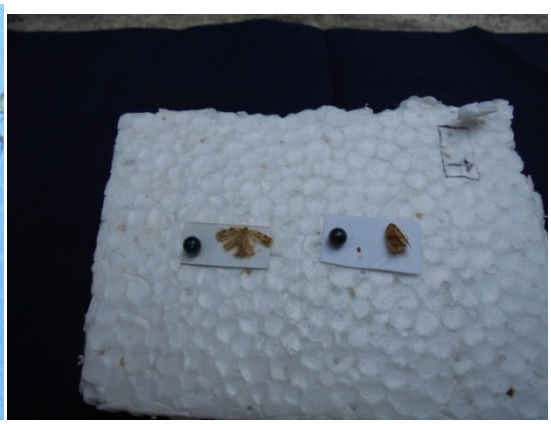
Table 12. Mann-Whitney Test for sensory evaluation

	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Acceptability
LocationI	8.54	9.92	10.50	10.50	10.50	10.50	10.50	10.50
Location II	16.46	15.08	14.50	14.50	14.50	14.50	14.50	14.50
C.D	0.005**	0.078**	NS	NS	NS	NS	NS	NS

Table 13. Benefit cost ratio for strawberry

Particulars	Location I (Central midlands)			Location II (High ranges)		
	Open field	Greenhouse	Fan and pad	Open field	Greenhouse	Fan and pad
Total cost incurred	9580	12809	20342	9580	12809	20342
Benefit	14560	10560	18784	28704	25024	20256
B/C ratio	1.5	0.82	0.92	3.0	1.95	1.0

Leaf webbing by Torticidae(Caterpillar)



Adult of Torticidae

Leaf feeding by a Semi looper

Leaf feeding by *Amsacta albistriga*

Incidence of Alternaria leaf spot in strawberry leaves

Microscopic view of *Alternaria* spp.

Plate 10. Pest and diseases of strawberry

black mulch in open condition) recorded highest score for colour and texture. Plants planted in open field in high ranges recorded the highest score for sensory characters.

4. 5 Post harvest study

4.5.1 Shelf life in days

The growing systems, time of planting, type of mulch and even the locations have no significance effect on shelf life of strawberry. It is evident that strawberry has a maximum shelf life of 3 days when stored in ambient temperature after harvest at 75per cent ripened stage.

4.6 Pest and disease incidence

During the entire period of study, there was not much severe incidence of pests and diseases. Leaf feeding looper was observed in fan and pad system in Location I. Pests such as Hairy caterpillar - *Amsactaalbistriga*(Walker)(Lepidoptera: Arctidae) andatorticidae-green caterpillar was observed in Location II in all the three systems.Alterneria leaf spot disease is common in both locations*viz*;Central midlands and High ranges.

4.7 Benefit cost ratio of strawberry

The benefit cost ratio indicates value of output per rupee of the cost incurred. This ratio will serve as a measure, which would indicate whether the cost incurred is commensurate with the returns obtained. Benefit cost ratio of strawberry was estimated with respect to various cost concepts for the two locations and the results are presented below.

An analysis of various costs and returns in strawberry cultivation revealed the extent of profitability of the enterprise. The details are presented in a $100m^2$ unit

basis for a period of six months. The analysis given in Table 13 and Appendix VIII showed that the variable cost including labour charge and plant material is maximum compared to other costs. Labour charge include cost of labour incurred for land preparation and irrigation. Since the crop was grown in existing structures, depreciation is calculated on the basis of ten years of establishment. In Central midlands, B:C ratio was more than one in open field compared to 0.82 in greenhouse and 0.92 in fan and pad system.

An analysis of benefit cost ratio of strawberry in High ranges (Table 13 and Appendix IX) revealed that B:C ratio was maximum of 3.0 in open field compared to 1.95 in greenhouse and 1.0 in fan and pad system. Comparing the two locations, the B:C ratio is almost double in open field and greenhouse of High ranges.

DISCUSSION

5 DISCUSSION

The study pertaining to the performance of strawberry (*Fragaria x ananassa* Duch.) under three systems of growing, two time of planting and two types of mulching has been undertaken at two locations. The results are discussed under six heads namely vegetative growth attributes, flower attributes, yield attributes, quality attributes, post harvest study and pest and disease incidence.

5.1 Vegetative growth attributes

5.1.1 Plant height

In Central midlands, among the systems of growing, fan and pad system recorded the maximum plant height irrespective of the age of the plant. In High ranges, among the systems of growing, greenhouse system recorded the maximum plant height at all stages of growth. (Table 4a, Fig. 1).High relative humidity and low light intensity prevailing inside the system may have influenced plant height in fan and pad system and greenhouse. The results in the present study are similar to the findings of Lieten (2002).

5.1.2 Number of leaves per plant

In Central midlands, among the systems of growing, open system recorded the maximum number of leaves per plant in later stages of growth. However, in High ranges, open system recorded the maximum number of leaves per plant in all stages of growth (Table 5a, Fig. 2). This is in accordance with the findings of Yahya and Atherton (1995) in strawberry.

Among the different time of planting, planting in the last week of September showed significantly higher number of leaves per plant at all stages of

Fig1. Effect of growing systems on plant height

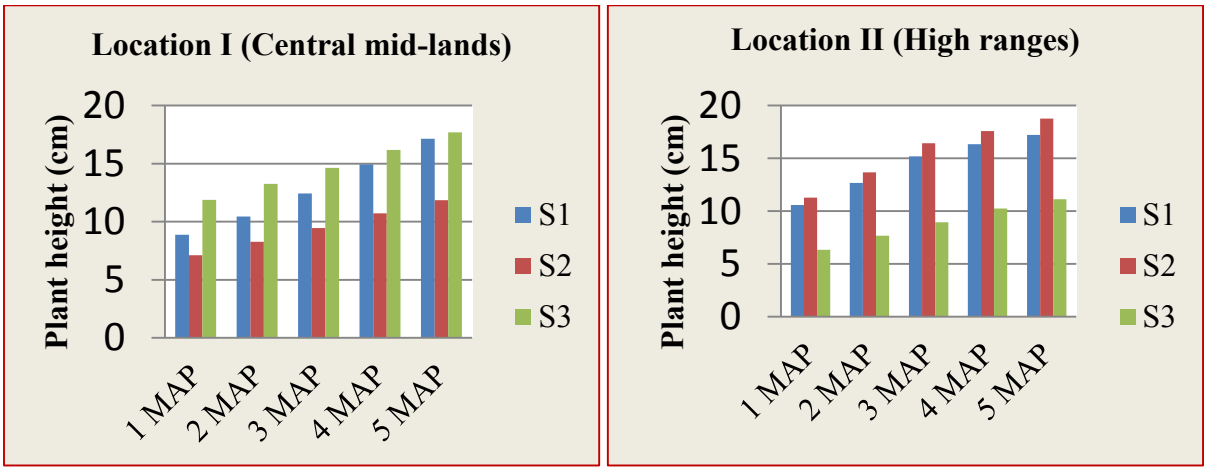


Fig 2. Effect of growing systems on number of leaves

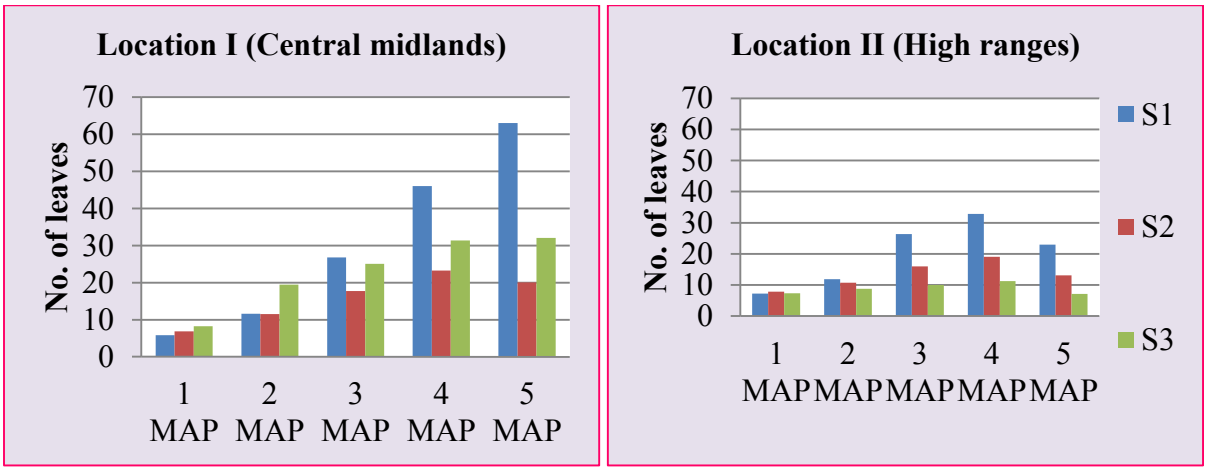
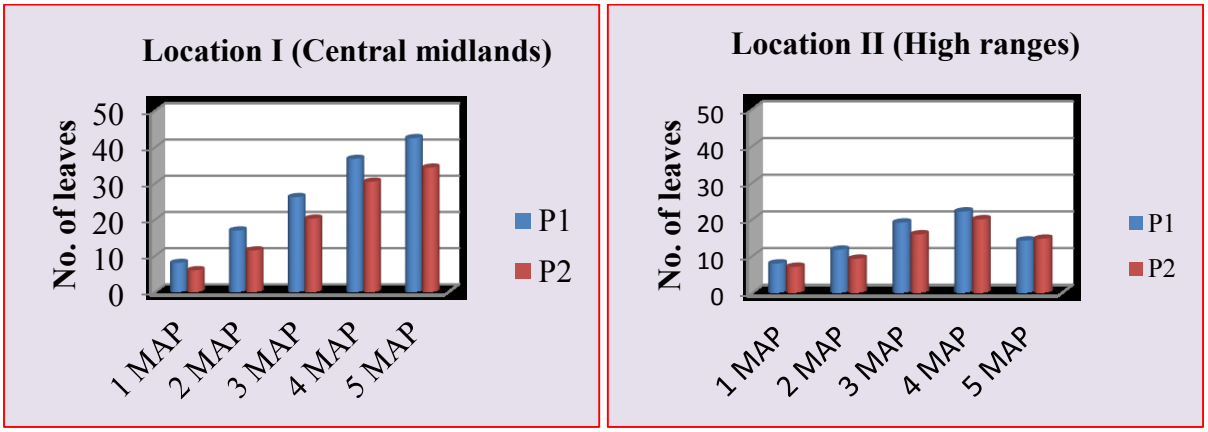


Fig 3. Effect of time of planting on number of leaves



growth in Central midlands and High ranges (Fig. 3). This is in conformity with the findings of Rahman *et al*. (2014) in strawberry.

In the present experiment, mulch had no significant effect on production of leaves at both locations. In contrary to the findings, Angrej and Gaur (2007), Das *et al*. (2007), Ravi *et al*. (2010), Rhakho *et al*. (2014) and Bakshi *et al*. (2014) reported that black polyethylene mulch resulted in maximum number of leaves in strawberry.

5.1.3 Plant spread

In Central midlands, among the three growing systems, fan and pad system recorded maximum plant spread in early stages of growth. In High ranges, greenhouse system recorded the maximum plant spread (Table 6a, Fig. 4).The favorable environmental conditions inside the systems would influence the production of more plant height which ultimately resulted in more plant spread. An enhanced vegetative growth under increased relative humidity was reported in strawberry by Lieten (2002).

Among the different time of planting, planting in the last week of September had significantly higher plant spread in early stages of growth (Fig. 5). Favorable effect of planting strawberry during last week of September was reported by Rajbir *et al*. (2007).

5.2 Flowering attributes

5.2.1 Days to first flowering

In Central midlands among three growing systems, fan and pad system had significant influence on days to first flowering (Table 7a, Fig. 6). The reason for this finding could be attributed to congenial temperature and light intensity

Fig 4. Effect of growing systems on plant spread

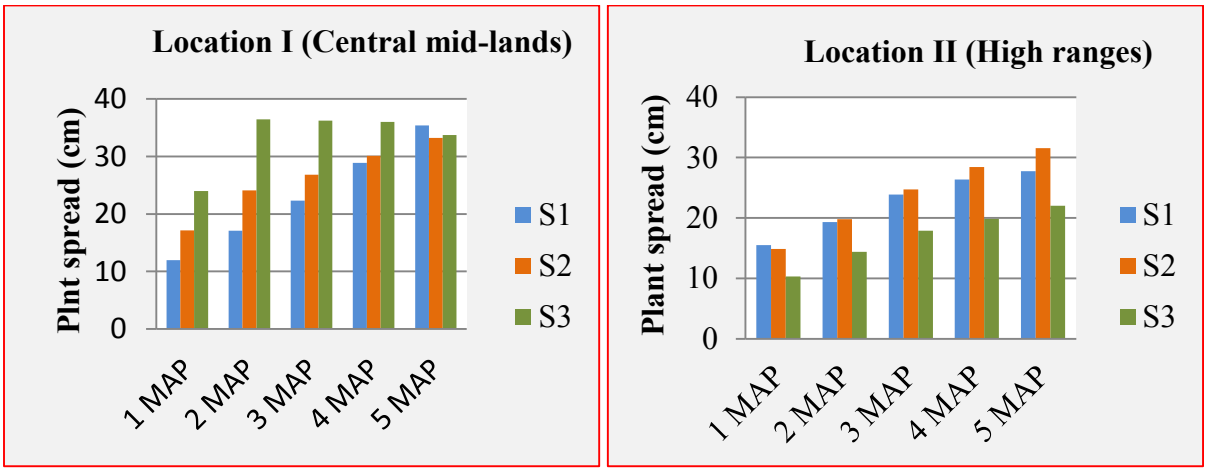


Fig 5. Effect of time of planting on plant spread

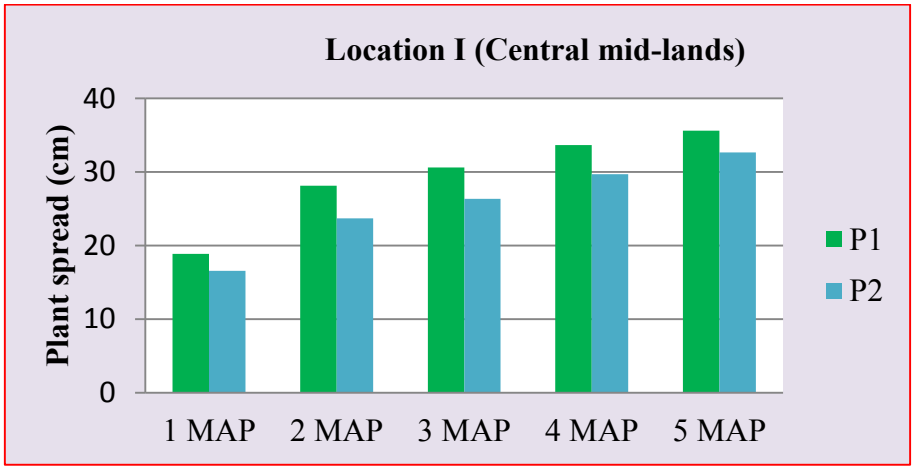
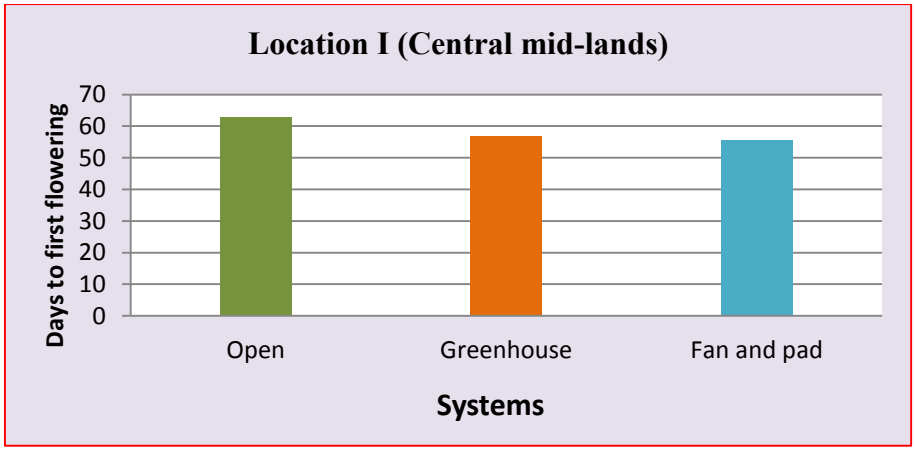


Fig 6. Effect of growing systems on days to first flowering



prevailing under fan and pad system influencing early flowering. The days to first flowering was not significant in high ranges. However in High ranges, early flowering was observed irrespective of the system of growing and the days to first flowering was from 40-41 days. The favorable temperature, short day condition, high relative humidity prevailing in high ranges may have influence on early flowering (Appendix-IV and V).

The influence of mulch on days to first flower opening was significant only in Central midland region (Table 7a, Fig. 7). Plants mulched with black polyethylene recorded early flowering. The positive influence of black mulch on early flowering in strawberry was reported by Pollard *et al*. (1989); Abbott and Gough (1992); Hassan *et al*. (2000); Singh and Asrey (2005); Singh *et al*. (2006) and Rajbir*et al*. (2007). The results indicated that in High ranges, both black and white mulch are suitable for early flowering in strawberry.

In Central midland region, growing system and mulch interaction had significant influence on days to first flowering (Table 7b, Fig. 8). Under fan and pad system, black mulch had significant influence on early flowering.

5.2.2 Number of flowers per plant

In Central midland region, systems of growing had no significant influence on number of flowers per plant (Table 7a).However, in high ranges, among the systems of growing, open system recorded maximum number of flowers per plant (Table 7a, Fig. 9).Higher number of leaves and maximum plant spread were observed under open condition, which might have influenced the production of maximum number of flowers per plant in High ranges. Congenial environmental conditions prevailing in high ranges favored the production of maximum number of flowers per plant (Appendix-IV).

Fig 7. Effect of mulch on days to first flowering

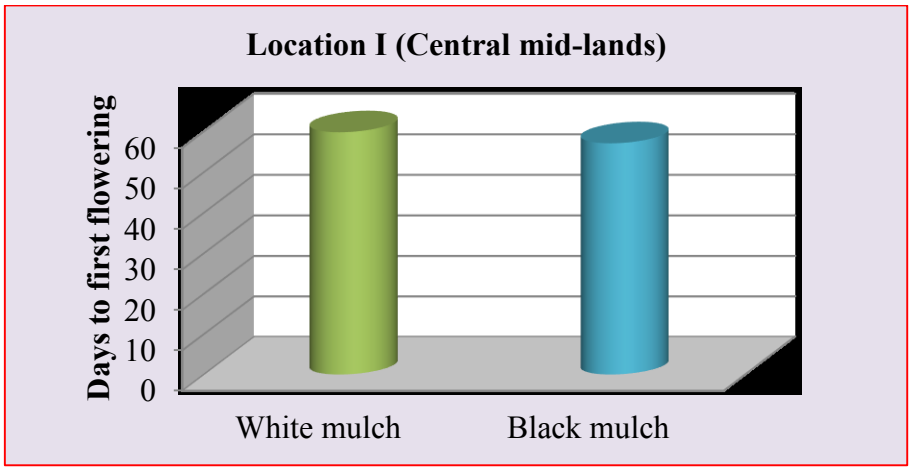


Fig 8. Interaction effect of system and mulch on days to first flowering

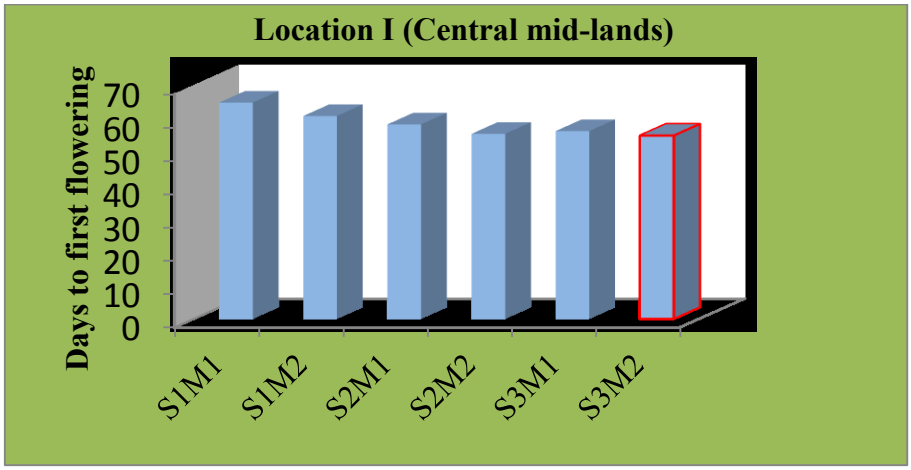
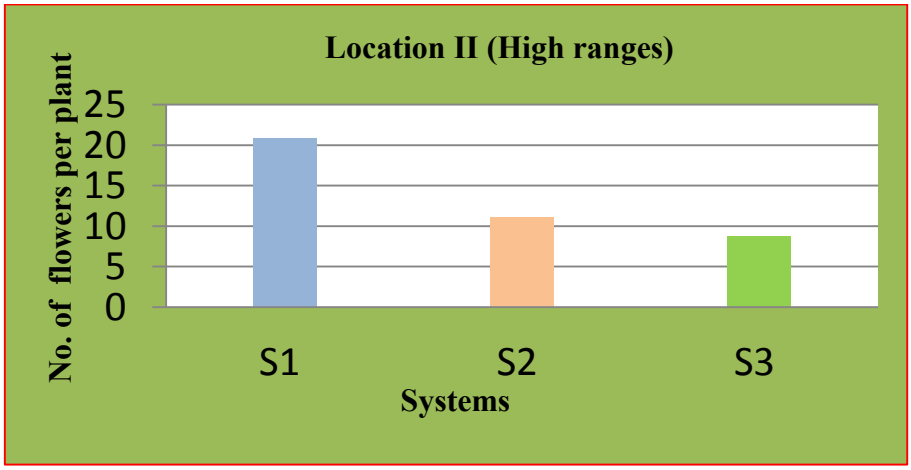


Fig 9. Effect of growing system on number of flowers per plant



Time of planting and mulch had no significant influence on number of flowers per plant in both locations (Table 7a).

Growing system and mulch interaction had significant influence in the production of flowers per plant in High ranges (Table 7b, Fig. 10). Under open condition, black mulch had significant influence on production of maximum number of flowers per plant.

5.2.3 Number of clusters per plant

In Central midlands, growing system had no significant influence on number of clusters per plant. However in High ranges, among the growing systems, open system recorded maximum number of clusters per plant (Table 7a, Fig. 11). The result indicated that under open system, plants produced more number of flowers per plant. This may lead to increase theproduction of number of clusters per plant.

The results indicate that time of planting and mulch has not much influence on number of clusters per plant in both the locations.

However growing system and mulch interaction had significant influence in the production of number of clusters per plant in High ranges (Table 7b, Fig. 12). Under open system, black mulch resulted in maximum number of clusters per plant.As reported earlier, the number of flowers per plant was maximum in open system with black mulch which might have resulted in maximum number of clusters per plant.

Fig 10. Interaction effect of system and mulch on number of flowers per plant

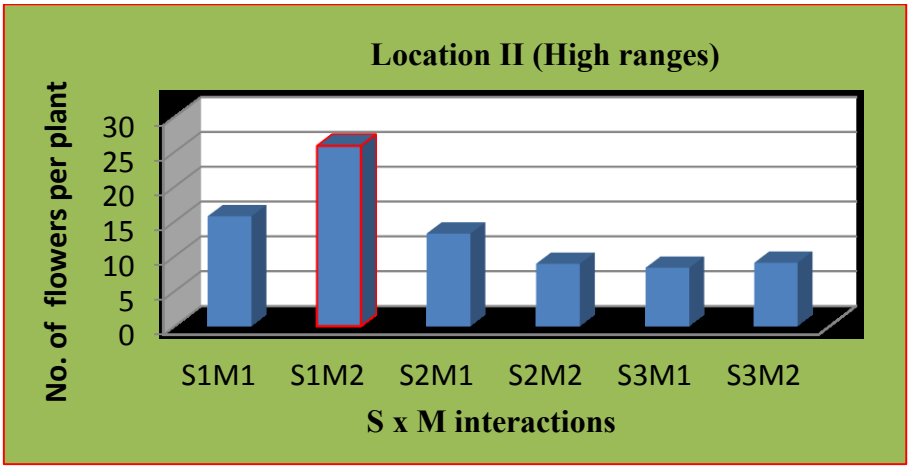


Fig 11. Effect of growing system on number of clusters per plant

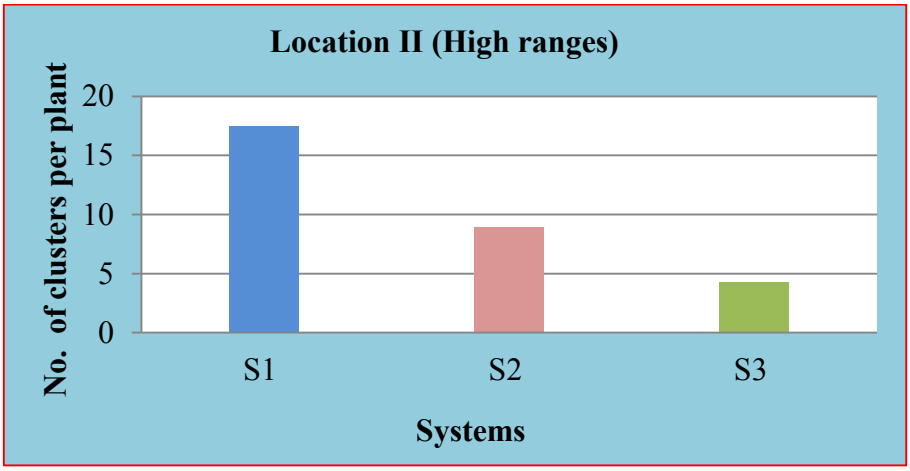
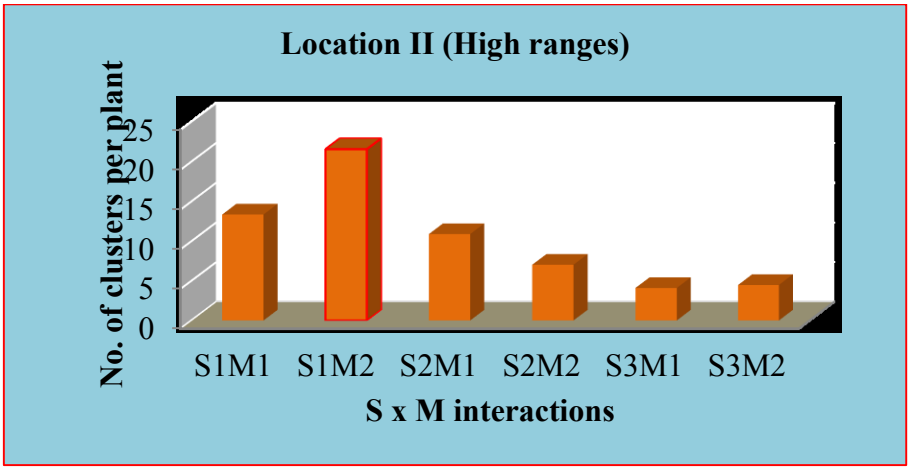


Fig 12. Interaction effect of growing system and mulch on number of clusters per plant



5.3 Yield attributes

5.3.1 Number of fruits per plant

Among the three growing systems, fan and pad systemrecorded the maximum number of fruits per plant in Central midland region(Table 8a,Fig. 13).The plants under fan and pad system exhibited increased plant height andmaximum plant spread. This may be the reason for maximum number of fruits per plant in fan and pad system. In High ranges, open system recorded maximum number of fruits per plant (Fig. 13). As discussed earlier, plant height, number of leaves, number of flowers and number of clusters per plant were maximum in plants grown under open condition. Hence in the same corollary, this result could be explained that system of growing has influence on number of fruits per plant.

Among different time of planting, planting in the last week of September recorded the highest number of fruits per plant (Table 8a, Fig. 14). Number of leaves and plant spread were maximum in the previous treatment which might have resulted in higher number of fruits per plant. However in High ranges, the time of planting has no significant effect on number of fruits per plant.

The growing system and mulch interaction had significant influence on production of fruits per plant in High ranges (Table 8b, Fig. 15). Open system with black mulch showed the maximum number of fruits per plant. Earlier result indicated that the number of flowers per plant and number of clusters per plant were maximum in open system with black mulch. This may be the reason for the production of maximum number of fruits per plant in open field with black mulch.

Fig 13. Effect of growing system on number of fruits per plant

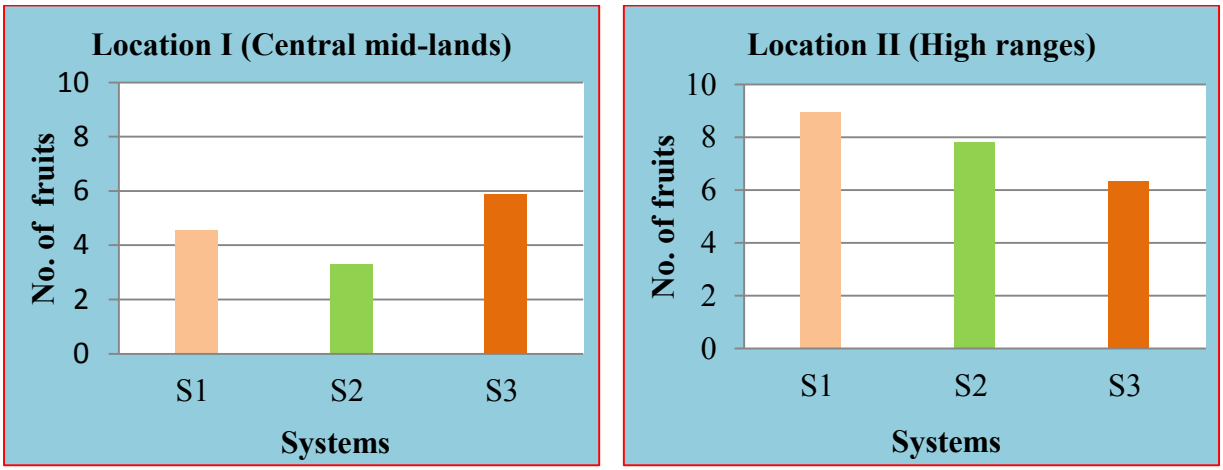


Fig 14. Effect of time of planting on number of fruits per plant

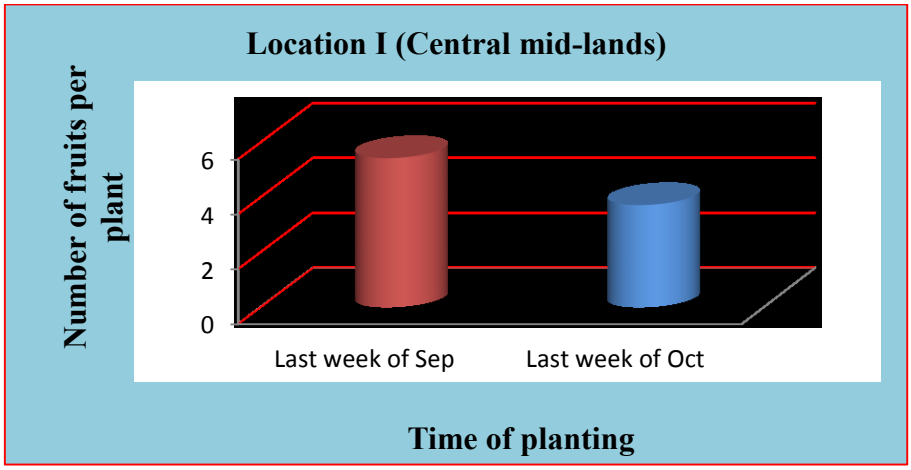
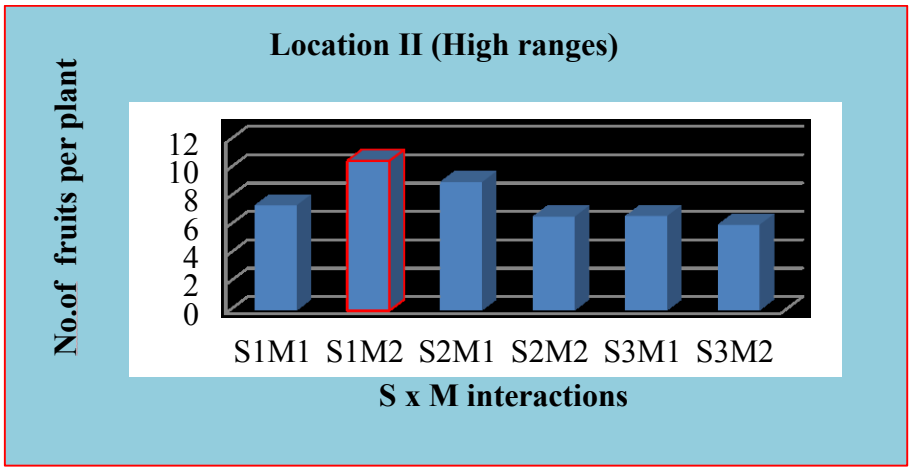


Fig 15. Interaction effect of system and mulch on number of fruits per plant



5.3.2 Yield per plant

Among the growing systems, plants under open, greenhouse and fan and pad system recorded 32.67 g, 23.75 g and 40.98 g yield per plant respectively in the Central midlands (Table 8a). However, there was no significant difference in yield per plant among different growing systems. The growing systems had significant influence on yield per plant in High ranges. Open, greenhouse and fan and pad system recorded 80.35 g, 61.27 g and 41.52g yield per plant respectively. Open condition recorded significantly higher yield per plant in High ranges (Table8a, Fig. 16).

Time of planting did not show any significant influence on yield per plant in both the locations.

Mulch had no significant influence on yield per plant in both locations. Non significant influence of mulch on plant height, number of leaves, plant spread, number of flowers per plant and number of clusters per plant in different stages of growth was already reported.

Growing system and mulch interaction had significant influence on yield per plant in High ranges (Table 8b, Fig. 17). Under open system, black mulch resulted in maximum yield per plant in High ranges. Earlier result indicated that number of flowers, number of clusters and number of fruits per plant were maximum in open condition with black mulch. This may be the reason for higher yield per plant observed in the open field with black mulch.

5.3.3 Average fruit weight per plant

Among the growing systems, no significant difference in average fruit weight per plant was observed in Central midlands. However in High ranges, the growing systems had significant influence on average fruit weight per plant.

Fig 16. Effect of growing system on yield per plant

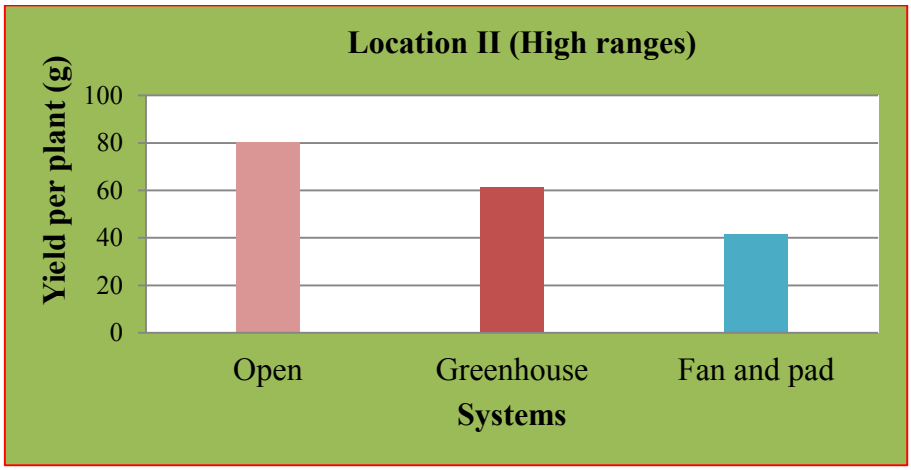


Fig 17. Interaction effect of system and mulch on yield per plant

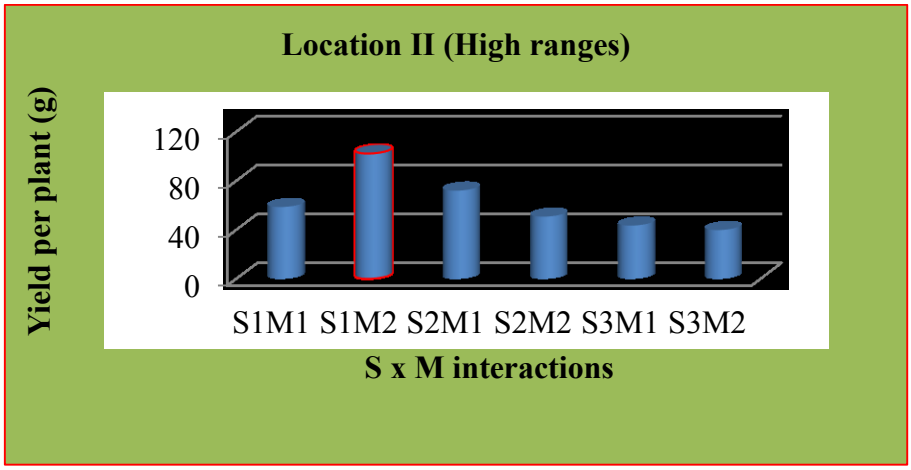
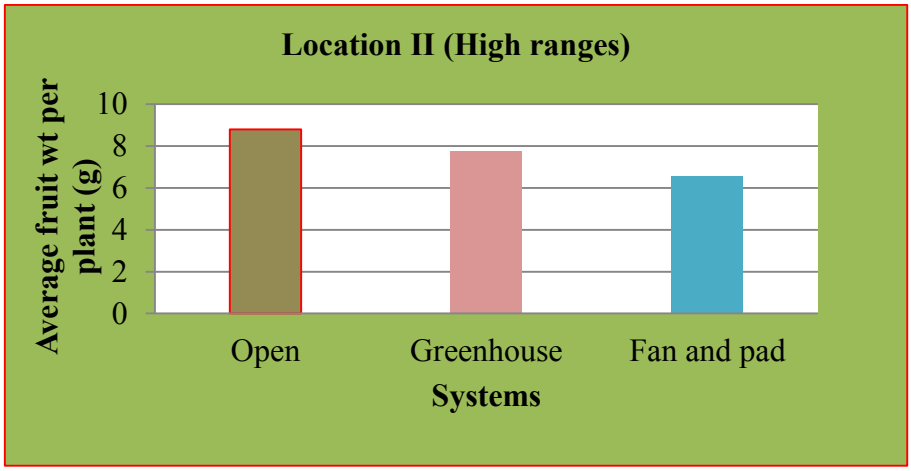


Fig 18. Effect of growing system on average fruit weight per plant



Plants under open, greenhouse and fan and pad system recorded8.79 g, 7.76 g and 6.56 g average fruit weight per plant respectively. Plants under open condition recorded significantly higher average fruit weight per plant in High ranges (Table 8a, Fig. 18).

Time of planting and mulch had no significant influence on average fruit weight per plant in both the locations.

5.3.4 Days to first harvest

Among the three growing systems, greenhouse had significant influence on days to first harvest in Central midlands. Plants in greenhouse recorded earliness in flowering which may lead to early harvesting of strawberry fruits. However in High ranges, growing systems had significant influence on days to first harvest. Maximum number of leaves, maximum number of flowers and clusters per plant were recorded in open condition which may lead to early harvest of strawberry (Table 8a, Fig. 19).

The influence of time of planting on days to first harvest was not significant in Central midlands and High ranges.

The influence of mulch on days to first harvest was significant in Central midlands (Table 8a, Fig. 20). Plants mulched with black polyethylene took lesser days to harvest. The positive influence of black mulch on early flowering resulted in early harvest of strawberry. However in High ranges, the mulch had no significant influence on days to first harvest.

Growing system and mulch interaction had significant influence on days to first harvest only in Central midlands (Table 8b, Fig. 21). Under fan and pad

Fig 19. Effect of growing system on days to first harvest

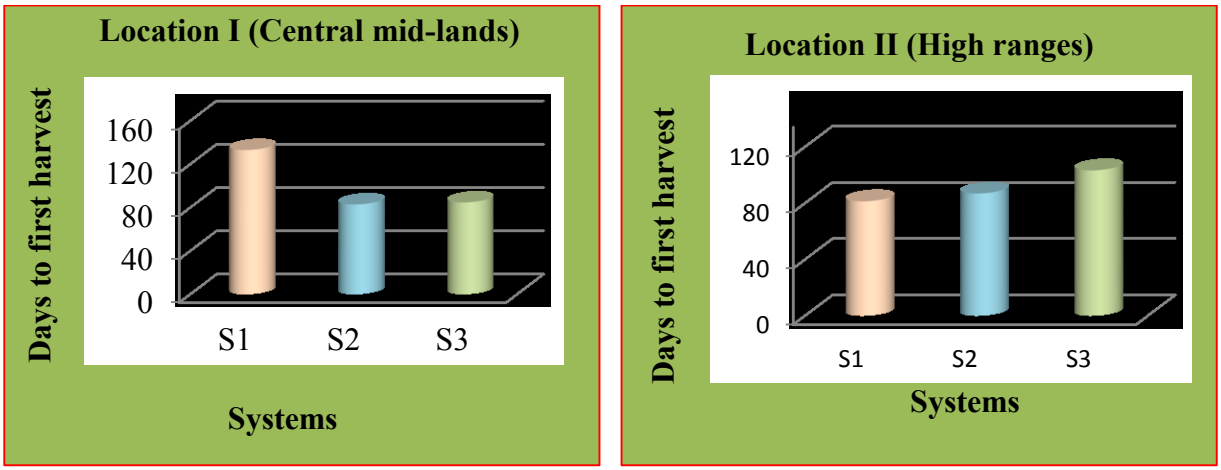


Fig 20. Effect of mulch on days to first harvest

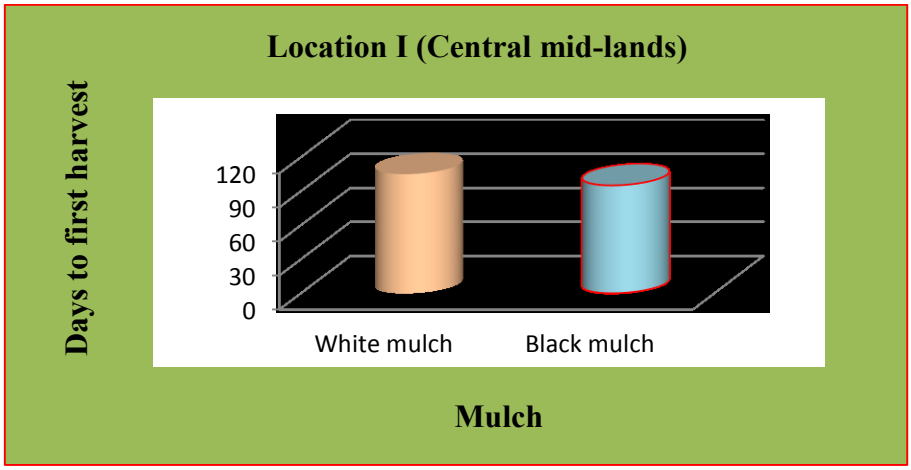
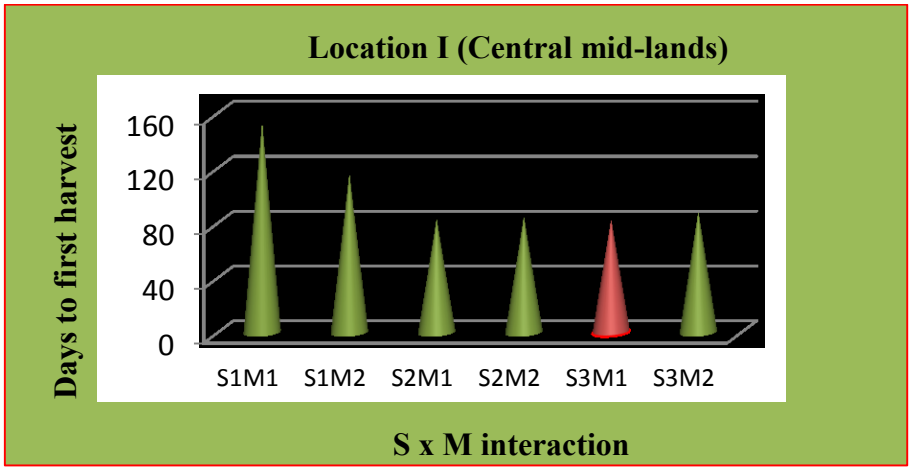


Fig 21. Interaction effect of system and mulch on days to first harvest



system, white mulch recorded minimum days (81.67) to first harvest. The combination of open system with white mulch recorded maximum days (151.33) to first harvest.

5.3.4 Days to final harvest

Among the three growing systems, open system had significant influence on days to final harvest in Central midlands. Late flowering of plants grown in open condition may be the reason. However, in High ranges, greenhouse had significant influence on days to final harvest (Table 8a, Fig. 22). It is assumed that the congenial environmental conditions prevailing in the greenhouse extended the days to final harvest in High ranges (Appendix-IV and V).

Time of planting had no significant influence on days to final harvest in Central midlands. However in High ranges, planting in the last week of October resulted in significantly maximum days (160.94) to final harvest (Fig. 23).

Mulch had no significant effect on days to final harvest in both the locations.

Growing system and mulch interaction had significant influence on days to final harvest. Under open system, white mulch recorded maximum days to final harvest in Central midlands. However, in High ranges, P x M, S x M and S x P x M interactions had significant influence on days to final harvest. The combination of planting in last week of October and white mulch resulted in maximum days to final harvest. In S x M interaction, the combination of greenhouse and white mulch recorded maximum number of days to final harvest.

Fig 22. Effect of growing system on days to final harvest

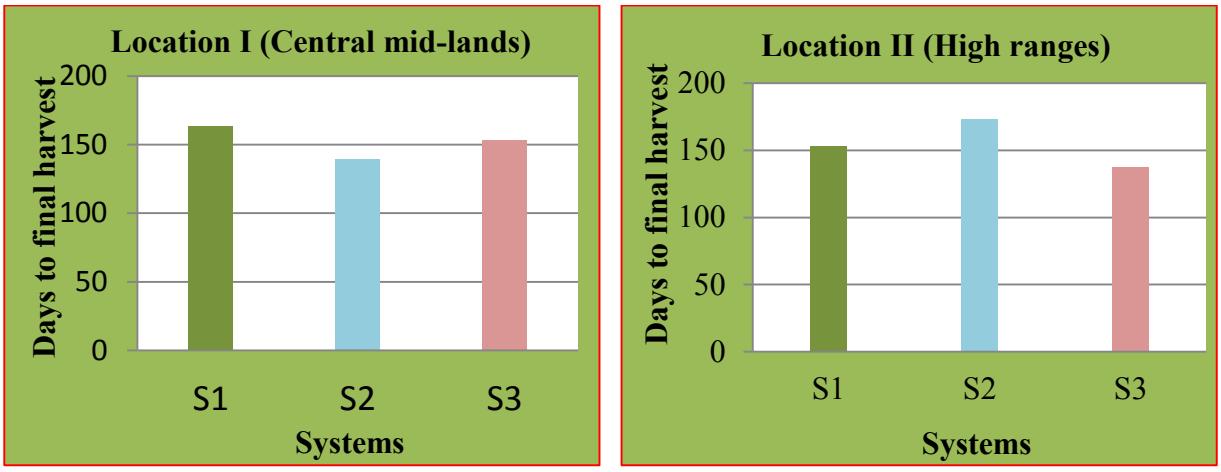


Fig 23. Effect of time of planting on days to final harvest

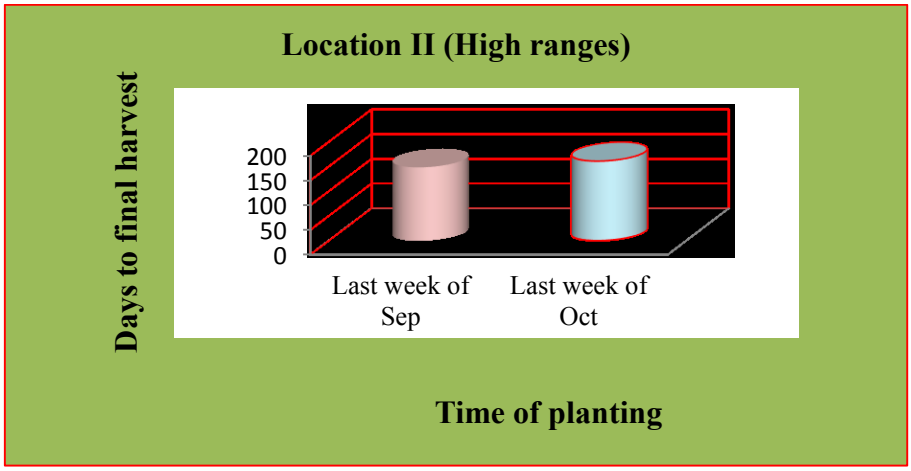
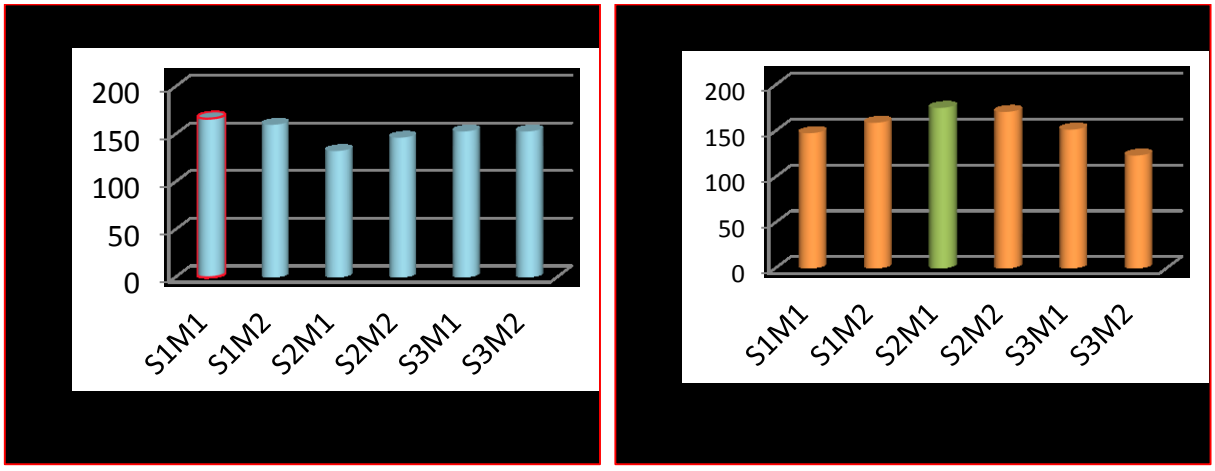


Fig 24. Interaction effect of system and mulch on days to final harvest



In S x P x M interaction, the combination of fan and pad system, last week of October planning and white mulch resulted maximum days to final harvest(Table 8b and Fig. 24, Fig. 25 and Fig. 26)

5.4 Quality attributes

5.4.1 TSS

Growing systems did not influence TSS in Central midlands. In High ranges, among the systems of growing, greenhouse recorded maximum TSS (Table 9a, Fig. 27). Days to final harvest was maximum in greenhouse and the plants got maximum time for accumulation of better sugars in the fruits which might have resulted in increased TSS in plants grown under greenhouse condition.

In Central midlands, among different time of planting, planting in last week of September resulted in higher TSS (Table 9a, Fig. 28). Better quality of fruit from early planting (last week of September) may be due to the availability of more time for accumulation of better sugar and ascorbic acid content. These results agree with the earlier findings of Rajbi r*et al.* (2007) and Rahman *et al.* (2014) in strawberry.

Time of planting and mulch interaction influenced significantly on TSS content of fruits in Central midlands. The combination of last week of September planting and white mulch recorded maximum TSS (Table 9b, Fig. 29). The result may be attributed to the synergesic effect of early planting of strawberry in white mulch. In high ranges, S x P and S x M interaction on TSS was significant (Table 9b, Fig. 30). The combination of greenhouse and last week of September planting recorded maximum TSS content. This might be due to the combined effect of early planting at congenial environmental conditions prevailing in greenhouse.

Fig 25. Interaction effect of time of planting and mulch on days to final harvest

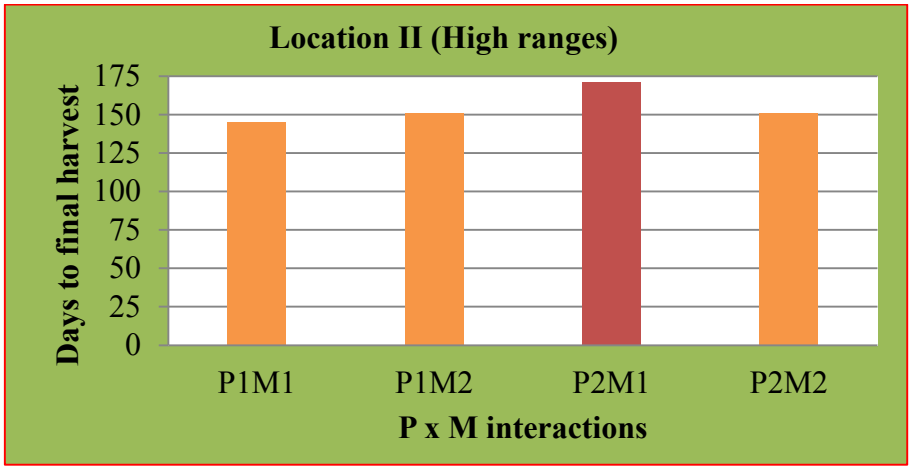


Fig 26. Interaction effect of system, time of planting and mulch on days to final harvest

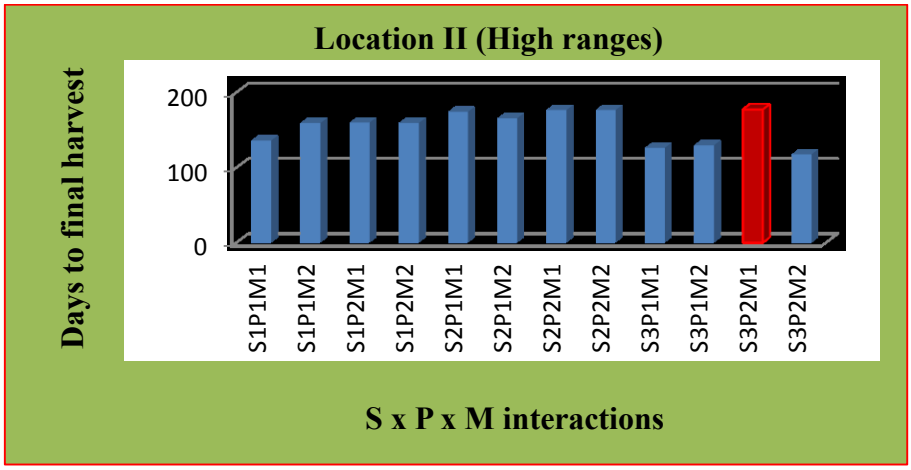


Fig 27. Effect of growing system on TSS of strawberry

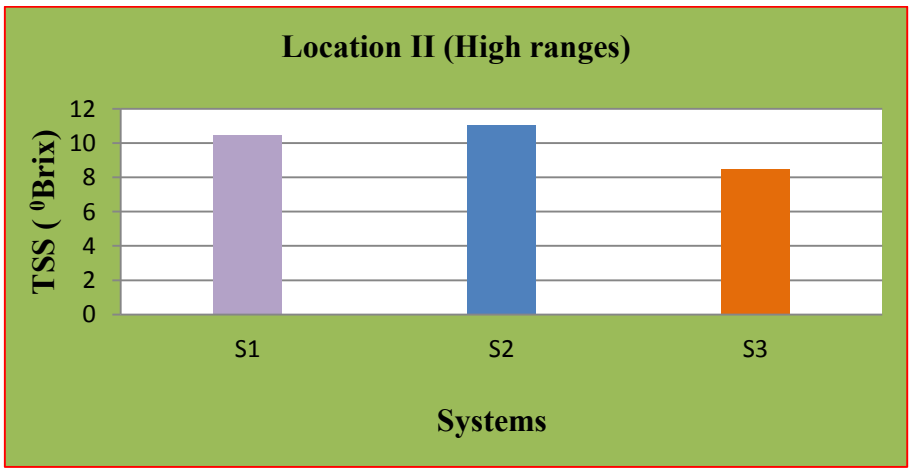


Fig 28. Effect of time of planting on TSS of strawberry

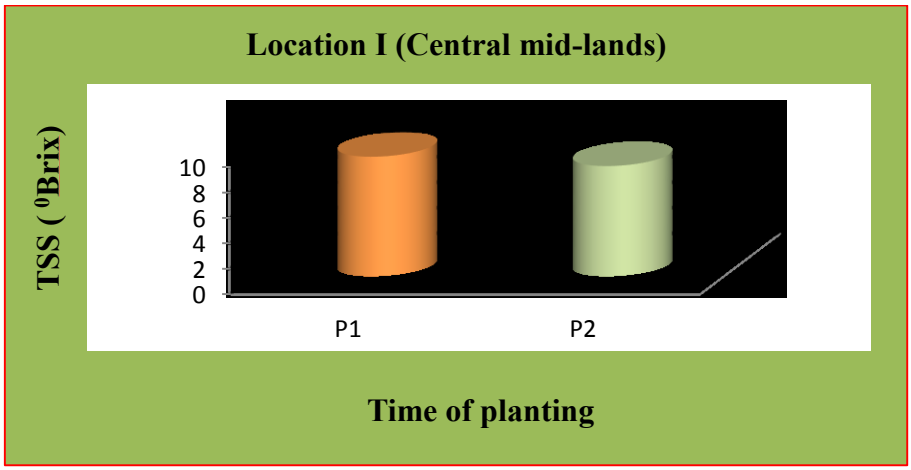


Fig 29. Interaction effect of time of planting and mulch on TSS of strawberry

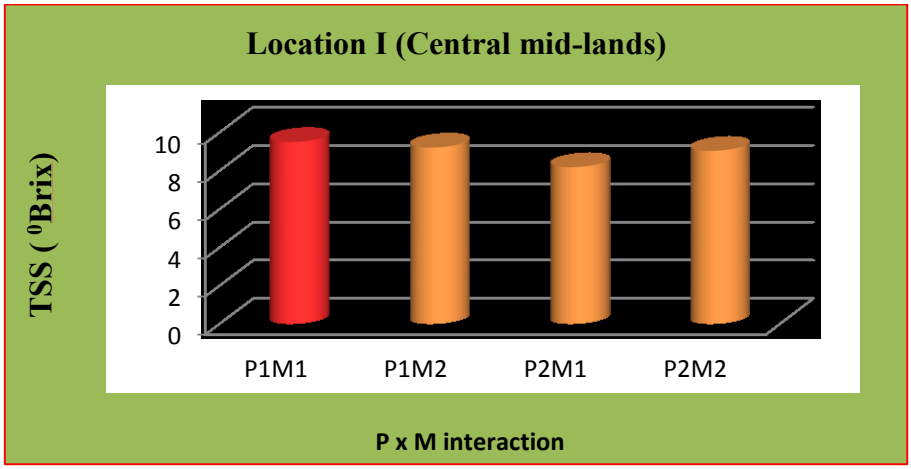
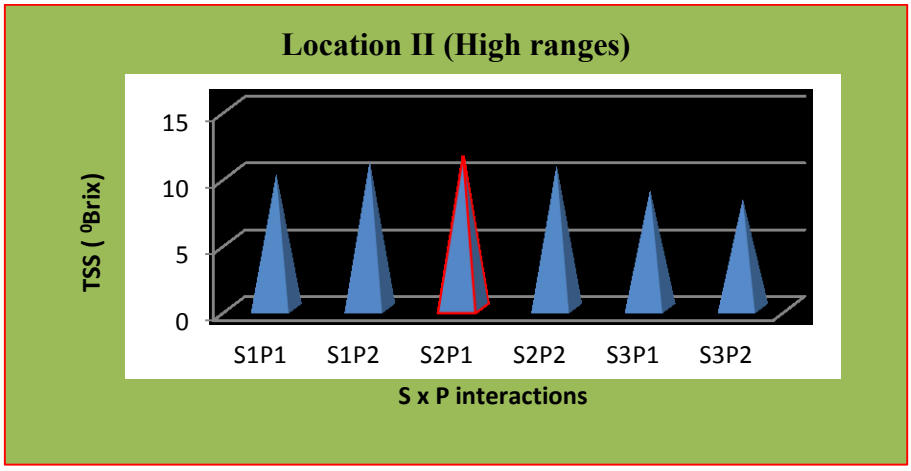


Fig 30. Interaction effect of system and time of planting on TSS of strawberry



In S x M interaction, under greenhouse, white mulch recorded maximum TSS (Fig. 31).

5.4.2 Acidity

Systems of growing did not influence much on acidity of fruits in Central midlands (Table 9a). However, in High ranges, greenhouse grown plants recorded the lowest acidityof fruits (Table 9a, Fig. 32). Earlier results indicated that TSS content was maximum in fruits harvested from greenhouse. Fruits harvested with high TSS have lower acid content. This may be the reason for lowest acidity in fruits harvested from greenhouse. Similar observations were made by Kumar *et al*. (2011) in strawberry cv. Chandler.

Time of planting had no significant influence on acidity of fruits in both the locations. Similarly, mulching also did not influence the acidity of fruits in both locations.

5.4.3 TSS/ acidity ratio

Growing systems, time of planting, mulch and S x P, S x M, P x M and S x P x M interactions had no significant influence on TSS/acidity ratio in Central midlands (Table 9a, 9b).

Among the growing systems, greenhouse recorded maximum TSS/acidity ratioof fruits only at High ranges (Table 9a, Fig. 33). Under greenhouse system, maximum TSS and lowest acidity of fruits was recorded which leads to maximum TSS/ acidity ratio in strawberry fruits harvested from greenhouse.

The time of planting and mulch interaction had significant influence on TSS/acidity ratio of strawberry fruits in Central midlands. White mulch and last week of September planting recorded maximum TSS/acidity ratio of strawberry

Fig 31. Interaction effect of system and mulch on TSS of strawberry

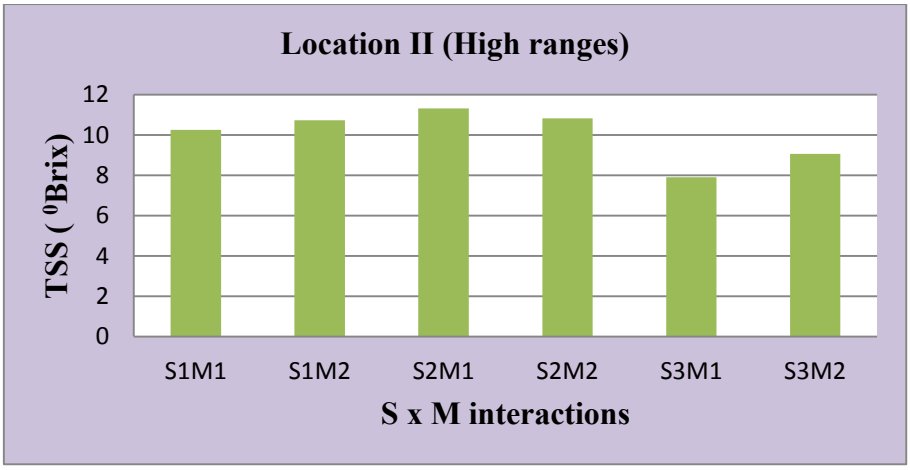


Fig 32. Effect of growing system on acidity of strawberry

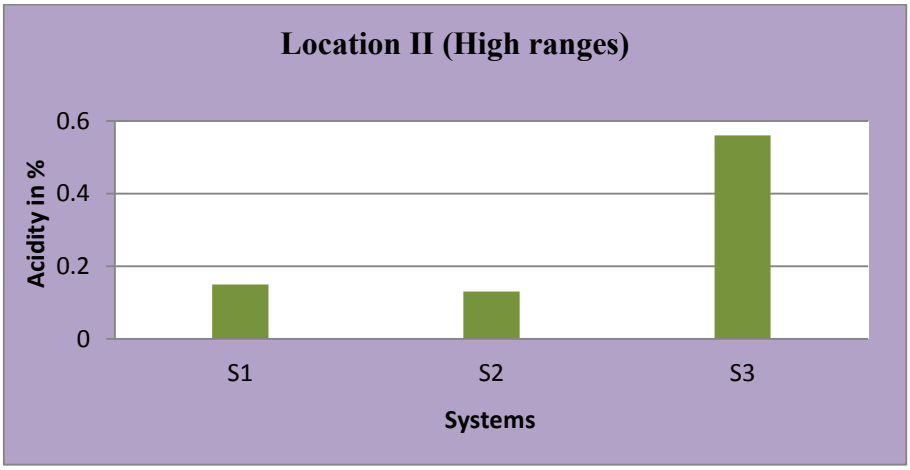
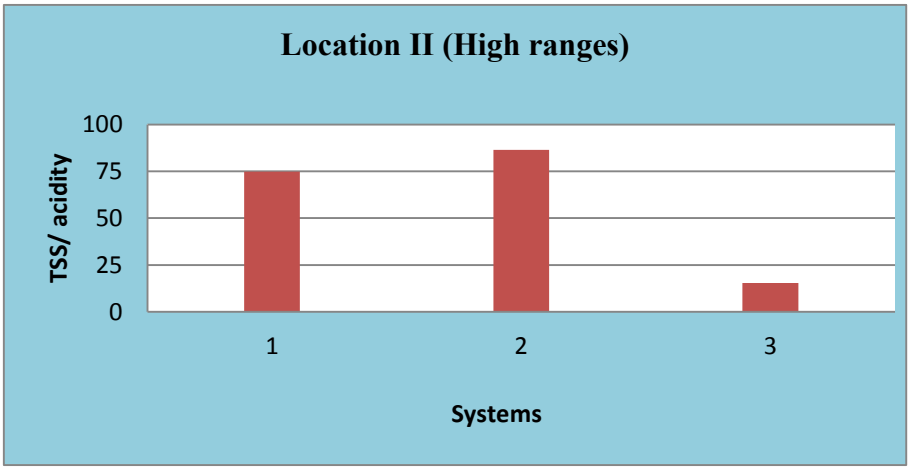


Fig 33. Effect of growing system on TSS/acidity of strawberry



(Table 9b, Fig. 34). Earlier result indicated maximum TSS recorded in last week of September planting with white mulch which may be the reason for maximum TSS/acidity ratio.

5.4.4 Total sugars

In Central midlands, growing systems had significant influence on the total sugar content of strawberryfruits. Planting in open system recorded maximum total sugars content of the fruits.In open system, temperature is low when compared to greenhouse and humidity is low compared to fan and pad system. The combined effect of low temperature and low humidity leads to the production of quality fruits. High temperature and high humidity are detrimental to fruit quality. Similar findings were given by Lieten (2002) and Hassan *et al*. (2000). However in High ranges, total sugars was significantly higher in greenhouse. The congenial environmental conditions available in the greenhouse lead to the production of quality fruits. Earlier results indicated that fruits obtained from greenhouse have maximum TSS and minimum acidity. Hence in the same corollary, greenhouse grown plants produce fruits with maximum total sugars (Table 9a, Fig. 35).

Time of planting did not influence the total sugars content of strawberry fruits in both locations.

Mulch had significant influence on total sugars content only at High ranges (Fig. 36). Plants mulched with white polyethylene resulted in maximum total sugars content of strawberry fruits in High ranges.

Time of planting and mulch interaction had significant influence in total sugars content of fruit in Central midlands (Table 9b). Planting in last week of October with white mulch recorded maximum total sugars content of fruits

Fig 34. Interaction effect of time of planting and mulch on TSS/Acidity of strawberry

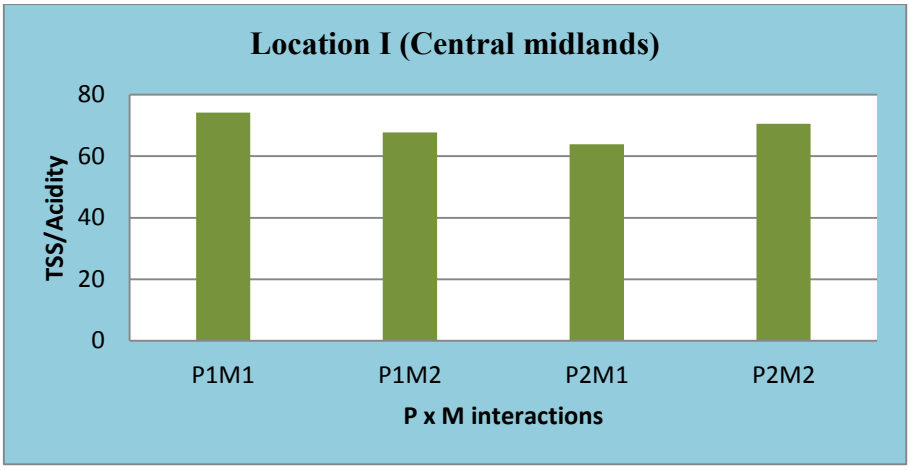


Fig 35. Effect of growing system on total sugars of strawberry

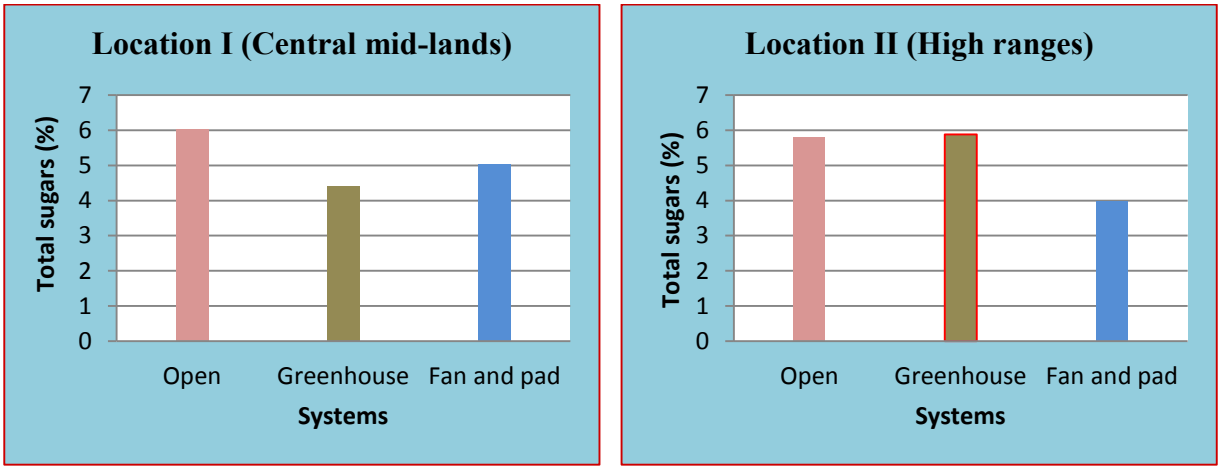


Fig 36. Effect of mulch on total sugars of strawberry

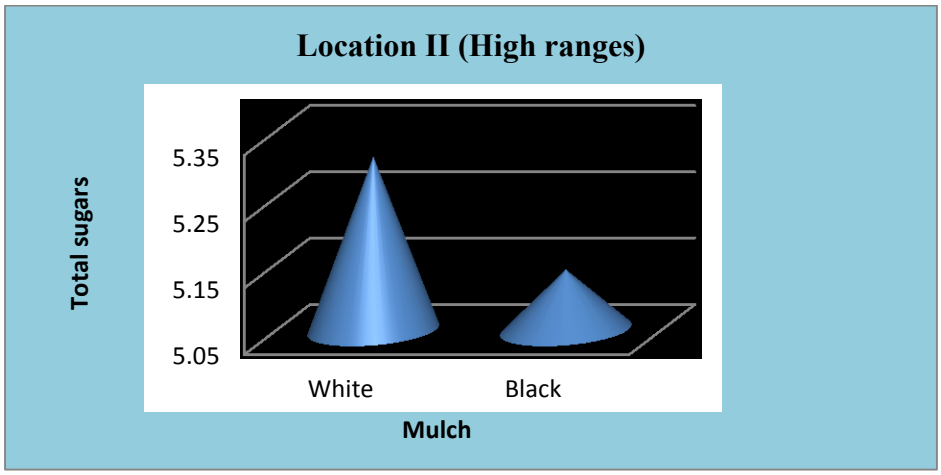


Fig 37. Interaction effect of time of planting and mulch on total sugars of strawberry

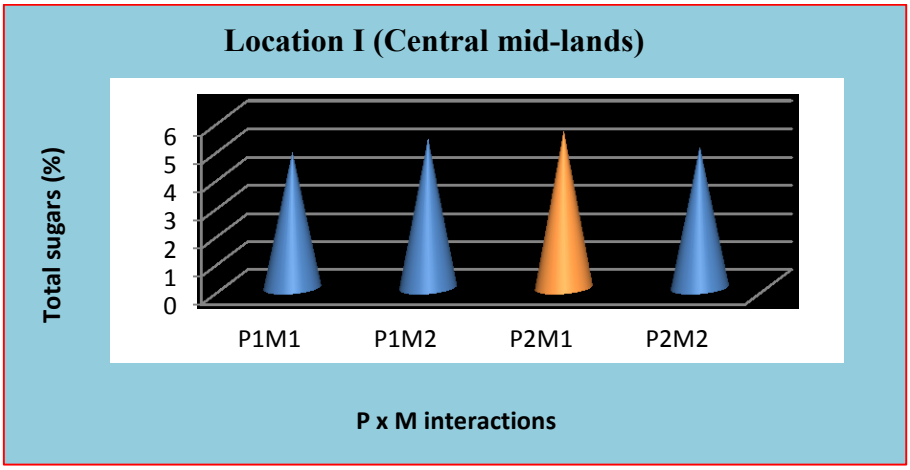


Fig 38. Interaction effect of system and time of planting on total sugars of strawberry

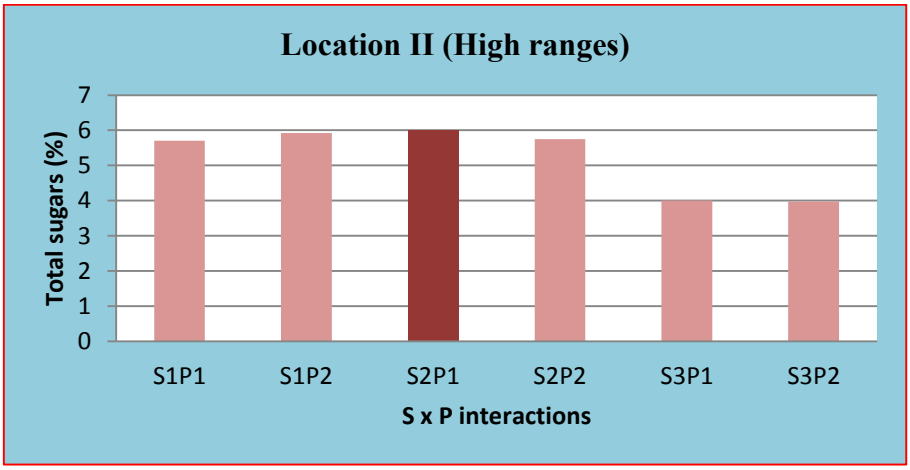


Fig 39. Interaction effect of system and mulch on total sugars of strawberry

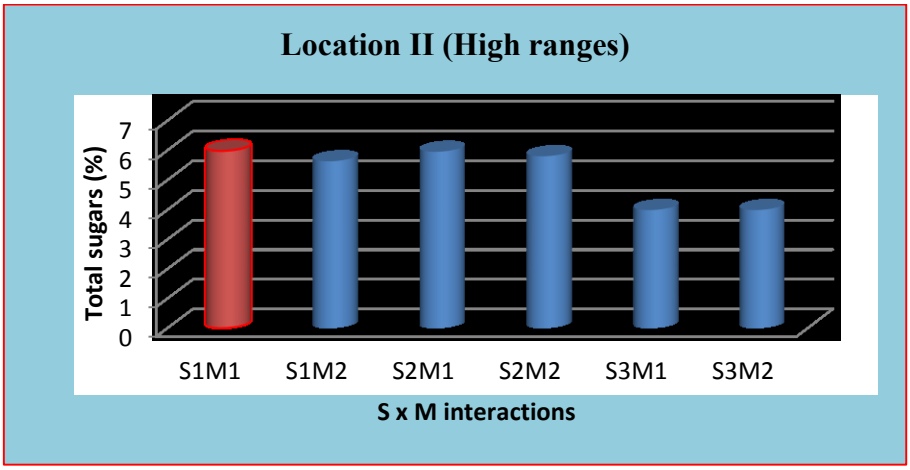


Fig 40. Monthly mean temperatures (^{0}C) in different growing systems at 8 am

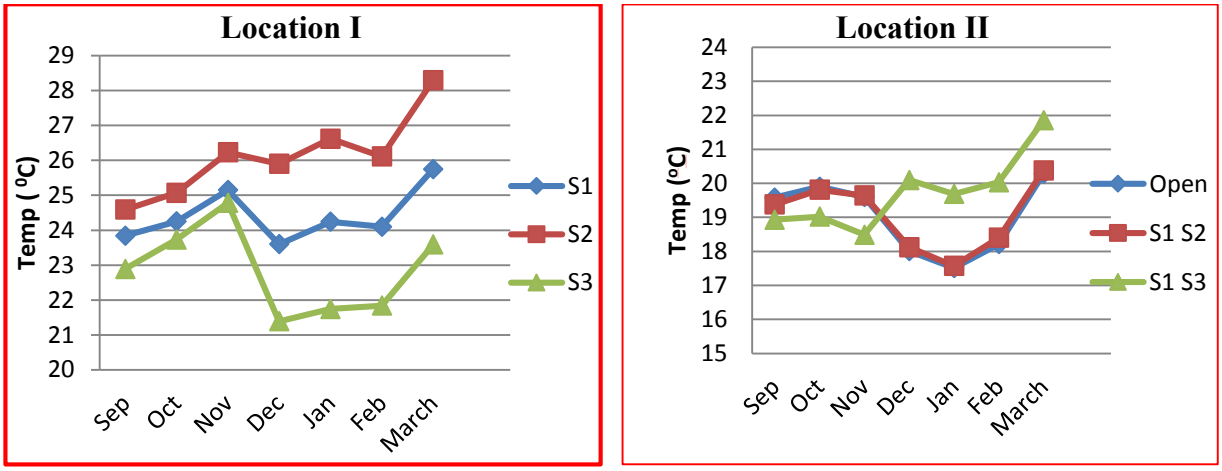


Fig 41. Monthly mean temperatures (^{0}C) in different growing systems at 2.30 pm

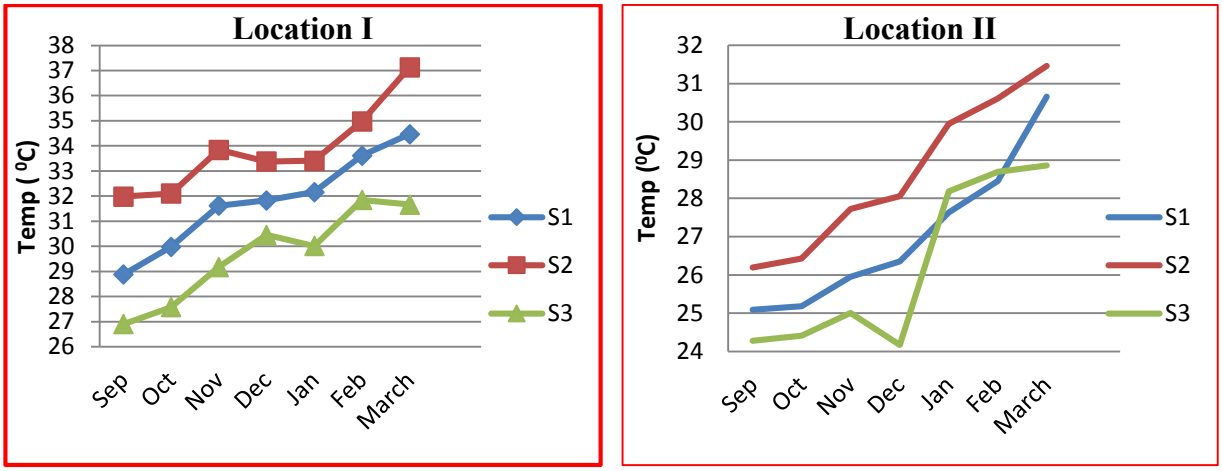


Fig 42. Monthly mean relative humidity (%) in different growing systems at 8 am

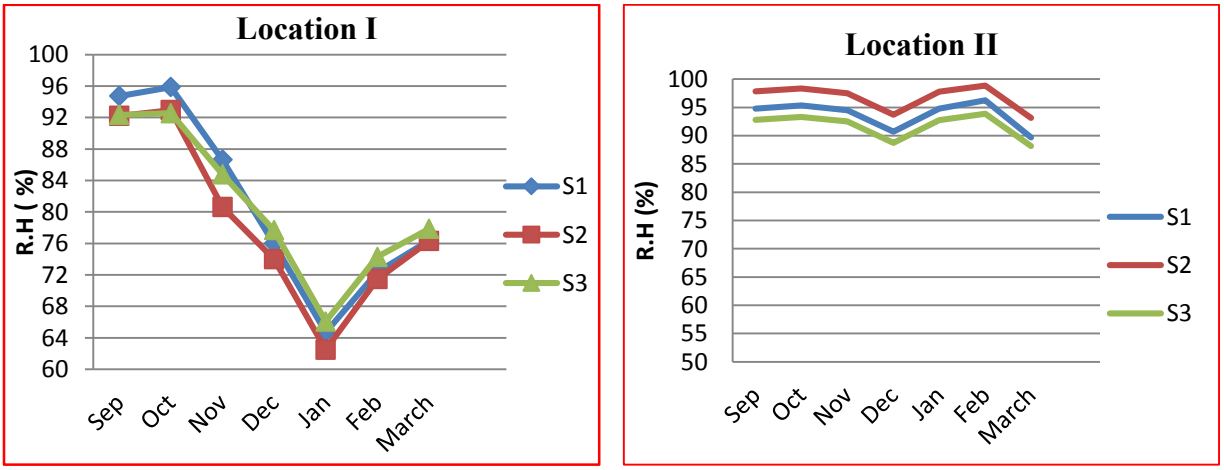


Fig 43. Monthly mean relative humidity (per cent) in different growing systems at 2.30 pm

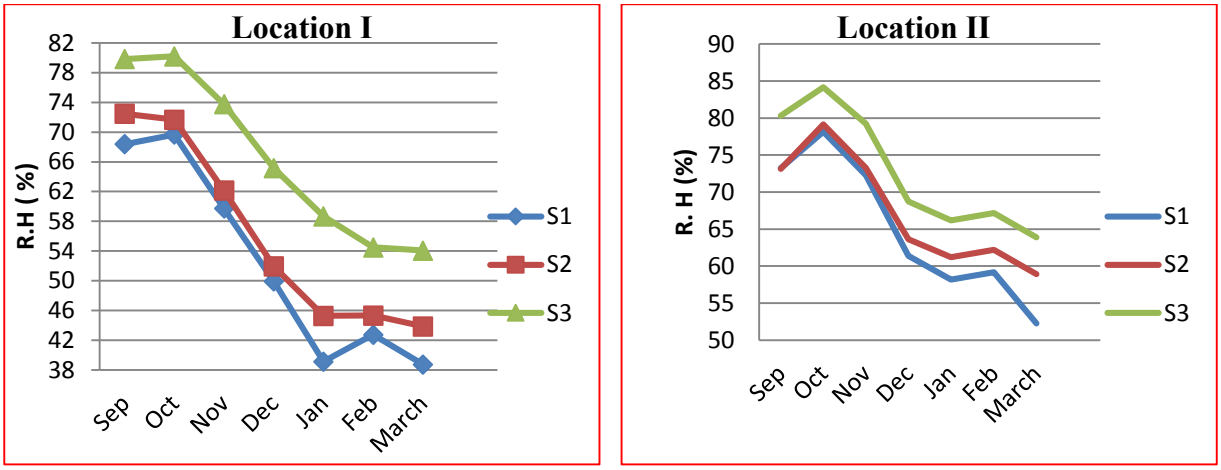


Fig 44. Light intensity (lux) in different growing systems at 12.30 pm

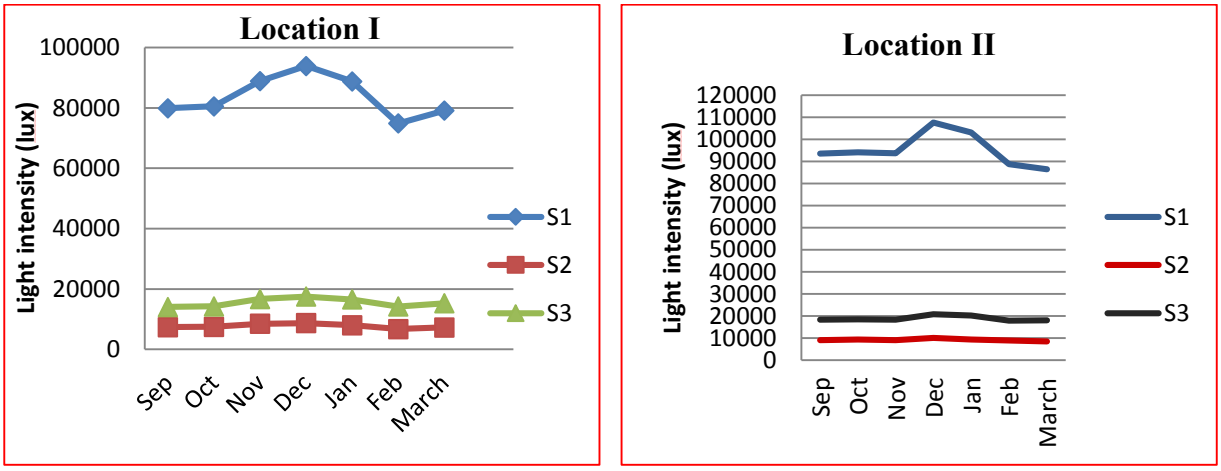
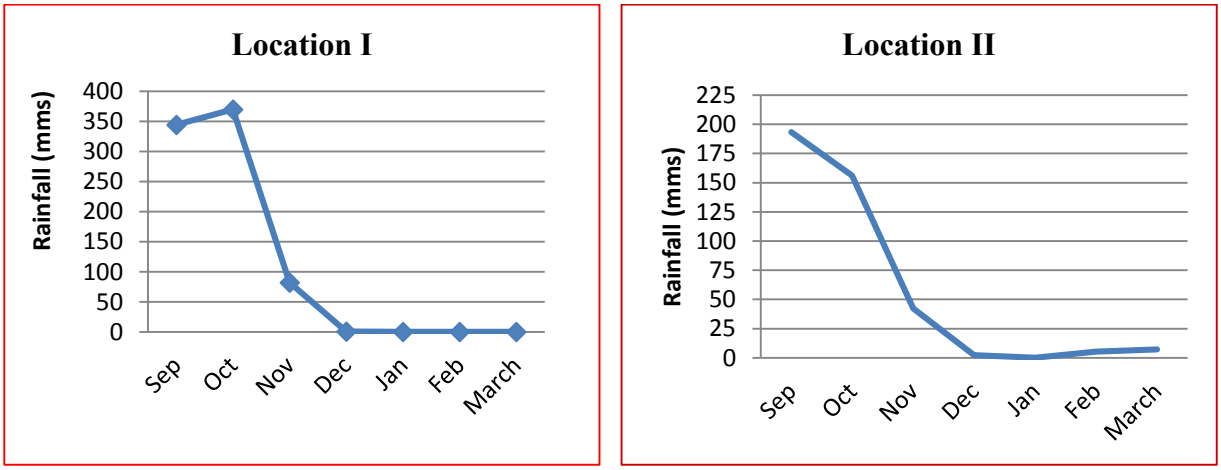


Fig 45. Monthly mean rainfall (mm) during the cropping period



(Fig. 37). In High ranges, S x P and S x M interaction had significant influence on total sugars content of the fruits. The combination of last week of September planting in greenhouse resulted inmaximum total sugars content of strawberry fruits (Fig. 38). Under open condition, white mulch recorded maximum total sugars of strawberry (Fig. 39).

5.5 Sensory evaluation

Sensory qualities are very important from the consumer's point of view. It depends on characters like colour, taste, flavor and texture. Overall acceptability of any fruit is based on all these characters(Tables10 and 11).

In Central mid-lands, the overall sensory score was highest in plants planted in last week of September in open field with white mulch (T1).Earlier results indicated that among the three growing systems, open system produced fruits with maximum total sugar content. Among the different time of planting, last week of September planting had maximum influence on TSS. Among the two types of mulch, white mulch produces maximum TSS and total sugar content. The cumulative effect of all these factors may lead to best quality fruits in treatment combination of plants planted in last week of September in open field with white mulch (T1).

In High ranges, the overall sensory score was the highest in T_2 (plants planted in last week of September in open field with black mulch). Among the three growing systems, open system is on par with greenhouse in producing fruits with high content of TSS and total sugars. Better quality of fruit from early planting (last week of September) may be due to the more time for accumulation of better sugar and ascorbic acid. This was in accordance with the findings of Rajbir*et al.* (2007) and Rahman*et al.* (2014) in strawberry.

Comparing the two locations, significant difference was observed in appearance and colourwhich are the quality factors that attracts the consumers. Fruits harvested from high ranges have better appearance and colour compared to fruits obtained from Central midlands. The temperature in the high ranges is low compared to Central midlands (Table 12).

5.6 Pest and Disease incidence

During the entire period of study, there was no severe incidence of pests and diseases at both locations. However in Central midlands, pests and disease incidence wasobserved more in plants grown under fan and pad system. This might be due to the congenial environmental conditions mainly low temperature and high humidity influence the pest and disease incidence in fan and pad system.In high ranges, mild incidence of pests (*Amsactaalbistriga* and Torticidae) and disease (Alternaria leaf spot)was found in open, greenhouse and fan and pad system. Pests 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 Central midlands and High ranges. The contribution of cost incurred for construction was found to be higher for greenhouse and fan and pad system in both locations. The yield and returns was found to be higher in open system. The analysis revealed that open system is beneficial for cultivating strawberry in both locations.

SUMMARY

6. Summary

The study on "Performance of strawberry (*Fragaria x ananassa* Duch.) in different growing conditions" was undertaken with the objective to evaluate the performance of strawberry under three systems of growing, two time of planting and two types of mulching in Central midlands and High ranges of Kerala.

The study was undertaken at College of Horticulture, Vellanikkara with humid tropical climate and at Krishi Vigyan Kendra, Ambalavayal with humid sub-tropical climate from September 2013 - March 2014. Commercially cultivated strawberry variety Winter Dawn of one month old tissue culture plants was used for study. Three systems of growing namely open field, greenhouse and fan and pad system were used. Two time of planting namely last week of September and last week of October were taken for planting. The experiment was laid in RBD with 12 treatments and 3 replications. Observations on vegetative growth attributes, flower attributes, yield attributes, quality attributes, postharvest study, pest and disease were also observed.

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

In Central midlands, fan and pad system (S_3) recorded significantly higher plant height compared to all the other systems. In High ranges, greenhouse recorded maximum plant height compared to all other systems.

Time of planting, mulch and the interactions did not have significant influence on plant height during the all stages of growth in both the locations.

Open condition recorded significantly high number of leaves per plant in both the locations.

Planting in the last week of September (P_1) was resulted in higher number of leaves per plant in both the locations.

In Central midlands, interaction $S_3P_1M_1$ had maximum number of leaves per plant at early stages of growth. However in High ranges, under open system, last week of September planting (S_1P_1) recorded significantly higher number of leaves per plant.

In Central midlands, fan and pad system (S_3) recorded maximum plant spread compared to all other systems. In High ranges, greenhouse (S_2) recorded the maximum plant spread compared to other systems of growing.

Last week of September planting recorded maximum plant spread in Central midlands.

Mulch and interactions had no significant effect on plant spread in both the locations.

In Central midlands, fan and pad system took minimum duration for flowering compared to other growing systems.

Black mulch took minimum duration for flowering in Central midlands.

Among interactions, fan and pad system with black mulch (S_3M_2) took minimum days to first flowering in Central midlands.

Growing systems, time of planting, mulch and their interactions had no significant effect on number of flowers per plant in Central midlands. In High ranges, open system (S_1) recorded highest number of flowers per plant. Open system with black mulch (S_1M_2) recorded significantly highest number of flowers per plant in High ranges.

Growing systems, time of planting, mulch and their interactions had no significant effect on number of clusters per plant in Central midlands. In High ranges, open field (S_1) recorded the maximum number of clusters per plant.

Highest number of clusters per plant was recommended in open field with black mulch.

In Central midlands, fan and pad system (S_3) recorded maximum number of fruits per plant. In High ranges, open system (S_1) recorded maximum number of fruits per plant.

Last week of September planting recorded maximum number of fruits per plant in Central midlands. In High ranges, time of planting has no significant effect on number of fruits per plant.

Mulch had no significant effect on number of fruits per plant in both locations.

Among interactions, open field with black mulch (S_1M_2) recorded maximum number of fruits per plant in High ranges.

Yield per plant was not significantly influenced by growing systems, time of planting, mulch and their interactions in Central midlands. In High ranges, open field (S_1) recorded maximum yield per plant compared to other growing systems. Among interactions, open field with black mulch (S_1M_2) recorded the maximum yield per plant compared to all other interactions.

Average fruit weight per plant is not significantly influenced by growing systems in Central midlands. In High ranges, Open field (S_1) recorded maximum average fruit weight per plant compared to other growing systems.

Time of planting, mulch and their interactions had no significant effect on average fruit weight per plant in both locations.

In Central midlands, greenhouse recorded minimum number of days to first harvest. In High ranges, open field (S_1) recorded minimum number of days to first harvest.

Time of planting had no significant effect on days to first harvest in both locations.

Black mulch took minimum days to first harvest in Central midlands.

The interaction of white mulch and fan and pad system (S_3M_1) resulted in minimum days to first harvest in Central midlands.

Open system (S_1) recorded maximum number of days to final harvest in Central midlands. In High ranges, greenhouse (S_2) recorded maximum number of days to final harvest.

Time of planting had no significant effect on days to final harvest in Central midlands. Last week of October planting (P_2) recorded the maximum days to final harvest in High ranges.

Mulch had no significant effect on days to final harvest in both locations.

In Central midlands, planting in open system with white mulch (S_1M_1) recorded maximum days to final harvest. In High ranges, among the interactions, planting in the last week of October and white mulch (P_2M_1), greenhouse and white mulch (S_2M_1), planting in the last week of October in fan and pad system with white mulch ($S_3P_2M_1$) resulted in maximum days to final harvest of strawberry.

In Central midlands, growing system had no significant effect on TSS of strawberry. Greenhouse (S_2) recorded significantly higher TSS content in High ranges.

Last week of September planting (P_1) recorded maximum TSS of fruits in Central midlands. Time of planting had no significant influence on TSS content of fruits in High ranges.

Mulch had no significant influence on TSS content of fruits in both locations.

Among the interactions, planting in last week of September with white mulch (P_1M_1) recorded maximum TSS content of fruits in Central midlands. In High ranges, planting in last week of September in greenhouse (S_2P_1) and planting in greenhouse with white mulch (S_2M_1) recorded highest TSS content in strawberry fruits.

Growing systems had no significant effect on acidity of fruits in Central midlands. In High ranges, greenhouse system (S_2) recorded minimum acidity content of fruits.

Time of planting, mulch and their combinations had no significant influence on acidity of fruits in both locations.

Growing systems had no significant effect on TSS/acidity of strawberry fruits in Central midlands. TSS/acidity was maximum in greenhouse (S_2) compared to all other growing systems in High ranges.

Time of planting and mulch had no significant influence on TSS/acidity of fruits in both locations.

Planting of strawberry in last week of September with white mulch (P_1M_1) recorded maximum TSS/acidity in Central midlands. In High ranges, interactions had no significant influence on TSS/acidity of strawberry fruits.

In Central midlands, open system recorded maximum total sugars of strawberry. In High ranges, greenhouse system (S_2) recorded the maximum total sugar content of fruits.

Time of planting had no significant influence on total sugar content of fruits in both locations.

In Central midlands, mulch had no significant effect on total sugar content of fruits. In High ranges, white mulch (M_1) recorded maximum total sugar content of fruits.

Among interaction, last week of October planting and white mulch (P_2M_1) recorded the highest total sugars content of fruits in Central midlands. In High ranges, last week of September planting in greenhouse (S_2P_1), planting in open condition with white mulch (S_1M_1) recorded the highest total sugar content of fruits.

In Central midlands, the highest total sensory score was recorded in fruits obtained from plants planted in September in open field with white mulch (T_1). In High ranges, planting in last week of September in open field with black mulch (T_2) recorded the highest total sensory scores.

The growing systems, time of planting, type of mulch and their interactions had no significance influence on shelf life of strawberry fruits.

Based on the benefit cost ratio, open field is beneficial for cultivating strawberry in both locations.

Fruits from High ranges were found to be superior in colour and appearance than fruits from Central midlands.

It is concluded that strawberry can grow and flower in both locations. In Central midlands, strawberry could be planted in last week of September with black or white polyethylene mulch under open field for early flowering, maximum number of fruits of better quality. In High ranges, strawberry could be planted in last week of September with black polyethylene mulch under open field for early fruiting, higher yield and better quality fruits.

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APPENDIX

WEATHER DATA

Appendix-I

Monthly mean temperatures (^{0}C) during the period from September 2013 to March 2014 indifferent growing systems in Location I

Month	Open (S_1)		Green house (S_2)		Fan and pad (S_3)	
	8.00 am	2.30pm	8.00am	2.30pm	8.00am	2.30 pm
September 2013	23.84	28.88	24.59	31.98	22.89	26.90
October 2013	24.25	29.98	25.07	32.10	23.73	27.58
November 2013	25.15	31.62	26.23	33.84	24.78	29.18
December 2013	23.60	31.83	25.90	33.38	21.39	30.45
January 2014	24.24	32.16	26.62	33.41	21.74	30.01
February 2014	24.10	33.61	26.11	34.98	21.84	31.85
March 2014	25.75	34.47	28.30	37.13	23.59	31.66
Mean	24.42	31.79	26.12	33.83	22.85	29.66

WEATHER DATA

Appendix-II

Monthly mean relative humidity (per cent) during the experiment from September 2013 to March 2014 in different growing systems in Location I

Month	Open (S_1)		Greenhouse (S_2)		Fan and pad (S_3)	
	8.00 am	2.30pm	8.00am	2.30pm	8.00am	2.30 pm
September 2013	94.73	68.39	92.21	72.47	92.32	79.83
October 2013	95.87	69.68	92.94	71.68	92.55	80.19
November 2013	86.63	59.73	80.63	62.13	84.77	73.77
December 2013	75.97	49.90	74.00	51.94	77.68	65.16
January 2014	64.71	39.13	62.48	45.29	66.06	58.68
February 2014	72.36	42.75	71.46	45.32	74.29	54.50
March 2014	76.35	38.74	76.29	43.87	77.84	54.06
Mean	80.95	52.62	78.57	56.10	80.79	66.60

WEATHER DATA

Appendix – III

Monthly mean light intensity (lux) and rainfall during the period from September 2013 to March 2014

in different growing systems in Location I

Month	Open (S_1)	Greenhouse (S_2)	Fan and pad (S_3)	Rainfall (mm)
September 2013	79878.50	7384.82	14053.37	344.1
October 2013	80512.9	7474.84	14300.00	369.8
November 2013	88926.67	8481.67	16696.67	82.0
December 2013	93864.52	8708.07	17493.55	0.5
January 2014	88803.23	8006.45	16574.19	0.0
February 2014	74882.14	6753.57	14232.14	0.0
March 2014	79083.87	7270.97	15277.42	0.0
Mean	83707.40	7725.77	15494.85	113.77

WEATHER DATA

Appendix - IV

Monthly mean temperatures (^{0}C) during the period from September 2013 to March 2014 in different growing systems in Location II

Month	Open (S_1)		Greenhouse (S_2)		Fan and pad (S_3)	
	8.00 am	2.30pm	8.00 am	2.30pm	8.00 am	2.30pm
September 2013	19.58	25.09	19.38	26.19	18.93	24.28
October 2013	19.90	25.18	19.81	26.43	19.02	24.41
November 2013	19.60	25.95	19.64	27.72	18.49	25.01
December 2013	18.01	26.35	18.12	28.06	20.10	24.17
January 2014	17.51	27.63	17.57	29.95	19.69	28.18
February 2014	18.21	28.45	18.40	30.61	20.03	28.69
March 2014	20.28	30.66	20.38	31.46	21.85	28.86
Mean	19.01	27.04	19.04	28.63	19.73	26.23

WEATHER DATA

Appendix - V

Monthly mean relative humidity (per cent) during the period from September 2013 to March 2014 in different growing systems in Location II

Month	Open (S_1)		Greenhouse (S_2)		Fan and pad (S_3)	
	8.00 am	2.30 pm	8.00 am	2.30 pm	8.00 am	2.30 pm
September 2013	94.80	73.24	97.82	73.15	92.78	80.33
October 2013	95.32	78.16	98.32	79.16	93.32	84.16
November 2013	94.50	72.26	97.50	73.26	92.50	79.23
December 2013	90.71	61.39	93.71	63.61	88.71	68.71
January 2014	94.77	58.19	97.77	61.19	92.77	66.19
February 2014	96.23	59.19	98.87	62.19	93.87	67.19
March 2014	89.68	52.23	93.16	58.90	88.16	63.90
Mean	93.72	64.95	96.74	67.35	91.73	72.82

WEATHER DATA

Appendix - VI

Monthly mean light intensity (lux) and rainfall during the period from September 2013 to March 2014 in different growing systems in Location II

Month	Open (S_1)	Greenhouse (S_2)	Fan and pad (S_3)	Rainfall (mms)
September 2013	93500.30	9056.00	18380.00	193.4
October 2013	94158.06	9375.00	18487.10	156
November 2013	93603.23	9076.13	18435.16	42.2
December 2013	107597.42	10153.55	20855.16	2.4
January 2014	103014.19	9452.55	20179.03	0
February 2014	88817.42	8900.97	17942.58	5.2
March 2014	86400.32	8590.97	18141.29	7.2

Appendix VII

Monthly mean sunshine hours from July 2013 to June 2014

July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June
11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5

Appendix – VIII

Benefit Cost Ratio of Location I (Central midlands)- 100m^{2}for six months

Particulars	Open system (Rs.)	Greenhouse (Rs.)	Fan and pad (Rs.)
1. Rent on land	25	25	25
2.Labour charges	5M + 5W =5x330 + 5x240 =1650 + 1200 = 2850	2850	2850
3. Planting material	320plants x Rs12 = 3840	3840	3840
4. Mulch	35 foot x 7 x Rs 7 =1225	1225	1225
5. Fertilizer (100 m^2)	200	200	200
6. Cow dung (100Kg)	100 Kg x Rs10 =1000	1000	1000
7. Pseudomonas (3Kg)	3 Kg x Rs 60 =180	180	180
8. Plant protection chemicals	20	20	20
9. Irrigation charges	240	240	240
10. Depreciation on fixed capital (10% of cost)*	--	3229	10762
11.Total cost	9580	12809	20342
12. Benefit	**320 plants x 4.55 x Rs 10 =14560	320 plants x 3.3 x Rs 10 =10560	320 plants x 5.87 x Rs 10 =18784
10. B/C ratio	14560/9580=1.5	10560/12809=0.82	18784/20342=0.92

*- After 10 years ofestablishment

**-10% crop loss occur due tounpredictable reasons

Appendix –IX

Benefit Cost Ratio of Location II (High ranges)- 100m^{2}for six months

Particulars	Open system (Rs.)	Greenhouse (Rs.)	Fan and pad (Rs.)
1. Rent on land	25	25	25
2.Labour charges	5M + 5W =5x330 + 5x240 =1650 + 1200 = 2850	2850	2850
3. Planting material	320 plants x Rs 12 = 3840	3840	3840
4. Mulch	35 foot x 7 x Rs 7 = 1225	1225	1225
5. Fertilizer (100 m^2)	200	200	200
6. Cow dung (100Kg)	100 Kg x Rs10 =1000	1000	1000
7. Pseudomonas (3Kg)	3 Kg x Rs 60 =180	180	180
8. Plant protection chemicals	20	20	20
9. Irrigation charges	240	240	240
10. Depreciation on fixed capital (10% of cost)*	--	3229	10762
11.Total cost	9580	12809	20342
12. Benefit	**320 plants x 8.97 x Rs 10 =28704	320 plants x 7.82 x Rs 10 =25024	320 plants x 6.33 x Rs 10 =20256
10. B/C ratio	28704/9580=3.0	25024/12809=1.95	20256/20342=1.0

*- After 10 years ofestablishment

**-10% crop loss occur due tounpredictable reasons

Appendix –X

Score card fororganoleptic evaluation

Name of the judge:

Date:

Characteristics	Scores				
	T_1	T_2	T_3	T_4	T_5
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

PERFORMANCE OF STRAWBERRY (*Fragariaxananassa*Duch.)IN DIFFERENT GROWING CONDITIONS

By

ANU KURIAN

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the

requirements for the degree of

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DEPARTMENT OF POMOLOGY AND FLORICULTURE

COLLEGE OF HORTICULTURE

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ABSTRACT

The study on "Performance of strawberry (*Fragaria x ananassa* Duch.) in different growing conditions" was conducted at College of Horticulture, Vellanikkara, Thrissur and Krishi Vigyan Kendra, Ambalavayal, Wayanad, Kerala from September 2013 to March 2014. The main objective was to compare the performance of strawberry (*Fragaria x ananassa* Duch.) under three growing conditions (open field, greenhouse and fan and pad system) and under two agro ecological zones of Kerala (Central mid-lands and High ranges).

Among the growth characters, plant height and plant spread were maximum in the fan and pad system in Central midlands. More number of leaves per plant was recorded under open condition. Number of leaves and plant spread were the maximum with planting in the last week of September. In High ranges, plant height and plant spread were highest in the greenhouse system and maximum number of leaves was recorded in open condition. Number of leaves per plant recorded was maximum in last week of September planting.

In Central mid-lands, minimum days to first flowering (55.67 days) was recorded under fan and pad system. The systems of growing had no effect on number of flowers and number of clusters per plant. Days to first flowering was minimum (57.11 days) in plants mulched with black polyethylene. Early flowering (55.0 days) was observed when mulched with black polyethylene in fan and pad system. In High ranges, number of flowers (20.78) and number of clusters per plant (17.47) were highest under open condition. Systems of growing had no effect on days to first flowering. Plants in the open condition with black polyethylene mulch resulted in maximum number of flowers (25.85) and number of clusters per plant (21.57) per plant.

Among the yield attributes, in Central midlands, fan and pad system was the best with respect to production of fruits per plant (5.87). Systems of growing had no effect on yield and average fruit weight per plant. Greenhouse was the best with respect to early harvest (82.67 days) of fruits whereas harvesting priod extended up to 163.25 days under open condition. Planting in last week of September recorded maximum number of fruits per plant (5.43). Early harvest (95.06 days) was recorded when mulched with black polyethylene. In High ranges, maximum number of fruits (8.97), yield (80.35 g), average fruit weight (8.79 g) per plant and early harvest of fruits (81.17 days) were observed in open condition. Maximum number of fruits (10.53) and highest yield (102.17 g) per plant were recorded in plants with black polyethylene mulch under open condition.

In Central midlands, systems of growing had no effect on content of total soluble solids (TSS), acidity, TSS/acidity ratio. Highest total sugars (6.03%) was recorded in open condition. Time of planting and mulch had no effect on quality parameters. In High ranges, lowest acidity (0.13 %), highest TSS (11.07 ^{0} Brix), TSS/acidity ratio (86.46) and total sugars (5.88 %) were recorded under greenhouse condition.

In Central mid-lands, the overall sensory score was highest in plants in the open field which were planted in the last week of September with white mulch. However, in High ranges, the overall sensory score was highest in open filed, planted in last week of September with black polyethylene mulch. The fruits harvested from High ranges had better appearance and colour compared to fruits obtained from Central midlands.