PRODUCTION DYNAMICS OF STRAWBERRY (*Fragaria x ananassa* Duch.) IN KERALA

by

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(2015-22-005)

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KERALA, INDIA

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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COLLEGE OF AGRICULTURE
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2020

DECLARATION

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

Vellanikkara

Date: 18/12/2020

Anu Kurian

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CERTIFICATE

Certified that this thesis **"Production dynamics of strawberry (*Fragaria x ananassa* Duch.) in Kerala"** is a record of research work done independently by **Ms. Anu Kurian (2015-22-005)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associate ship to her.

18/12/2020

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Date: 18/12/2020

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(Chairperson, Advisory committee)
Associate Director of Research
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We, the under signed members of advisory committee of **Ms. Anu Kurian (2015-22-005)**, a candidate for the degree of **Doctor of Philosophy in Horticulture** with major field in **Fruit Science**, agree that the thesis entitled **"Production dynamics of strawberry (*Fragaria x ananassa* Duch.) in Kerala"** may be submitted by **Ms. Anu Kurian (2015-22-005)**, in partial fulfilment of the requirement for the degree.

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Introduction

1. INTRODUCTION

Strawberry is a unique soft fruit crop known for its tantalizing aroma, bright red colour, juicy texture, sweetness and high nutritive value (Kher *et al.*, 2010). Due to its genetic diversity, high heterozygous nature and environmental adaptations, it is the most widely distributed fruit crop worldwide.

In 2018, the total global strawberry production was 8.34 MT. China was the largest strawberry producer in the world with 3.8 MT of strawberry which is 42 per cent of the global output. U.S. ranked second with 1.4 MT. China and USA together accounts for about 57 per cent of total world strawberry production. The other major producers were Mexico and Egypt (5%, each), Turkey and Spain (4%, each) (FAO, 2018). The major strawberry producing states in India are Haryana, Mizoram, Meghalaya, Maharashtra, Himachal Pradesh and Jammu and Kashmir (APEDA, 2018).

Strawberry is a low creeping perennial herb with a compressed stem called crown, having a growing tip at the top and roots at the base. New leaves and flower clusters emerge from apical meristem in the crown. Fruit is botanically known as an aggregate accessory fruit in which the fleshy part is derived not from the plant's ovaries but from the receptacle that holds the ovaries. Strawberry performs better under temperature ranges between 15°C to 35°C (Rani and Ahmad, 2012) and soil rich in organic contents with light clay to loam and a pH range of 5.6 to 6.5. Strawberry is grown commercially in temperate climatic conditions of the world. However, with the availability of day-neutral varieties, it can be grown well in tropical and subtropical climatic condition of India (Sharma, 2002).

Health benefits of strawberry includes its property as anti-carcinogenic, anti-diabetic, antioxidant and anti-viral against polio (Asrey and Patel, 2003;, 2007). Strawberries are a good source of natural antioxidants (Wang and Jiao, 2000) and phytochemicals such as carotenoids, vitamins, phenols, flavonoids, dietary glutathionone and metabolites (Larson, 1988). Strawberry fruits have low calorific value, absence of cholesterol and higher level of minerals like phosphorus, potassium, calcium, iron, manganese and especially vitamin C (40- 100mg/10g berries), various forms of vitamin B (B_1, B_2, B_3, B_5 and B_6) and proteins, which make it ideal for health conscious consumers (Kumar *et al*., 2011).

Strawberry has a high demand for table purpose as well as for value addition like jam, jelly, purees, juice concentrate, canning, ice-cream preparation, beverages, rose red wine, soft drinks and other quality products. Strawberry is canned and shipped in frozen conditions in many western countries. India exports strawberry mainly to Malaysia, Bangladesh and Austria.

Our state, Kerala is blessed with different agro-ecological conditions and altitudinal variations which are suitable for various crops. Sizeable areas in the high ranges of Idukki and Wayanad districts fall under sub tropical - temperate climatic category, even though high altitude areas are found all along the Western Ghats. The low altitude region, endowed with humid tropical climate is spread over the entire length of the state. The earlier research results have proved that strawberry can be even grown in the plains of Kerala during September to March under open condition.

Temperature and photoperiod are the most important environmental factors that affect the transition from vegetative to flowering phase of strawberry. Effect of environmental factors on yield and quality of strawberry was reported by many authors in the past (Crespo *et al.*, 2010; Larrouy *et al.*, 2011; Neri *et al.*, 2012). Strawberry cultivars showed considerable amount of variation regarding their adaptability to a particular agro-climatic condition. Compatible genotypes and good management practices is of paramount importance for successful strawberry cultivation (Asrey and Singh, 2004; Ahsan *et al.*, 2014). This observation has opened the possibilities for commercial as well as homestead cultivation of strawberry in Kerala.

The present climatic scenario of Kerala is highly favourable for the introduction and cultivation of exotic horticultural crops. Strawberry is gaining popularity among all age group consumers. It is amongst the few crops, which gives quick and very high returns per unit area on the capital investment, as the crop is ready for harvesting within six months of planting (Bakshi *et al.*, 2014). In Kerala, land value is increasing and the per capita land holding is decreasing day by day. The different systems of cultivation like vertical garden, grow bags, hanging pots *etc.* for growing strawberry will aid in the inclusion of strawberry in the urban and peri-urban horticultural programme which is the need of the hour. Keeping in view of the facts mentioned above, the present trial was planned and carried out to assess the performance of different varieties of strawberry in respect of quality and yield of strawberry in the tropical and sub-tropical climatic conditions of Kerala, to standardize the nutrient requirement and spacing of strawberry for commercial cultivation in Kerala, and also for developing growing systems for homestead cultivation.

Review of Literature

2. REVIEW OF LITERATURE

In this chapter, relevant literatures based on the objectives of the research are reviewed and presented in the order of variety, nutrients, spacing, growing systems, growing media and post-harvest aspect. The influence of crop and environmental factors, and pest and disease incidence are also reviewed.

2.1. Vegetative growth attributes

The plant height, number of leaves, plant spread and number of crowns are the vegetative growth attributes of strawberry. The vegetative growth of the crop is influenced by variety, nutrients, spacing and different growing systems. Studies on the response of crop to different growth attributes are reviewed and discussed here under.

2.1.1 Variety

Experiment was conducted to study the effect of number of crowns on the production of strawberry *cvs.* Chandler, Oso Grande, Pajaro and Vilanova, revealed that there is no significant effect in production due to increase in crown number in *cvs.* Oso Grande and Vilanova, but in Chandler and Pajaro, there was a linear increase in production (Galarza *et al*., 1997).

The effects of different planting densities on the growth and yield of strawberry cultivars were studied using two strawberry *cvs.* Sanga Sengana and Chandler in Srinagar, Jammu and Kashmir revealed that Sanga Sengana was superior in terms of plant height (7.24 cm) (Ahmad**,** 2009).

Research on evaluation of the performance of 17 strawberry genotypes under Garhwal Himalayan conditions revealed that variety Dana (26.03 cm) and Chandler

(23.22 cm) were superior in plant height compared to other varieties (Rao and Lal, 2010).

Varietal performance of strawberry *cvs*. RABI-3 and BARI-1 were evaluated at Horticulture Farm, SAU, Bangladesh revealed that the highest plant height, number of leaves and minimum number of days to flowering were recorded in RABI-3 compared to BARI-1 (Akter *et al*., 2013).

Experiment was conducted using five strawberry cultivars *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 revealed that *cv*. Camarosa exhibited maximum vegetative growth followed by FA 008 and BARI Strawberry-1 (Rahman *et al*., 2014).

Field trial was conducted to assess different cultivars of strawberry such as Sweet Charlie, Camarosa and Festival in Supaul district of Bihar revealed that short day *cv*. Festival found to be the best performing variety with respect to plant height (21.34 cm) compared to day neutral varieties like Sweet Charlie and Camarosa (Das *et al*., 2015).

Six strawberry cultivars *viz*., Kordestan, Parose, Marak, Queen, Selva and Camarosa were evaluated for the adaptability and yield performance in the tropical climatic condition of Iran revealed that cultivar Marak and Camarosa had significantly maximum leaf length compared to other cultivars (Asadpoor and Tavallali, 2015).

Performance of nine strawberry varieties *viz.*, Addie, Belrubi, Brighton, Chandler, Dana, Etna, Fern, Pajaro and Selva were studied under mid hill region of Kullu valley of Himachal Pradesh revealed that the maximum plant height was recorded with *cv*. Belrubi (16.37 cm) followed by *cv*. Chandler and Pajaro. Whereas, the maximum plant spread was recorded in *cv*. Fern followed by *cv*. Belrubi (M *et al*., 2016).

A research trial was carried out in the sub-tropical region of Punjab using five strawberry cultivars *viz*., Chandler, Tioga, Fern, Selva and Blackmore at 30 cm x 40 cm spacing proved that *cv*. Chandler found to be the best in producing maximum number of shoots, leaves, runners and flowers. While cultivar Selva was the least among all these parameters (Kaur *et al*., 2017).

Evaluation of eight strawberry var. FA-006, FA-007, FA-008, FA-015, FA-016, FA-017, FA-022, BARI strawberry-1 were evaluated under field conditions of Bangladesh revealed that BARI strawberry-1 out performed in vegetative characters compared to other genotypes (Mahmuda *et al*., 2017).

Gaikwad *et al.* (2018) conducted a trial to evaluate the performance of cultivars *viz*., Camarosa, Winter Dawn, Nabila and Seascape under Mahabaleshwar conditions revealed that the cv. Nabila recorded the highest plant height (30.80 cm)**,** while the cultivar Winter Dawn recorded the highest plant spread which was found on par with cultivar Camerosa and Nabila.

Experiment conducted to assess different cultivars of strawberry *viz.*, Nabila, Rania, Kamila, Camarosa, Flavia and Flaminia in plain region of Chattisgarh revealed that Nabila produced higher vegetative growth in terms of plant height, number of leaves and plant spread (Neetu and Sharma, 2018).

2.1.2. Nutrients

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

Ram and Gaur (2003) studied the effect of different levels of nitrogen fertilizer (0, 50, 100, 150 or 200 kg N ha^{-1}) on the growth of strawberry and reported that the plant height and number of leaves of plant were increased with increasing rate of application of N.

Rana and Chandel (2003) conducted an experiment to study the effect of nitrogen and biofertilizers on growth of strawberry *cv*. Chandler in Himachal Pradesh resulted that maximum number of leaves (26.20) was observed in plants applied with *Azotobacter* inoculation combined with 100 kg N ha^{-1}.

A field trial was conducted to study the effect of increasing N rates on vegetative growth, yield and quality of strawberry revealed that at high N rates, accumulation of high levels of ammonium and soluble salts in soil which lead to the suppression of plant growth (Haynes and Goh, 2008).

Santos and Chandler (2009) studied the effect of different rates of nitrogen on strawberry cultivars Festival and Winter Dawn and found that canopy diameter increased linearly with increasing rate of nitrogen from 0.5 to 0.9 kg ha^{-1}.

Research work conducted by Umar *et al*. (2009) on strawberry *cv*. Chandler to study the effect of FYM integrated with urea and *Azotobacter* on growth, yield and quality of strawberry revealed that application of 25 per cent N through FYM + *Azotobacter* and 100 per cent N through urea + *Azotobacter* had positive impact on vegetative growth of strawberry.

Studies conducted by Yadav *et al.* (2010) revealed that an integrated nutrient supply of FYM (50 t ha^{-1}) along with N: P: K (80 kg: 40 kg: 40 kg per ha) application was essential for the sustainable production of strawberry. Maximum plant growth and yield were obtained when 50 per cent of nitrogen is substituted with vermicompost (16.5 t ha^{-1}).

Gupta and Tripathi (2012) conducted an experiment to study the effect of *Azotobacter* and vermicompost on growth of strawberry *cv*. Chandler revealed that combined application of *Azotobacter* at 7 kg ha^{-1} + vermicompost at 30 t ha^{-1} significantly increased the plant height and number of leaves per plant.

A trial was conducted to study the effect of different levels of phosphorous on the growth and yield of strawberry revealed that P level of 150 kg P_2O_5 ha^{-1} recorded maximum vegetative growth attributes compared to 0, 50, 100 kg ha^{-1} (Akter *et al*., 2013).

Studies conducted by Khalid *et al*. (2013) on the effect of different organic amendments on the vegetative growth of strawberry *cv*. Chandler revealed that organic amendments such as FYM and vermicompost increased vegetative growth such as plant height, number of leaves and canopy spread of strawberry.

Studies conducted by Lata *et al*. (2013) in strawberry *cv*. Chandler found out that combined application of different nutrients from different sources are beneficial for growth of strawberry under subtropical conditions of Lucknow.

An experiment was laid to study the response of biofertilizers on the vegetative and yield parameters of strawberry under subtropical conditions of Uttar pradesh using four biofertilizers *viz.*, VAM, *Azotobacter*, *Phosphobactor* and *Azospirillum* resulted that vesicular arbuscular mycorrhizae (VAM) showed a significant increase in plant height compared to other treatments (Pandit *et al*., 2013).

An experiment conducted by Kumar *et al*. (2014) to study the effect of different levels of nitrogen (0, 75,100,125,150 kg N ha^{-1} on growth and yield of strawberry *cv*. Sweet Charlie revealed that maximum number of leaves per plant (13.16), plant spread (20.66 cm), number of fruits (23.93) and yield per plant (362.88 g) was recorded with the application of 100 kg N ha^{-1}.

Studies conducted by Sarkar and Ibotui (2017) in the foot hills of Nagaland revealed that application of vermicompost @ 6-8 t ha^{-1} along with *Azotobacter* resulted in higher yield and quality of strawberry fruits.

Higher yield and quality strawberries were obtained from strawberry fields fertilized with nitrates and ammonium using 100 kg N ha^{-1} together with calcium nitrate (Sprogis *et al*., 2017).

An experiment was conducted to study the effect of organic manures such as poultry manure, vermicompost, FYM and biofertilizers such as *Azotobacter* on the growth, yield and quality of strawberry *cv*. Sweet Charlie showed that 50 per cent Vermicompost + 50 per cent Poultry Manure + *Azotobacter* was found to be the best among the various treatments (Soni *et al*., 2018).

2.2. Flowering attributes

2.2.1. Variety

Joolka and Badiyala (1983) suggested that days to first flowering was a varietal character and might be the difference among the varieties for their adaptability to cool temperature condition.

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

Experiment conducted to study the flowering, fruiting and yield characteristics of eight strawberry cultivars under subtropical conditions of Uttar Pradesh revealed that *cv*. Seascape produced highest number of flowers per plant (4.736) compared to all other varieties (Deepa *et al*., 2011).

Rahman *et al*. (2014) evaluated 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 and reported that the genotype Camarosa took the maximum number of days to first flowering (89.00 days) 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).

Kaur *et al*. (2017) conducted a research to evaluate some strawberry cultivars *viz*., Chandler, Tioga, Fern, Selva and Blackmore in sub-tropical region of Punjab indicated that strawberry *cv*. Chandler proved to be the best in producing maximum number of shoots, leaves, runners and flowers along with yield parameters.

Strawberry varieties were evaluated under the Chattisgarh plains of India using six varieties revealed that cultivar Nabila produced maximum number of flowers while early flowering and fruiting were exhibited by *cv*. Camarosa (Neetu and Sharma, 2018).

Strawberry cultivars *viz*., RABI 2, RABI 3, Camarosa and Festival were evaluated with BARI Strawberry-1 as check variety revealed that the genotype BARI

Strawberry-1 which had lowest number of leaves (12.33), minimum leaf length and breadth gave earlier flowering compared to other genotypes (Ahmed *et al.*, 2019).

2.2.2. Nutrients

Strawberry plants (*Fragaria x ananassa* Duch. *cv.* Aliso) were grown in nursery under three levels of N application such as 80, 320 and 640 Kg N ha^{-1} revealed that N application in the nursery @ 320 Kg N ha^{-1} showed early flowering and higher total yields compared to other levels (Rodger *et al.*, 1985).

Strawberry plants grown at different levels of nitrogen levels showed that N deficiency lowered the number of flowers, fruits and lead 50% reduction in total yield (Deng and Woodward, 1998).

Ali *et al*. (2003) conducted studies to determine the effect of different combinations of Nitrogen, Phosphorous and FYM on yield and quality of strawberry showed that strawberry field applied with 150 kg N ha^{-1}, 100 kg P ha^{-1} and 20 t FYM ha^{-1} produced maximum number of flowers (14.60) than all other treatments.

An experiment was carried out by Prasad (2009) to study the response of inorganic and biofertilizers on growth**,** yield and quality of strawberry revealed that a significant increase in growth, yield and quality parameters was obtained by the application of NPK (40:80:40 kg/ha) along with *Azotobacter* + PSB inoculation.

Studies conducted by Yadav *et al*. (2010) using different combinations of organic and inorganic fertilizers resulted that maximum number of flowers per plant (29.60) was recorded with *Azotobacter* inoculated with 50% N substitution by vermicompost and remaining 50% through inorganic fertilizer in two equal splits at establishment and before flowering stage.

Azotobacter at 6 kg ha^{-1} + vermicompost at 30 t ha^{-1} had significant influence on early flowering (56.15 days and 54.15 days, respectively), number of flowers (67.48 and 64.51 respectively) during two seasons in strawberry *cv.* Chandler (Gupta and Tripathi, 2012).

Among the nutrients, N and K are the most required nutrients and they interact for the increase in yield and improvement of plant nutrition (Taiz & Zeiger, 2013).

An experiment was conducted to evaluate different levels of phosphorus such as 60 kg ha^{-1}, 70 kg ha^{-1}, 80 kg ha^{-1} and 90 kg ha^{-1} on the growth, yield and fruit quality of strawberry *cvs*. Karona and Tuft revealed that Phosphorus at 90 kg ha^{-1} significantly influenced earliness in flowering (Ahmad *et al.*, 2017).

2.3 Yield attributes

2.3.1. Varieties

Effect of two day/night temperature on fruit set and fruit growth in two cultivars, ‘Nyoho’ and ‘Toyonoka’ were studied. Cultivar Nyoho shown no significant difference in fruit set at both temperatures, while cultivar Toyonoka had much lower fruit set at 30/25 ^{0}C than at 23/18 ^{0}C (Ledesma *et al*., 2008).

Among the varieties studied, Sanga Sengana was found to be superior in number of fruits per plant (28.32) and yield (11.84 t ha^{-1}), (Ahmad, 2009).

Santos and Chandler (2009) conducted an experiment to study the performance of strawberry cultivars over two seasons resulted that *cv*. “Strawberry Festival” produced highest total number of fruits and average fruit weight over two years.

Neocleous and Vasilakakis (2012) conducted an experiment using three strawberry cultivars such as Camarosa, Selva and Fern revealed that total yield obtained from Camarosa (442.00 g plant^{-1}) and Fern (447. 00 g plant^{-1}) was higher than that of Selva (379. 00 g plant^{-1}).

Eighteen strawberry varieties were taken for study under organic farming production system in temperate region of Kashmir valley resulted that variety Gorella recorded maximum fruit yield/plant (262.50 g), followed by variety Confutura (260.20 g), Chandler (259.37g) and Brighton (256.50 g)**,** (Singh *et al*., 2012).

Path coefficient studies were conducted to study the degree of relationship of different characters on yield revealed that the correlation between number of flowers and number of fruits per plant was very high in strawberry. Length of fruit had positive direct effect on yield per plant while breadth of fruit had a negative direct effect on yield (Rao *et al*., 2010; Emdad *et al*., 2013).

Among the five promising strawberry cultivars *viz*., Sweet Charlie, Festival, Camarosa, FA 008 and BARI strawberry-1 which were studied under sub-tropical climatic conditions of Bangladesh revealed that Sweet Charlie produced the maximum number of fruits (39.00) and yield (667.22 g plant^{-1}) while BARI strawberry-1 produced minimum fruits (12.00) and yield (79.71 g plant^{-1}) (Rahman *et al*., 2014).

Gaikwad *et al.* (2018) evaluated the performance of cultivars mainly Camerosa, Winter Dawn, Nabila and Seascape under Mahabaleshwar conditions revealed that the *cv*. Seascape recorded higher fruit weight (24.40 g) and yield (839.00 g) plant^{-1} which was statically on par with the *cv*. Winter Dawn (Fruit weight of 21 g, yield plant^{-1} of 820 g) (Singh *et al*., 2008; Sharma *et al*., 2014).

Aslam (2017) conducted an experiment titled "Evaluation of promising strawberry (*Fragaria x ananassa* Duch.) varieties for Wayanad" using five *cv*. Crystal, Winter Dawn, Sweet Charlie, Sabrina and Eliyana revealed that *cv*. Winter Dawn produced higher yield of 139.50 g plant^{-1} and 123.30 g plant^{-1} in both open field and greenhouse**,** respectively.

Chaitanya *et al*. (2017) evaluated two strawberry varieties BARI strawberry-1 and Rabi strawberry-1 in Bangladesh revealed that average fruit weight and fruit yield were maximum in Rabi strawberry-1.

Neetu and Sharma (2018) conducted a research to assess six different cultivars of strawberry *viz.,* Nabila, Rania, Kamila, Camarosa, Flavia and Flaminiain in plain regions of Chattisgarh revealed that Nabila produced maximum number of flowers (27.40), fruits (24.70) and yield (655.00 g) per plant.

2.3.2. Nutrients

Effect of nitrogen fertilizer treatments on growth, yield and quality of strawberry grown in poly bags revealed that plants fertilised with urea solution as soil application 1 g N per plant showed early flowering compared to 0 g and 2 g N per plant (Ibrahim and Mohamed, 1993).

Experiment conducted to study the effects of nitrogen nutrition using *cvs.* Dania, Elsanta, Bogota and Pandora resulted in the findings that increase in nitrogen increases the number of flower meristems which might aggravate internal competition and in turn impairs flower development, resulted in smaller fruits (Rindom and Hansen, 1995).

Studies were conducted to determine the effect of different combinations of nitrogen, phosphorous and FYM on yield of strawberry showed that strawberry field applied with 150 kg N ha^{-1}, 100 kg P ha^{-1} and 20 t FYM ha^{-1} produced maximum number of fruits (9.0), berry weight (5.8 g), yield (7.0 t ha^{-1}) than other treatments (Ali *et al*., 2003).

In strawberry *cv*. Sweet Charlie, number of fruits harvested per plant increased with increasing rates of N up to 150 kg ha^{-1} and further increasing up to 200 kg ha^{-1} shows a decreasing trend (Ram and Gaur, 2003).

Effect of nitrogen (0, 60, 80 and 100 kg N ha^{-1}) and biofertilizers (*Azoctobacter*, *Azospirillum* and *Azoctobacter* + *Azospirillum*) on strawberry *cv*. Chandler revealed that the maximum yield (79.12 q ha^{-1}) was recorded with *Azoctobacter* inoculation combined with 60 kg N ha^{-1} (Rana and Chandel, 2003).

Experiment conducted to evaluate the effects of nitrogen fertilization on sole cropping and inter cropping of strawberry and broad bean using three levels of nitrogen (0, 80 and 160 kg ha^{-1}) revealed that 80 kg ha^{-1} nitrogen application gave maximum yield on strawberry in both sole cropping and inter cropping (Karlidag and Yildirim, 2007).

An experiment conducted to study the impact of fertiliser applications on yield and quality of strawberries *cv*. Elsanta revealed that fertigation with 60 kg N ha^{-1} was sufficient for high yield and good fruit quality. Strawberry also required huge amounts of potassium during its fruit development (Martinsson *et al*., 2006).

Studies on integrated use of poultry manure, urea and *Azotobacter* on strawberry *cv*. Chandler revealed that plants applied with urea + *Azotobacter* did not differ significantly from the yield obtained from plants receiving 25 per cent nitrogen in the form of poultry manure + 75 per cent through urea + *Azotobacter* and 50 per cent nitrogen through poultry manure + 50 per cent through urea in augmented with *Azotobacter* (Umar *et al*., 2008).

Santos and Chandler (2009) studied the effect of different rates of nitrogen on strawberry cultivars Festival and Winter Dawn and found that in *cv*. Festival, total marketable fruit weight increased linearly with increasing rate of nitrogen from 0.5 to 0.9 kg ha^{-1}. In contrast, total marketable fruit weight of *cv*.Winter Dawn remained unchanged with different N rates.

Studies conducted on strawberry *cv*. Chandler on the effect of FYM, urea and Azotobacter on yield revealed that both 100 per cent N in the form of urea + Azotobacter and 25 per cent N as FYM, 75% N as urea + Azotobacter significantly increased yield (Umar *et al*., 2009).

Application of 25 per cent N as green leaf manure + 75 per cent N as urea augmented with biofertilizers resulted in maximum yield of 35.8 t ha^{-1} in strawberry (Umar *et al*., 2010).

50 per cent nitrogen substitution as vermicompost + remaining as inorganic fertilizers along with Azotobacter recorded maximum fruit yield (10.2 t ha^{-1}) and maximum fruits (22.27) per plant (Yadav *et al*., 2010).

Andriolo *et al*. (2011) studied the effect of nitrogen concentration in nutrient solution on soilless cultivation of strawberry and reported that optimum nitrogen concentration for maximum fruit yield was estimated to be 8.9 mmol N l^{-1}.

Ahmad *et al*. (2011) conducted an experiment comprising four levels of nitrogen (0, 100, 150 and 200 kg ha^{-1}) and three levels of potassium (0, 75 and 150 kg ha^{-1}) on strawberry revealed that both N and K each applied @150 kg ha^{-1} significantly improved number of fruits and fruit yield per plant.

Mishra and Tripathi (2011) observed that combined application of *Azotobacter* and Phosphorous solubilizing bacteria (each at 6 kg ha^{-1}) significantly increased the yield (322.17 g) per plant.

D' Anna *et al*. (2012) concluded that in greenhouses, low rates of nitrogen (120 kg ha^{-1}) achieved same production as the higher doses of nitrogen (320 kg ha^{-1}) in open condition.

Effect of nitrogen sources on the productivity and fruit quality of strawberry *cv*. Camarosa revealed that 100 per cent N substitution as ammonium sulphate has a positive influence on fruit yield and quality of strawberry (El-Sawy *et al*., 2012).

Gupta and Tripathi (2012) conducted an experiment to study the effect of *Azotobacter* and vermicompost on growth of strawberry *cv*. Chandler revealed that combined application of *Azotobacter* 6 kg ha^{-1} + vermicompost 30 t ha^{-1} significantly increased maximum number of fruits set per plant (39.21 and 36.19 respectively) during two seasons.

A field experiment was conducted in strawberry using four biofertilizers such as VAM, Azotobacter, Phosphobacter and Azospirillum revealed that VAM @12 kg ha^{-1} increased the yield up to 30.14 t ha^{-1} which was 41.63 per cent higher over the control (Pandit *et al*., 2013).

An experiment was conducted to study the effect of different levels of nitrogen (0, 75,100,125,150) N ha^{-1} on growth and yield of strawberry *cv*. Sweet Charlie revealed that maximum number of leaves per plant (13.16), spread (20.66 cm), number of fruits (23.93) and yield plant^{-1} (362.88 g) was recorded with the application of 100 kg N ha^{-1} (Kumar *et al*., 2014).

A field experiment was conducted to study the effect of fertigation on growth, yield and fruit quality of strawberry *cv*. Chandler revealed that fertigation using recommended NPK dose (150: 100: 120 kg ha^{-1}) gave significantly higher fruit length, breadth and fruit weight compared to conventional application of recommended dose of fertilizers in soil (Kachwaya and Chandel, 2015).

Medeiros *et al*. (2015) conducted a pot experiment to evaluate the effect of N and P fertilization in the presence and absence of K revealed that increase in application of N and P along with K increased the number of fruits (15 fruits) per plant.

An experiment was conducted to evaluate the effect of potassium on growth of strawberry var. Chandler in Pakistan revealed that K application of 600 g in 6.75 m^2 of soil increased the number of fruits and yield of strawberry (Shamaila *et al.*, 2016).

An experiment was conducted to evaluate different levels of phosphorus *viz.*, 60 kg ha^{-1}, 70 kg ha^{-1}, 80 kg ha^{-1} and 90 kg ha^{-1} on the growth, yield and fruit quality of strawberry *cvs*. Karona and Tuft revealed that phosphorus at 80 kg ha^{-1} significantly influenced number of fruits and yield (Ahmad *et al.*, 2017).

Field experiment was conducted to study the effect of different levels of fertilizers on the growth of strawberry *cv*. Winter Dawn revealed that 80 per cent of recommended dose of fertilizers showed significant increase in total yield of strawberry (Bharade and Bhagat, 2017).

Experiment conducted to study the influence of different combinations of fertilizers and manures on the growth of strawberry *cv*. Douglas revealed that integrated and combined application of nutrient sources as organic manures (Vermicompost) and chemical fertilizers significantly affected growth and quality of strawberry production (Wani *et al*., 2017).

Experiment was conducted on integrated nutrient management of strawberry *cv*. Chandler revealed that maximum yield was obtained when a combination of 75% recommended dose (N:P:K- 150:75:100 kg ha^{-1}) + 25% Vermicompost + *Azotobacter* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} was used (Kushwah *et al*., 2018).

2.4 Quality attributes

2.4.1 Varieties

The presence or absence of PMG (Pelargonidin 3- malonyl glucoside) in 17 strawberry varieties affecting colour development were studied in Japan revealed that PMG had negligible role in colour development but the balance of three major anthocyanins *viz*., PMG, cyaniding 3-glucoside and pelargonidin 3-glucoside affect colour development in strawberry (Yoshida *et al*., 2002).

Meyers *et al*. (2003) conducted an experiment using eight cultivars to study the effect of varieties on anthocyanin pigment reported that there is a strong difference among different cultivars and average anthocyanin concentration is 414 mg kg^{-1}. The anthocyanin concentration of richest variety (Earliglow) has twice the concentration than the poorest.

The fruits of 13 strawberry varieties were chemically analysed at two stages of ripening *viz*., the stage of technological ripeness and stage of complete ripeness. Variety Mohawk had the high TSS content. Statistical differences among the fruits of the same cultivar and different maturity stages was noted except in case of citric acid and sucrose content (Sturm *et al*., 2003).

Among the strawberry varieties**,** Sanga Sengana and Chandler were studied in Srinagar, Jammu and Kashmir showed that Chandler was superior in TSS (8.38 ^{0} Brix), acidity (0.69 %) and vitamin C content (65.48 mg 100g^{-1} of pulp) (Ahmad, 2009).

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 100g^{-1}).

Jami *et al*. (2015) conducted an experiment to study the physical and chemical characters of ten strawberry cultivars revealed that *cv*. Ofra had high ascorbic acid content of 97.03 mg per 100 g of fruit followed by sweet Charlie (94.77 mg per 100 g).

2.4.2. Nutrients

Nitrogen application @ 90 kg ha^{-1} increased the vitamin C content in strawberry cultivars Dukat and Senga Sengana (Kopanski and Kaweci, 1994).

Odongo *et al*. (2011) conducted an experiment using farm yard manure (0, 18, 36, and 54 t ha^{-1}) and triple super phosphate (0, 17, 34 and 68 kg ha^{-1}) resulted that high farm yard manure and moderate triple super phosphate can substantially increase quality attributes of strawberries.

Studies were conducted by Yoshida *et al*. (2002) to determine the effect of nutrient deficiency in the colour development and anthocyanin content of strawberry *cv*. ‘Nyoho’ revealed that anthocyanin synthesis in strawberry fruits may be reduced by N deficiency.

Strawberry *cv*. Sweet Charlie were applied with 0, 50, 100, 150 or 200 kg N ha^{-1} in field condition, the ascorbic acid and total acidity of fruits increased with increasing rates of N up to 150 kg ha^{-1} and decreasing there after (Ram and Gaur, 2003).

Rana and Chandel (2003) conducted an experiment to study the effect of nitrogen and biofertilizers on growth of strawberry *cv*. Chandler in Himachal Pradesh resulted that maximum TSS (8.78 ^{0} Brix) content was recorded with the application of *Azotobacter* combined with 80 kg N ha^{-1}.

Studies were conducted to determine the effect of different combinations of Nitrogen, Phosphorous and FYM on quality of strawberry showed that strawberry field applied with 150 kg N ha^{-1}, 100 kg P ha^{-1} and 20 t FYM ha^{-1} produced maximum TSS (10.30 ^{0} Brix), Vitamin C contents (42.15 %) than other treatments (Ali *et al*., 2003).

A field trial was conducted to study the effect of increasing N rates as urea on quality of strawberry revealed that increase in rate of N application lead to reduction of ascorbic acid content and increase in polyphenols in fruits (Haynes and Goh, 2008).

Umar *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 nitrogen through FYM + 75 per cent nitrogen in the form of urea + Azotobacter.

Mishra and Tripathi (2011) observed that combined application of *Azotobacter* and Phosphorous 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 100g^{-1} edible material) content of strawberry.

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

Singh *et al.* (2012) conducted an experiment to study the effect of integrated nutrient supply on yield, quality and fertility status of soil under rainfed conditions of Kashmir Valley, India. Their study showed that combined application of bioagents and organic manure improved the quality of strawberry.

Studies conducted by Bouzari *et al*. (2015) revealed that β-Carotene was not found in any significant amount (<1.0 mg kg^{-1}) in strawberry.

Cao *et al.* (2015) conducted an experiment to study the effect of P fertilizer on the quality of strawberry revealed that irrigation with different concentrations of P fertilizer (phosphoric acid) once a week from the beginning of white stage of strawberry showed that P content and soluble solids content in fruits from plants treated with 6.0 mM phosphoric acid increased 45.0% and 16.7% respectively, by improving the flavour of strawberry.

An experiment was conducted to evaluate different levels of phosphorus such as 60 kg ha^{-1}, 70 kg ha^{-1}, 80 kg ha^{-1} and 90 kg ha^{-1} on the growth, yield and fruit quality of strawberry *cvs*. Karona and Tuft revealed that phosphorus at 60 kg ha^{-1} significantly influenced fruit qualities (Ahmad *et al.*, 2017).

According to studies conducted by Pritwani and Mathur (2017) observed that β-carotene content was not quantifiable in strawberry (*Fragaria vesca*), being present at levels below detection limit.

Studies conducted by Febrianti *et al*. (2018) revealed that average concentration of β-Carotene of eight different tropical fruits collected from different parts of Java, Indonesia revealed that strawberry has the lowest Beta carotene content of 5.69 mg 100^{-1}g compared to other fruits.

2.5. Response of crop to different spacing

Ferree (1988) observed that by increasing the plant spacing to 30 cm x 60 cm, reduces the flower number and fruit set percentage (Umar *et al*., 2009).

Aswathi and Badiyala (1993) concluded that TSS and total sugars of strawberry were significantly higher when strawberries were planted at wider spacing (30 cm x 60 cm) than closer spacing (30 cm x 15 cm).

Studies conducted by Petersen (1998) revealed that higher the planting density, higher will be the yield and it will produce larger and quality fruits. This is in conformity with the findings of Paranjpe *et al*. (2008) and De Camacaro (2004).

High density planting resulted in higher yield, larger berries and best quality fruits (Petersen, 1998; Legard *et al*., 2000; De Camacaro, 2004; Paranjpe *et al*., 2008).

Legard *et al*. (2000) studied different plant spacings with in row revealed that marketable yields were higher at narrower spacing (23 cm) than wider spacing (46 cm).

An experiment was conducted to study the effect of spacing on yield of strawberry using different spacings such as plant spacings of 20, 30 and 40 cms, row spacings of 50 cms and 70 cms in *cv*. Chandler revealed that row spacing of 50 cm and plant spacing of 20 cm gave significantly higher yield. The quality parameters such as TSS, acidity and ascorbic acid were found to be higher in wider spacing of 40 cm x 70 cm than closer spacing in strawberry (Tripathi *et al*., 2000).

The effects of plant spacing on vegetative growth, flowering and fruiting were studied in the strawberry *cvs.* Elsanta and Bolero for two years revealed that highest harvest index and yield were obtained in closer spacing (De Camacaro *et al.*, 2004).

Ahmad (2009) conducted an experiment to study the effect of plant density (30 cm × 40 cm × 30 cm or single row planting, 30 cm × 50 cm × 60 cm or double row planting, and 30 cm × 60 cm × 90 cm or triple row planting) on the growth and yield of strawberry revealed that double row planting resulted in the highest yield per plant (195.36 g), fruit weight (8.08 g) and vitamin C content (62.51 mg 100 g^{-1} of pulp).

Ram *et al*. (2009) evaluated various plant spacings 30 cm × 15 cm (Single row system), 30 cm × 30 cm (Single row system), 30 cm × 45 cm (Single row system), 30 cm × 60 cm (Single row system), 30 cm × 15 cm (Double row system), 30 cm × 30 cm (Double row system) and 30 cm × 30 cm (Flat bed system) to study the effect of different spacings on growth, flowering, fruiting, yield and quality of strawberry *cv.* Chandler and reported that maximum plant growth, flowering and yield attributes were recorded in lowest plant spacings of 30 cm × 15 cm and 30 cm × 30 cm with single row planting system.

A field experiment was conducted on a silty clay-loam soil in Palampur, Himachal Pradesh, India, to study the effects of mulch and row spacing (15 cm, 30 cm or 45 cm) on the performance of strawberry *cv*. Tiogo revealed that fruit yield and number of runners were highest under a closer spacing of 15 cm (Sharma, 2009).

An experiment was conducted at the Horticultural Research Farm of Babasaheb Bhimrao Ambedkar University, Lucknow to study the effect of spacing on the growth of strawberry using two spacings 30 cm x 30 cm and 30 cm x 15 cm revealed that 30 cm ×30 cm spacing was found to be the best in terms of plant growth *viz*. plant height, spread of plants, number of leaves and leaf area**,** while spacing of 30 cm x 15 cm significantly influenced number of flowering, fruit length, fruit width, yield and quality of strawberry cv. Chandler. Low density planting (30 cm x 30 cm) produced less acidic fruits compared to those fruits obtained from high density planting (30 cm x 15 cm)~~,~~ (Sonkar *et al*., 2012).

Research work conducted by Tariq *et al*. (2013) to study the impact of different planting densities on growth and yield of strawberry revealed that high planting density showed that plants grown at low planting distance (15 cm x 30 cm) on all growth media produced more vegetative growth compared to plants grown with higher spacing (30 cm x 60 cm). The quality parameters such as TSS and ascorbic acid were significantly higher in high density planting.

Research work conducted to study the impact of media and spacing on the growth of strawberry *cv*. Chandler in open condition using control (soil alone), soil + peat moss, soil + FYM, soil + poultry manure using three different plant-to-plant spacing of 20, 30, and 50 cm, revealed that a soil + peat moss combined with 20 cm plant-to-plant spacing improve the production of strawberry *cv*. Chandler (Shahzad *et al*. 2018).

2.6. Response of crop to growing systems

Strawberry *cv*. Chandler was evaluated under five growing systems *viz*., polyethylene bags, soil less media, high tunnel, green house and open field condition on ridges to evaluate the effects of different cultivation systems on vegetative growth, production and fruit quality showed that all the vegetative, reproductive and quality parameters are higher under tunnel condition as compared to other growing systems (Qureshi *et al*., 2012).

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

Gunduz and Ozdemir (2014) conducted experiments by growing strawberries in three growing conditions: greenhouse, plastic tunnel and open-field. They observed that the growing conditions were only significant for total phenolic content, fructose and total sugar content.

Kurian (2015) conducted a research to study the performance of strawberry *cv*. Winter Dawn in different growing systems *viz*., open field, greenhouse and fan and pad revealed that open condition recorded maximum number of fruits and yield per plant in the high ranges of Kerala.

Pandey *et al*. (2015) conducted a study to determine the effects of growing environment on various growth, yield and fruit quality parameters of strawberry *cv*. Winter Dawn under semi-arid conditions of Rajasthan and found that open field recorded highest total sugars (5.15 %), Vit-C (50.32 mg 100^{-1}g) and total anthocyanin (38.90 mg) content compared to naturally ventilated polyhouse.

Adak and Gozlekci (2016) observed that in strawberry, yield parameters were not significantly influenced by different growing systems such as plastic high tunnel (CSS), single shelf system (SSS) and double shelf systems (DSS) in modern greenhouses in Mediterranean coastal areas of Turkey.

2.7. Response of crop to growing medium

Research was conducted to study the effect of different growing media such as pumice, perlite, perlite-pumice (1:1) and perlite-peat (1:1) in strawberry *cvs*. Tioga and Cruz revealed that growing media had no effect on growth of strawberry (Ozeker *et al*., 1999).

In a study on the effect of different media *viz.*, forest soil, finpeat, peat + perlite (1:1), perlite, peat, finpeat + perlite (1:1) on strawberry *cvs*. Fern and Camarosa in Turkey revealed that vegetative growth of strawberry was found to be maximum in peat and finpeat (Ercisli *et al*., 2005).

Caso *et al*. (2009) evaluated four substrates on the growth of strawberry *cv*. Chandler and their results showed that rice husk (100%) has favourable physicochemical properties for the growth and development of the strawberry resulted in the highest yield (496.73 g plant^{-1}).

Effect of soil addition on physical properties of perlite based media on strawberry *cv*. Camarosa revealed that addition of soil to perlite improved the water retention and root parameters of strawberry (Ors and Anapali, 2010).

Research conducted to study the effect of different growing media *viz*., (control) soil + sand (1: 1), soil + silt + FYM (1: 1: 1), soil + silt + leaf manure (1: 1:1), soil + silt + poultry manure (1: 1: 1) and soil + silt + coconut coir dust (1: 1: 1) on the growth of strawberry revealed that coconut coir dust when used as media produced favourable effects on number of flowers (96.00), average number of fruits (72.96) per plant compared to other treatments (Ayesha *et al*., 2011).

Neocleous and Vasilakakis (2012) conducted an experiment using three strawberry cultivars such as Camarosa, Selva and Fern using cocopeat and rockwool as growing media revealed that total yield obtained using cocopeat media was higher (451.00 g plant^{-1}) than using rockwool media (395.00 g plant^{-1}).

Effect of growing media and cultivar on the quality parameters of strawberry in soilless culture were studied using three cultivars *viz*., Camarosa, Mrak and Selva and six growing substrates showed that the total anthocyanin content (222.65 mg 100 g^{-1}) was highest in Camarosa variety in vermicompost + perlite + cocopeat (15:40:45), the highest of TSS (8.66) was in *cv*. Selva and that of titrable acidity was in *cv*. Camarosa in vermicompost + perlite + cocopeat substrate (5:45:50) (Ameri *et al*., 2012).

The impact of different media *viz*., silt + sand + FYM, coir, peat moss on quality of strawberry showed that silt+ sand+ FYM proved better for reproductive growth and quality characters such as TSS. Media peat moss had positive impact on ascorbic acid content of fruits. Coir based growing media did not show satisfactory improvement in vegetative and reproductive growth attributes (Tariq *et al*., 2013).

Effect of different growing media on the fruit yield of strawberry revealed that strawberries grown on soil + peat moss gave best fruit yield and fruit quality (Al-Raisy *et al*., 2010; Shahzad *et al*., 2018).

Thakur and Shylla (2018) conducted a study to evaluate the influence of different growing media such as perlite, perlite + FYM (1:1), cocopeat, cocopeat + FYM (1:1), perlite + cocopeat + FYM (1:1:1), soil + FYM (Control) on the growth and yield of strawberry *cv*. Chandler revealed that perlite + FYM (1:1) media was most effective in improving plant growth and yield parameters of strawberry in polyhouse conditions.

A pot experiment was conducted to investigate the effects of vermicompost on growth of strawberry using six different vermicompost ratios to soil showed that vermicompost (30%) dramatically improved soil microbial and enzyme activity, cation exchange capacity and root activity leads to a positive effect on strawberry growth (Zhang, 2018).

Experiment was conducted to study the effect of different substrates such as coco peat, vermiculite and perlite on growth of strawberry *cv*. chandler in soilless culture revealed that coco peat in combination with Perlite and vermiculite (50: 25:25) produced maximum growth as well as good quality fruits (Raja *et al*., 2019).

2.8 Postharvest study

Asghari *et al*. (2013) reported that both nitric oxide and putrescine effectively maintained fruit firmness, soluble solids, vitamin C, red colour, total phenols, total acidity, and overall quality. 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. Putrescine effectively enhanced the effects of nitric oxide in maintaining fruit quality indices.

2.9 Physiological parameters

2.9.1 Leaf area index

Flore and Lakso (1989) measured maximum photosynthetic rates for strawberry (13.9 µmol m^{-2} sec^{-1}).

2.9.2 Leaf area

Leaf area in strawberry increased from pre flowering to start of flowering, and thereafter it was gradually decreased at each later phenological stage. The NPK application increased leaf area at all the phenological stages with maximum value at 100: 80: 80 kg NPK ha^{-1} (Ali and Singh, 2017).

2.9.3 Nutrient uptake

Experiments were conducted to study the effect of dynamics of nutrient uptake by strawberry plants revealed that potassium was the nutrient absorbed at the highest rate compared to nitrogen, calcium, magnesium and phosphorus. High nitrogen content increases biomass and nitrogen content in plants but did not affect fruit yield and quality (Tagliavini *et al*., 2005).

2.10 Response of crop to environmental factors

2.10.1 Temperature

Studies conducted by Guttridge (1969) revealed that length of the night is the controlling factor for flower initiation in strawberry.

Temperatures above 25 ^{0}C can reduce fruit set (Abdelrahman,1984) and decrease fruit soluble solids content (Abdelrahman, 1984; Hellman and Travis, 1988).

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

According to Strik (1988), the optimum growth temperature of strawberry ranges from 10 ^{0}C to 26 ^{0}C.

The environmental factors affecting the growth of strawberry are water availability, day and night time temperatures, and day light intensities which affect fruit size (Avigdori- Avidov, 1986).

Research conducted in four strawberry *cvs*. Everberry, Enrai, Summerberry and Hecker observed that temperature between 20-25 ^{0}C was found to be best for flowering and temperature above 30 ^{0}C leads to abortion of flower buds (Kumakura and Shishido, 1995).

Exposure to high temperature (>30 ^{0}C) reduce number of achenes per fruit and fruit size (Mori, 1998). Strawberries grown at the highest temperature (30/22 ^{0}C) produce the dark reddest colour, the greatest flesh pigment intensity and anthocyanin content (Wang and Camp, 2000). Similar results were obtained from apple fruits harvested from different areas (Marais *et al*., 2001).

The influence of four day or night temperature combinations (18/12, 25/12, 25/22, 30/22 ^{0}C) on plant growth and fruit quality in strawberry *cvs*. Earliglow and Kent were studied and found that the optimum day/night temperatures for whole plant growth was 25/12 ^{0}C. Increasing the day/night temperatures to 30/22 ^{0}C inhibited plant and fruit growth, reduced citric acid content and increased malic acid content (Shiow and Mary, 2000).

Responses of two short day cultivars (Redgauntlet and Torrey) and three day neutral cultivars (Aptos, Brighton and Hecker) of strawberry to various temperature regimes were studied. Optimum temperature range for floral initiation and reproductive growth lies in a temperature range of 18/13 ^{0}C and 21/16 ^{0}C (Manakasem and Goodwin, 2001).

Wang *et al*. (2003) studied the effect of different plant growth temperatures on the antioxidant capacity of strawberry showed that plants grown at low day and night temperatures (18/12 ^{0}C) had low anthocyanin contents compared to plants grown at the highest day/night temperatures (30/22 ^{0}C).

Experiment conducted to study the effect of different mulches (paddy straw, black mulch) on the quality of strawberry revealed that more anthocyanin content in fruits is related to the elevated temperature under plastic mulch (Truax and Gagnon 1993; Moor *et al*., 2005)**.**

Michel *et al*. (2006) studied the effects of photoperiod, day and night temperature and their interactions on flower and inflorescence emergence of strawberry *cvs*. Korona and Elsanta showed that plants exposed to short-day treatment (10 or 12 h photoperiod) for 21 days or longer, emerged flowers at temperatures between 12 and 18 ^{0}C. A short-day treatment (10 or 12 h photoperiod) of 28 days resulted in highest numbers of inflorescences and flowers per plant.

Verheul *et al*. (2006) studied the effect of different day and night temperatures and photoperiod on the flowering of strawberry and reported that a daily photoperiod of 12 or 13 h is required for flowering. A day temperature of 18 ^{0}C and/or a night temperature of 12 ^{0}C were optimal for early flowering. The number of flowers on the inflorescence increased with decreasing day temperature.

High temperature (21 ^{0}C) promotes runner production in both short day and long day condition (Sonsteby and Heide, 2007).

Ledesma *et al*. (2008) studied the effects of two day/night temperature regimes (23/18 ^{0}C, 30/25 ^{0} C) on fruit set and flower growth in two strawberry *cvs***.** Nyoho and Toyonoka and found that high temperature (30/25 ^{0}C) significantly lowered the number of flowers (8.4 and 5.7), fruits, days to ripening and fruit weight than at 23/18 ^{0}C in both cultivars.

Effect of night temperature on floral induction of strawberry varieties revealed that at the optimum day temperature of 18 ^{0}C, short day flowering response of the cultivars increased significantly with increasing night temperature from 9-18 ^{0}C (Sonsteby and Heide, 2008).

An experiment was conducted to study the effect of climate change on growth of strawberry *cv*. Camarosa revealed that an increase in temperature will result in early flowering but reduction in total yield (Palencia *et al*., 2009).

Singh *et al*. (2012) studied the effect of microclimate inside the low tunnels on off season production of strawberry and reported that under low tunnels covered with 75 % and 50 % shade net, UVS polythene (200 µm) and in open field, UVS polythene caused the minimum temperature (15±2 ^{0}C) and ± 6 % higher RH during the whole growing period favourable for the growth, development and quality improvement in strawberry.

Experiment carried out in strawberry *cv*. Camarosa in the province of Huelva, Spain revealed that between early production and temperature, and between total production and temperature, there was a linear relationship and further leads to a conclusion that strawberry production could be affected by climate change (Palencia *et al*., 2013).

2.10.2 Humidity

Strawberry plants treated with conditions of low night humidity (50-55 per cent) and high night humidity (90-95 per cent) for 40 days did not show any increase in total dry weight and leaf area in response to high night humidity. Because of high root pressure developed due to high humidity, the five major elements (N, P, K, Ca and Mg) got accumulated in the younger leaves of strawberry (Choi *et al*., 1997).

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

Singh *et al*. (2012) studied the effect of microclimate inside the low tunnels on off season production of strawberry reported that under low tunnels skinned with 75% and 50% shade net, UVS polythene (200 µm) and in open field, UVS polythene resulted in a 2-6 per cent higher relative humidity than control during whole growing period.

2.10.3 Light intensity

Ueno (2013) conducted a study to investigate the effect of light intensity on the floral initiation of strawberry revealed that vegetative growth increased when the supplementary light intensity was above 10 lux and flower bud differentiation was inhibited at a supplementary light intensity above 20 lux in Red Star and above 10-20 lux in Kogyoku.

2.10.4 Photoperiod

Strawberry plants *cv*. Earliglow were forced under short days or long days in a greenhouse and their floral development were studied. Short days enhanced floral induction but delayed differentiation (Durner and Poling, 1987).

LeMiere *et al*. (1996) studied the effects of temperature and photoperiod on flower and inflorescence initiation in the strawberry *cv*. Elsanta and reported that photoperiod had no significant effect on the rate of flower initiation. In case of secondary and tertiary inflorescences, the rate of flower initiation increased with increasing temperature.

Konsin *et al*. (2001) showed that in strawberry *cv*. Korona a shorter photoperiod (12 h) was more effective in initiating the formation of branch crowns from the axillary buds of the main crown, whereas in long day (18 h), no branch crowns were formed.

Perpetual-flowering or everbearing strawberry cultivars are qualitative (obligatory) LDPs at high temperatures (> 25 ^{0}C). Only at temperatures below 10 ^{0}C, they appear to be more-or less day-neutral plants (Nishiyama and Kanahama, 2002; Sonsteby and Heide, 2009)

Hidaka *et al*. (2014) conducted a study to determine the optimum photoperiod requirement to obtain high fruit yields in forcing culture of strawberry showed that 12 h photoperiod of supplemental lighting increased leaf photosynthesis and translocation of large amounts of carbon from leaf to fruit to obtain higher yields.

2.10.5 Altitude

Guerrero-Chavez *et al*. (2015) conducted a study on the influence of the site altitude on strawberry phenolic composition and quality at different altitudes such as 900 m, 1.1 m, 1.2 m and 1.5 m located in the northern part of Italy in strawberry *cv*.

Elsanta and reported that higher the elevation above sea level, the lower was the final accumulation of anthocyanins in strawberry fruits.

2.11. Pest and Diseases

Fungal leaf spots on strawberry caused by *Phyllosticta fragaricola* revealed typical birds eye view spots with three zones of different colours. Alternate light and darkness under natural conditions favoured growth of the fungi. None of the strawberry varieties was immune or resistant to *Phyllosticta* leaf spot (Jadhav, 1998).

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.).

Winter Dawn is a strawberry cultivar with shallow root system is moderately resistant to botrytis fruit rot and anthracnose fruit rot caused by *Colletotrichum acutatum* (Chandler, 2005).

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

Materials and Methods

3. MATERIALS AND METHODS

The investigation envisages to study the production dynamics of strawberry (*Fragaria x ananassa* Duch.) in 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 two seasons from September 2016 to March 2017 and September 2017 to March 2018 respectively in open field in two locations of Kerala *i.e.*, College of Agriculture, Thrissur (Central mid-lands) and Regional Agricultural Research Station (RARS), Ambalavayal (High ranges).

3.1.1. Locations

Location I is the College of Agriculture, Vellanikkara, Thrissur (Central mid-lands) is located at 10^0 31' N latitude and 76^0 3' E longitude, at an altitude of 22.25 m above mean sea level and enjoys the typical warm humid tropical climate of Kerala. Location II is the RARS, Ambalavayal (High ranges) is located at 76.12^0 E latitude, 11.37^0 N longitude and at an altitude of 974 m above mean sea level and enjoys mid sub-tropical climate.

3.1.2. Soil

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

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

Soil characters	**Location I**	**Location II**
A. Physical properties	**(Central mid-lands)**	**(High ranges)**
Mechanical composition		
Sand	77.5%	60.5%
Silt	5.0%	12.5%
Clay	17.5%	23.5%
Texture	Sandy loam	Sandy clay loam
B. Chemical properties		
Available nitrogen (kg ha^{-1})	8.2	8.4
Available phosphorous (kg ha^{-1})	11.2	11.9
Available potasssium (kg ha^{-1})	324.80	247.5
Organic carbon (%)	0.83	0.86
Electrical conductivity (mmhos cm^{-1})	0.04	0.03
pH	4.80	4.79
Calcium (mg kg^{-1})	342.63	291
Magnesium (mg kg^{-1})	97.13	96.9
Iron (mg kg^{-1})	13.95	40.40
Manganese (mg kg^{-1})	48.43	96.90
Copper (mg kg^{-1})	8.83	1.66
Boron (mg kg^{-1})	0.89	0.28
Sulphur (mg kg^{-1})	11.93	2.07

3.1.3. Climate

The climate of the experimental sites were tropical humid climate in College of Agriculture, Vellanikkara, Thrissur (Central mid-lands) and mild sub-tropical climate in RARS, Ambalavayal, Wayanad (High ranges). The weather conditions prevailed during the cropping period is shown in Table 2.

Table 2. Mean weather conditions of two locations *viz.*, Central mid-lands and High ranges during the cropping period

Weather parameters	**Central mid-lands**		**High ranges**	
	Season I (Sep 2016- March 2017)	Season II (Sep 2017- March 2018)	Season I (Sep 2016- March 2017)	Season II (Sep 2017- March 2018)
Max Temperature (^{0}C)	33.33	33.5	28.53	27.80
Min Temperature (^{0}C)	23.09	22.21	19.17	18.83
Relative humidity (%)	67.43	65.71	91.71	92.43
Rainfall (mm)	29.03	100.79	39.59	32.06
Sunshine hours (h)	6.61	6.93	6.46	5.77
Evapotranspiration (mm)	3.84	3.86	106.74	103.67
Wind speed (km h^{-1})	3.1	3.19	2.69	2.61

3.1.4. Seasons

The experiments were conducted during the period September 2016 - March 2017 to September 2017 - March 2018.

3.2. Materials

3.2.1. Variety

The varieties used for the experiments are Hadar, Sweet Charlie, Sabrina-1, Sabrina, Crystal, Winter Dawn, Gili, Barak. Healthy and disease free runners were procured from KF Bioplants Pvt. Ltd, Hadapsar, Pune in the month of September 2017 and September 2018.

3.2.2. Fertilizers

FYM, Urea, Single Super Phosphate and Muriate of Potash were used for the fertilizer application. FYM, ½ N, Full P and ½ K were applied as basal dose. Remaining ½ N and ½ K were applied 45 days after planting. Dosage of fertilizer application varies with the experiments.

3.2.3. Growing systems

Experiment was conducted in open field in two seasons at two locations. For the evaluation of different growing systems, 6 growing systems i.e., hanging pots, hanging pipes, hanging bottles, vertical garden, grow bags and raised beds were tried.

3.2.4. Growing media

Four growing media i.e., Soil: Cocopeat: FYM (1:1:1), soil: Cocopeat: Vermicompost (1:1:1), Cocopeat: Perlite: FYM (1:1:1) and Cocopeat: Perlite: Vermicompost (1:1:1)

3.3. Methods

3.3.1. Design of the experiment

Experiment I, II and III were laid out in Randomized block design. Experiment IV were completely randomized design.

3.3.2. Treatments

3.3.2.1 Experiment 1 Evaluation of strawberry varieties

Total treatments - 8

Replications – 3

Growing system: Raised beds

Bed size: 2.1 m x 1.6 m

Spacing: 30 cm x 40 cm

Number of plants per replication: 24

Table 3. Experiment I - Details of treatments

Notations	**Treatments**
V_1	Hadar
V_2	Sweet Charlie
V_3	Sabrina-1
V_4	Sabrina
V_5	Crystal
V_6	Winter dawn
V_7	Gili
V_8	Barak

3.3.2.2 Experiment 2 Nutrient management for strawbe rry

Treatments: 9

Replications: 3

Variety: Winter Dawn

Growing system: Raised beds

Bed size: 2.1 m x 1.6 m

Spacing: 30 cm x 40 cm

Number of plants per replication: 24

Table 4. Experiment II - Levels of nutrients

Manures/Fertilizers	**Levels of nutrients**
Farm yard manure (FYM)	10, 20, 30 t ha^{-1}
N	50, 75, 100 kg ha^{-1}
P_2O_5	20, 40, 80 kg ha^{-1}
K_2O	50, 75, 100 kg ha^{-1}

Table 5. The fractional factorial combinations of Experiment II

Notations	**Treatment combinations of FYM (t ha^{-1}), N, P_2O_5 and K_2O kg ha^{-1}**
T_1	10:50:20:50
T_2	10:75:40:75
T_3	10:100:80:100
T_4	20:50:40:100
T_5	20:75:80:50
T_6	20:100:20:75
T_7	30:50:80:75
T_8	30:75:20:100
T_9	30:100:40:50
T_{10}	Absolute control

3.3.2.3 Experiment 3 Effect of spacing on growth and yield

Treatments: 6

Replications: 4

Variety: Winter Dawn

Growing system: Raised beds

Bed size: 2.1 m x 1.6 m

Table 6. Experiment III – Details of treatments

Notations	**Treatments**
T_1	30 cm x 60 cm
T_2	30 cm x 50 cm
T_3	30 cm x 40 cm
T_4	30 cm x 30 cm
T_5	30 cm x 20 cm
T_6	20 cm x 20 cm

3.3.2.4 Experiment 4 Evaluating different growing systems for home-gardening

Total treatment combinations: 24

Replications: 3

Number of plants per replication: 15

Table 7. Details of Experiment IV

Treatments	Details	Notations
Growing systems	Hanging pots	S_1
	Hanging pipes	S_2
	Hanging bottles	S_3
	Vertical garden	S_4
	Grow bags	S_5
	Raised bed	S_6
Growing media	Soil: Cocopeat: FYM (1:1:1)	M_1
	Soil: Cocopeat: Vermicompost (1:1:1)	M_2
	Cocopeat: Perlite: FYM (1:1:1)	M_3
	Cocopeat: Perlite: Vermicompost (1:1:1)	M_4

3.3.2. Preparation of land

The land was ploughed for 2-3 times and pulverized thoroughly and the field was made free of weeds. Soil fumigation with methyl bromide (1%) was done and covered soil with mulch sheet for two weeks to make soil free from soil borne pathogens. Chlorpyriphos @ 4ml/l was used for the control of termites. Manures and fertilizers were mixed with soil and raised beds were taken in such a way that water can run in either directions in the furrows between the beds.

3.3.3. Manuring

Full dose of FYM and P_2O_5, half N and K_2O was applied as basal dose. The remaining half dose of N and K_2O was applied 45 days after planting.

3.3.4. Mulching

Black polythene mulch was used as mulch sheet with the thickness of 14 µm (0.01 mm).

3.3.5. Planting

Hill system of planting was done in the open field. Raised beds of size 2.1 m x 1.6 m x 0.3 m were taken and a spacing of 1 m was given between the beds. Plants were planted at a spacing of 30 x 40 cm. Holes were made on the mulch depend on spacing. Plots were randomly selected for planting for each experiment. Planting was done during the last week of September. One month old strawberry plants were planted in late evening hours. Shade was provided for two weeks.

3.3.6. After planting

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

3.4. Observations

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

Central midlands

High ranges

Plate 1. Field in Central midlands and High ranges of Kerala

Soil sterilization

Manuring

Mulching

Plate 2. Cultural practices before planting

Plate 3. Lay out and planting in field

3.4.1. Observations on vegetative growth attributes

The following vegetative growth characters were observed and recorded.

3.4.1.1. Height of the plant

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

3.4.1.2. Number of leaves

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

3.4.1.3. Plant spread

The spread of plants were measured in East-West and North-South directions and their mean was worked out in centimeter (cm).

3.4.1.4. Number of crowns

The number of crowns was counted at the time of last picking.

3.4.2. Observations on flowering attributes

3.4.2.1. Days to first flowering

The days taken to produce first flower after planting was recorded.

3.4.2.2. Number of clusters per plant

The number of clusters of each plant was recorded.

3.4.2.3. Number of flowers per plant

The number of flowers (primary, secondary and tertiary) were recorded.

3.4.3. Observations on yield attributes

3.4.3.1. Number of fruits per plant

The total number of primary, secondary and tertiary fruits obtained per plant was counted and recorded.

3.4.3.2. Fruit length

The length of the fruit was measured with the help of vernier calipers and was expressed in cm. It was measured from calyx end to stylar end.

3.4.3.3. Fruit breadth

The breadth of the fruit was measured with the help of vernier calipers and was expressed in cm. It was measured in the broadest part of the longitudinal section.

3.4.3.4. Average fruit weight per plant

Weight of each fruit was recorded separately with the help of an electronic balance and average weight was calculated and expressed in gram (g).

3.4.3.5. Days to first harvest

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

3.4.3.6. Days to final harvest

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

3.4.3.7. Yield per plant

The yield of fruits from each plant was recorded separately and expressed in g $plant^{-1}$

3.4.4. Observations on quality attributes

3.4.4.1. Total soluble solids

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 by Ranganna (1977). A representative sample of 5 g macerated and digested with boiling water and made up to 100 ml. An aliquot of the filtrate was titrated against 0.1 N 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 and its content was expressed in percentage.

3.4.4.3. TSS/Acidity ratio

Ratio of TSS/Acidity of the fruit was calculated.

3.4.4.4. Total sugars

Total sugars content in the fruit was estimated as per the procedure described by Ranganna (1977). 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 upto 100 ml. The made up solution was titrated against a mixture of Fehling's A and B and total sugars content was expressed as percentage.

3.4.4.5. Ascorbic acid

Ascorbic acid content of fruit was estimated by the method suggested by Sadasivam and Balasubramaniam (1987). Five gram of fruit sample was taken and extracted with 4 per cent oxalic acid. Ascorbic acid content was estimated using standard indicator dye 2, 6-dichlorophenol indophenol and expressed as mg $100g^{-1}$.

3.4.4.6. Anthocyanin content

Hot water extraction of the sample was done by placing fifty grams of the homogenate in the beaker containing water equal to thrice the quantity of homogenate and then it was boiled for about five to six hours at 60-70 ^{0}C for complete extraction of the pigment. After extraction, the pigment was filtered with Whatman filter paper No. 1 and stored in glass bottles at refrigerated condition by covering with aluminium foil for protection from light (Harbone, 1978).

Flow chart for extraction of anthocyanin pigment

Harvest ripe strawberry fruits

↓

Wash thoroughly

↓

Extract pulp and remove seeds

↓

Homogenize the pulp

↓

Extract with hot water

↓

Filter the extract using Whatman filter paper No. 1

↓

Store in glass bottles covered with aluminium foil in refrigerator

Anthocyanin content estimation was done based on the method given by Iland *et al*. (1996). Malvidin-3-glucoside was used as the standard. 0.2 ml of the extract was transferred to a test tube. 3.8 ml of 1.0 M HCl was added to it and incubated for 22 h at room temperature by covering with parafilm. This step is critical for the full exposure of the colour. The absorbance of the acidified diluted extract was measured at 520 nm using a 1.0 M HCl blank in a UV spectrophotometer.

Anthocyanin content

$$= \frac{\text{Absorbance at 520 nm x D.F. x Final volume (ml) x Berry weight (g) x 1000}}{\text{D x 100 x Homogenate weight (g)}}$$

Where,

D.F. = Dilution factor

D= Absorbance of one per cent w/v solution of malvidin -3-glucoside

3.4.4.7. β carotene content

β carotene was estimated by AOAC (1975) method as described below. Ten grams of strawberry was taken in 150 ml conical flask and 40 ml water saturated butanol (WSB) was added. The contents of the flask were mixed vigorously for 1 minute and kept overnight (16-18 h) at room temperature under dark for complete extraction of β carotene. Next day, the contents were shaken again and filtered completely through the Whatman No.1 filter paper in to a 100 ml volumetric flask. The optical density of the clear filtrate was measured at 440 nm using spectrophotometer. Pure WSB was used as blank. The β carotene content was calculated from calibration curve from known amount of β carotene as discussed below and expressed as parts per million (ppm). Standard solution of β carotene (Sigma) was prepared in WSB at the concentration of 5µg/ml. WSB is prepared by mixing n-butanol with distilled water in 8:2 ratio. Calibration curve is made from known amounts of pure β carotene from 0.25 µg/ml which are prepared after suitable dilutions of original stock with WSB in calibrated 10 ml volumetric flasks (from 0.5 ml to 3 ml of standard solution in 10 ml) Absorbance of each dilution is measured and a calibration curve is established. β carotene content of unknown samples is calculated from standard curve.

3.4.4.8. Sensory evaluation

3.4.4.8.1. 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).

3.4.4.8.2. Preparation of score card

Score card including the quality attributes like appearance, colour, flavor, 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 I.

3.4.4.8.3. Organoleptic evaluation

Organoleptic evaluation of fruits was carried out using score card by 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.

3.4.4.9. 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.

3.4.4.10. Colour

Colour of the sample was visually observed and identified with the help of Universal Colour Language (UCL). The Universal Colour Language is a colour menu defined by the Inter – **S**ociety Colour Council, National Bureau of Standards in 1946 and approved by Royal Horticultural Society (Anonymous, 1999). A valid UCL colour code contains a value, plus hue and a hue modifier which are denoted by alphabets and numbers.

3.5. Pest and diseases

The incidence and severity of pests and diseases were observed and recorded.

3.6. Observations on weather parameters

Daily readings of temperature and relative humidity were recorded at 8.00 am and 2.30 pm using thermo-hygrometer. Temperature (^{0} C), relative humidity (%), rainfall (mm), sunshine hours (h), evapotranspiration (mm) and wind speed (km h^{-1}) were recorded during the crop period.

3.7. Analysis of soil samples

Soil samples were collected initially and after final harvest from the experimental plot. These samples were analyzed for pH, EC, organic carbon, available primary (N, P, K) and secondary (Ca, Mg, S) nutrients. The soil samples were dried in shade, processed and taken forward for analysis employing standard analytical procedures as outlined by Jackson (1973). Details of the methods employed and procedures adopted are given in Table 8.

Table 8. Methods of soil analysis

Sl. No	Parameters	Methods	References
1	pH	pH meter (soil water ratio 1:2.5)	Jackson (1973)
2	Electrical conductivity	Conductivity meter (soil:water ratio 1:2.5)	Jackson (1973)
3	Organic carbon	Walkley and Black chromic acid wet digestion method	Walkley and Black (1934)
4	Available nitrogen	Alkaline potassium permaganate method	Subbiah and Asija (1956)
5	Available phosphorus	Neutral normal ammonium acetate extraction and flame photometry	Jackson (1973)
6	Available potassium	Neutral normal ammonium acetate extraction and flame photometry	Stanford and English (1949)
7	Available calcium and magnesium	Neutral normal ammonium acetate extraction and titration with EDTA (versenate titration)	Hesse (1972)
8	Sulphur	Turbidimetry	Chesnin and Yien (1950)

3.8. Physiological attributes

Plants were selected randomly from each treatment and was tagged to measure physiological observations. Growth indices were worked at active vegetative stage and after final harvest. Sampling unit consisted of 9 plants per treatment (Three from each replication). The plant samples were uprooted and dried in hot air oven and the growth indices were computed as per the procedure given below. Observations were recorded for crop growth rate (CGR), relative growth rate (RGR), leaf area index (LAI) and Net assimilation rate (NAR).

3.8.1. Leaf area index

Leaf area index (LAI) is a unit less parameter. It was calculated using the formula given by Williams (1946).

$$\text{LAI} = \frac{\text{Total leaf area of plant}}{\text{Land area occupied by plant}}$$

Individual leaf area was taken using Portable Leaf area meter (LI 3000 A, LI-COR, Lincoln, Nebraska, U. S. A). Total leaf area was measured in all the selected plants and expressed as cm^2 $plant^{-1}$.

3.8.2. Relative growth rate

Relative growth rate (RGR) is the rate of increase in the dry weight per unit time. It was calculated by using the formula of Blackman (1919) and expressed as g g^{-1} d^{-1}.

$$\text{RGR} = \frac{\text{Log } W_2 - \text{Log } W_1}{T_2 - T_1}$$

Where,

W_1 and W_2= Dry weight of plant at time intervals T_1 and T_2 respectively.

3.8.3. Crop growth rate

Crop growth rate (CGR) is the rate of dry matter production per unit ground area per unit time. CGR was calculated by adapting the formula suggested by Watson (1952) and expressed as g m^{-2} d^{-1}.

$$\text{CGR} = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{1}{A}$$

Where,

W_1 and W_2 = Dry weight of plant at time intervals T_1 and $T_{2,}$ respectively

A = unit land area occupied by the plant (cm^2)

3.8.4. Net assimilation rate

Net assimilation rate (NAR) is the rate of dry weight increase per unit leaf area per unit time, which was calculated by the formula given by Gregory (1926) and expressed as mg cm^{-2} d^{-1}.

$$\text{NAR} = \frac{(W_2 - W_1)}{T_2 - T_1} \times \frac{(\text{Log } L_2 - \text{Log } L_1)}{L_2 - L_1}$$

Where,

L_1 and W_1 = Leaf area (cm^2) and dry weight of the plant (g) at time T_1

L_2 and W_2 = Leaf area (cm^2) and dry weight of the plant (g) at time T_2

3.8.5. Photosynthetic rate, transpiration rate and stomatal conductance

These measurements were performed using portable photosynthesis (PPS) (Model–LI-6400 of LICOR Inc. Lincoln, Nebraska, USA). A total of three measurements were taken in the same leaf for each selected plant. Leaf was inserted in leaf chamber. Reading was taken between 9.00 am and 12.00 pm using this instrument. The following parameters were recorded and the unit expressed is given in parenthesis.

Photosynthesis rate (μ mol CO_2 m^{-2} s^{-1})
Transpiration rate (mmol H_2O m^{-2} s^{-1})
Stomatal conductance (mol H_2O m^{-2} s^{-1})

3.9. Total chlorophyll content

Chlorophyll a, Chlorophyll b and total chlorophyll were estimated by the method suggested by Hiscox and Israelstam (1979). For chlorophyll estimation, 100 mg leaf sample was added to 10 ml DMSO (Dimethyl sulphoxide) and kept in darkness overnight. The final volume was made upto 25 ml after filtering. Then the chlorophyll content was estimated in spectrophotometer (Model-4001/4 Thermo spectronic, Thermo Electron Corporation, USA) at two wavelengths 645 mm and 663 mm and expressed as milligram g^{-1} fresh weight of plant tissue. The calculation was done by the following formulae.

Chlorophyll 'a' = [(12.7 x A663) – (2.69 x A645)] x V/1000 x W

Chlorophyll 'b' = [(22.9 x A645) – (4.68 x A663)] x V/1000 x W

Total chlorophyll = [(20.2 x A645) + (8.02 x A 663)] x V/1000 x W

Where

A= absorption at given wavelength

V= total volume of sample in extraction medium

W= Weight of sample

3.10. Plant and fruit analysis

Plant and fruit samples were collected from various treatments of experiment II. Select**ed** fully matured leaves along with the petioles during the active growth stage. They are oven dried at 70 ^{0}C to a constant weight. Samples were ground to pass through a 0.5 mm mesh and the required quantity of samples were digested and used for nutrient content analysis for N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and B. The method followed were shown in Table 9.

3.10.1. Nutrient uptake study

Based on the content of nutrients in the plant and fruit, the uptake was computed.

Table 9. Methods of plant and fruit analysis

Sl No:	Element	Method
1	Nitrogen	Modified Kjeldhal's digestion method (Jackson, 1973)
2	Phosphorus	Diacid digestion of leaf sample followed by filtration. Vanabdomolybdate phosphoric yellow colour in nitric acid system (Piper, 1966)
3	Potassium	Diacid digestion of leaf sample followed by filtration. Flame photometry determination (Jackson,1973)
4	Calcium and magnesium	Diacid digestion of leaf sample followed by filtration. The filtrate was collected, analyzed for Ca and Mg using Perkin-Elmer AAS(Piper, 1966)
5	Sulphur	Diacid digestion of leaf sample followed by filtration and estimation by turbidimetry (Massoumi and Cornfield, 1963)
6	Iron, manganese, zinc and copper	Diacid digestion of leaf sample followed by filtration. The filtrate was collected, analyzed for Fe, Mn, Zn and Cu using Perkin-Elmer AAS (Piper, 1966)
7	Boron	Determined by dry ashing (Gaines and Mitchell, 1979) and then colorimetrically by Azomethine-H (Bingham, 1982)

3.11. Economics of cultivation

The cost of various inputs and the prevailing labour charge in the locality were taken together and gross expenditure was computed and expressed in rupees per 100 m^2. The price of the fruits at current local market was taken as total receipts for computing gross returns and expressed in rupees per 100 m^2. Benefit: Cost ratio was worked out by dividing the gross return with total expenditure per 100 m^2. The details of market prices are furnished in Appendix IV.

3.12. Statistical analysis

The data pertaining to the growth parameters and floral parameters were subjected to statistical analysis by applying the technique of two factor analysis (pooled over seasons) (Gomez and Gomez, 1984).

Results

4. RESULTS

The present study pertaining to "production dynamics of strawberry (*Fragaria* x *ananassa* Duch.) in Kerala" was conducted during two seasons *viz.*, September 2016-March 2017 and September 2017- March 2018. The entire work was divided into four experiments and are presented with the following sub headings.

4.1 Evaluation of strawberry varieties

4.2 Nutrient management in strawberry

4.3 Effect of spacing on growth and yield

4.4 Evaluating different growing systems for home-gardening

Experiment-I

4.1 Evaluation of strawberry varieties

Observations on growth of strawberry under open condition during two seasons *viz.*, September 2016-March 2017 and September 2017-March 2018 at two locations *viz.*, Central mid-lands and High ranges of Kerala are presented in Tables 8a to 11b. Eight varieties were planted in study *viz.*, Hadar (V_1), Sweet Charlie (V_2), Sabrina-1 (V_3), Sabrina (V_4), Crystal (V_5), Winter Dawn (V_6), Gili (V_7) and Barak (V_8).

4.1.1 Vegetative characters

4.1.1.1 Plant height

Analysis of the data corresponding to the plant height of strawberry at two locations *viz.*, Central mid-lands and Hhigh ranges of Kerala are presented in Tables 10a and 10b.

Table 10a. Performance of different varieties of strawberry on plant height at Central midlands of Kerala

Varieties (V)	Central midlands														
	Plant height (cm)														
	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	Seasons		Mean	Seasons		Mean	Seasons		Mean	Seasons		Mean	Seasons		Mean
	I	II		I	II		I	II		I	II		I	II	
V_1	10.35	13.00	11.67	13.7	17.60	15.65	16.90	19.83	18.37	18.87	20.73	19.80	19.97	21.63	20.80
V_2	13.36	11.87	12.61	15.1	15.18	15.14	17.13	16.80	16.97	18.50	17.62	18.06	19.23	18.80	19.02
V_3	11.82	14.27	13.04	16.08	18.87	17.47	19.60	21.32	20.46	22.37	22.93	22.65	23.20	24.33	23.77
V_4	11.29	8.37	9.83	13.03	10.63	11.83	14.01	11.70	12.85	15.24	13.60	14.42	16.14	15.40	15.77
V_5	8.94	9.70	9.32	13.21	13.60	13.40	15.76	15.13	15.45	17.89	17.80	17.85	19.60	18.93	19.27
V_6	9.60	15.27	12.43	14.97	16.40	15.68	19.75	20.60	20.17	22.41	22.50	22.45	23.79	22.95	23.37
V_7	5.30	4.27	4.78	8.68	7.50	8.09	9.88	10.43	10.16	11.03	11.66	11.34	12.07	12.63	12.35
V_8	6.43	5.40	5.92	8.58	8.53	8.56	12.73	13.73	13.23	16.25	17.50	16.87	17.63	18.53	18.08
CD (0.05)			**1.17**			**1.08**			**0.69**			**0.59**			**0.50**

Table 10b. Performance of different varieties of strawberry on plant height at High ranges of Kerala

Varieties (V)	High ranges														
	Plant height (cm)														
	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	Seasons		Mean	Seasons		Mean	Seasons		Mean	Seasons		Mean	Seasons		Mean
	I	II		I	II		I	II		I	II		I	II	
V_1	12.34	12.39	12.37	16.25	15.86	16.06	16.58	17.28	16.93	18.83	18.22	18.52	19.44	19.45	19.44
V_2	11.07	10.34	10.71	14.31	14.11	14.21	17.65	16.23	16.94	19.44	19.42	19.43	21.30	21.75	21.53
V_3	12.50	13.04	12.77	15.33	14.16	14.74	13.10	16.75	14.93	17.30	18.14	17.72	18.60	20.89	19.74
V_4	11.52	12.84	12.18	14.61	14.60	14.61	16.91	18.58	17.74	18.32	19.82	19.07	20.18	21.89	21.04
V_5	12.22	13.32	12.77	14.75	15.64	15.20	14.95	17.56	16.26	19.09	19.43	19.26	20.13	20.61	20.37
V_6	13.32	14.12	13.72	14.64	15.45	15.05	15.83	19.18	17.51	20.74	21.31	21.03	21.31	22.20	21.75
V_7	7.25	7.48	7.37	8.93	8.44	8.69	11.79	9.20	10.50	11.52	12.19	11.86	13.68	13.64	13.66
V_8	8.74	9.63	9.19	11.45	10.87	11.16	13.71	12.26	12.98	13.55	13.40	13.47	14.96	14.64	14.80
CD (0.05)			**0.45**			**0.88**			**2.41**			**0.45**			**0.64**

Central mid-lands of Kerala

At 1 MAP, V_3 recorded the maximum height of 13.04 cm which was on par with V_2 (12.61 cm) and V_6 (12.43 cm). It was followed by V_1 (11.67 cm), V_4 (9.83 cm), V_5 (9.32 cm), V_8 (5.92 cm) and V_7 (4.78 cm). At 2 MAP, V_3 recorded the maximum height of 17.47 cm. It was followed by V_6 (15.68 cm), V_1 (15.65 cm), V_2 (15.14 cm), V_5 (13.40 cm), V_4 (11.83 cm), V_8 (8.56 cm) and V_7 (8.09 cm). At 3 MAP, V_3 recorded the maximum height of 20.46 cm which was on par with V_6 (20.17 cm). It was followed by V_1 (18.37 cm), V_2 (16.97 cm), V_5 (15.45 cm), V_8 (13.23 cm), V_4 (12.85 cm) and V_7 (10.16 cm). At 4 MAP, V_3 recorded the maximum height of 22.65 cm which was on par with V_6 (22.45 cm). It was followed by V_1 (19.80 cm), V_5 (18.06 cm), V_5 (17.85 cm), V_8 (16.87 cm), V_4 (14.42 cm) and V_7 (11.34 cm). At 5 MAP, V_3 recorded the maximum height of 23.77 cm which was on par with V_6 (23.37 cm). It was followed by V_1 (20.80 cm), V_5 (19.27 cm), V_2 (19.02 cm), V_8 (18.08 cm), V_4 (15.77 cm) and V_7 (12.35 cm).

High ranges of Kerala

At 1 MAP, V_6 recorded the maximum height of 13.72 cm. It was followed by V_3 (12.77 cm), V_5 (12.77 cm), V_1 (12.37 cm), V_4 (12.18 cm), V_2 (10.71 cm), V_8 (9.19 cm) and V_7 (7.37 cm). At 2 MAP, V_1 recorded the maximum height of 16.06 cm. It was followed by V_5 (15.20 cm), V_6 (15.05 cm), V_3 (14.74 cm), V_4 (14.61 cm), V_2 (14.21 cm), V_8 (11.16 cm) and V_7 (8.69 cm). At 3 MAP, V_4 recorded the maximum height of 17.74 cm which was on par with V_6 (17.51 cm), V_2 (16.94 cm), V_1 (16.93 cm) and V_5 (16.26 cm). It was followed by V_3 (14.93 cm), V_8 (12.98 cm) and V_7 (10.50 cm).At 4 MAP, V_6 recorded the maximum height of 21.03 cm which was followed by V_2 (19.43 cm), V_5 (19.26 cm), V_4 (19.07 cm), V_1 (18.52 cm), V_3 (17.72 cm), V_8 (13.47 cm) and V_7 (11.86 cm). At 5 MAP, V_6 recorded the maximum height of 21.75 cm which was on par with V_2 (21.53 cm). It was followed by V_4 (21.04 cm), V_5 (20.37 cm), V_3 (19.74 cm), V_1 (19.44 cm), V_8 (14.80 cm) and V_7 (13.66 cm).

Table 11a. Performance of different varieties of strawberry on number of leaves at Central midlands of Kerala

Varieties (V)	Central midlands														
	Number of leaves														
	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	Seasons		Mean	Seasons		Mean	Seasons		Mean	Seasons		Mean	Seasons		Mean
	I	II		I	II		I	II		I	II		I	II	
V_1	3.69	3.67	3.68	17.42	16.20	16.81	27.24	26.73	26.99	37.48	38.90	38.19	35.85	36.90	36.38
V_2	4.44	3.64	4.04	12.33	15.24	13.79	20.83	21.56	21.20	29.00	29.87	29.43	27.71	28.10	27.90
V_3	4.56	6.47	5.51	18.00	16.20	17.10	32.35	35.70	34.02	49.49	50.37	49.93	48.07	48.88	48.48
V_4	3.93	3.40	3.67	7.57	7.23	7.40	16.68	17.81	17.24	28.13	28.23	28.18	26.87	27.60	27.23
V_5	3.47	3.30	3.38	12.78	10.97	11.72	22.01	20.20	21.11	31.24	30.50	30.87	29.77	29.51	29.64
V_6	4.33	5.93	5.13	19.17	17.20	18.18	39.37	38.07	38.72	58.15	58.15	58.15	56.39	56.39	56.39
V_7	4.33	2.33	3.33	5.87	6.02	5.94	10.30	11.24	10.77	13.57	12.80	13.18	12.50	11.69	12.10
V_8	4.17	3.50	3.83	6.77	7.66	7.22	12.35	12.17	12.26	18.28	16.51	17.39	17.55	15.73	16.64
CD (0.05)			**0.54**			**1.35**			**1.8**			**2.29**			**2.24**

Table 11b. Performance of different varieties of strawberry on number of leaves at High ranges of Kerala

Varieties (V)	High ranges														
	Number of leaves														
	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	Seasons		Mean	Seasons		Mean	Seasons		Mean	Seasons		Mean	Seasons		Mean
	I	II		I	II		I	II		I	II		I	II	
V_1	5.32	5.80	5.56	9.26	6.87	8.07	14.77	11.50	13.13	26.79	24.23	25.51	20.48	22.07	21.27
V_2	6.33	6.65	6.49	12.46	7.27	9.86	20.20	18.73	19.47	24.53	25.80	25.17	20.20	18.80	19.50
V_3	8.00	7.63	7.82	11.25	11.48	11.37	23.90	24.20	24.05	35.13	36.07	35.60	30.60	30.95	30.78
V_4	3.97	4.60	4.28	7.77	6.62	7.19	10.27	10.39	10.33	12.56	12.05	12.31	15.13	16.07	15.60
V_5	5.00	5.20	5.10	7.78	7.11	7.44	11.00	10.78	10.89	15.73	15.75	15.74	19.62	21.15	20.39
V_6	6.32	6.47	6.39	13.12	7.60	10.36	25.50	25.40	25.45	36.80	37.37	37.08	40.44	35.20	37.82
V_7	3.17	3.47	3.32	6.60	5.75	6.17	10.67	7.26	8.96	13.53	10.33	11.93	13.23	12.21	12.72
V_8	5.67	7.44	6.55	7.58	8.78	8.18	11.33	10.27	10.80	14.47	14.07	14.27	16.82	17.33	17.08
CD (0.05)			**0.47**			**1.38**			**1.59**			**1.88**			**1.76**

4.1.1.2 Number of leaves

Analysis of the data corresponding to the number of leaves of strawberry at two locations viz., Central mid-lands and High ranges of Kerala are presented in Tables 11a and 11b.

Central mid-lands of Kerala

At 1 MAP, V_3 recorded the maximum number of leaves (5.51) which was on par with V_6 (5.13). It was followed by V_2 (4.04), V_8 (3.83), V_1 (3.68), V_4 (3.67), V_5 (3.38) and V_7 (3.33). At 2 MAP, V_6 recorded the maximum number of leaves (18.18) which was on par with V_3 (17.10). It was followed by V_1 (16.81), V_2 (13.79), V_5 (11.72), V_4 (7.40), V_8 (7.22) and V_7 (5.94). At 3 MAP, V_6 recorded the maximum number of leaves (38.72). It was followed by V_3 (34.02), V_1 (26.99), V_2 (21.20), V_5 (21.11), V_4 (17.24), V_8 (12.26) and V_7 (10.77). At 4 MAP, V_6 recorded the maximum number of leaves (58.15) which was followed by V_3 (49.93), V_1 (38.19), V_5 (30.87), V_2 (29.43), V_4 (28.18), V_8 (17.39) and V_7 (13.18). At 5 MAP, V_6 recorded the maximum number of leaves (56.39) which was followed by V_3 (48.48), V_1 (36.38), V_5 (29.64), V_2 (27.90), V_4 (27.23), V_8 (16.64) and V_7 (12.10).

High ranges of Kerala

At 1 MAP, V_3 recorded the maximum number of leaves (7.82) which was followed by V_8 (6.55), V_2 (6.49), V_6 (6.39), V_1 (5.56), V_5 (5.10), V_4 (4.28) and V_7 (3.32). At 2 MAP, V_3 recorded the maximum number of leaves (11.37) which was on par with V_6 (10.36). It was followed by V_2 (9.86), V_8 (8.18), V_1 (8.07), V_5 (7.44), V_4 (7.19) and V_7 (6.17). At 3 MAP, V_6 recorded the maximum number of leaves (25.45) which was on par with V_3 (24.05). It was followed by V_2 (19.47), V_1 (13.13), V_5 (10.89), V_8 (10.80), V_4 (10.33) and V_7 (8.96). At 4 MAP, V_6 recorded the maximum number of leaves (37.08) which was on par with V_3 (35.60). It was followed by V_1 (25.51), V_2 (25.17), V_5 (15.74), V_8 (14.27), V_4 (12.31) and V_7 (11.93). At 5 MAP, V_6

Table 12a. Performance of different varieties of strawberry on plant spread at Central midlands of Kerala

Varieties (V)	Central midlands Plant spread (cm)														
	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	Seasons		Mean	Seasons		Mean	Seasons		Mean	Seasons		Mean	Seasons		Mean
	I	II		I	II		I	II		I	II		I	II	
V_1	10.84	14.53	12.69	18.25	19.33	18.79	24.21	24.60	24.41	28.53	28.42	28.48	29.67	29.87	29.77
V_2	4.63	7.07	5.85	8.81	12.12	10.47	14.24	15.73	14.98	19.06	19.18	19.12	20.38	20.33	20.36
V_3	8.43	10.88	9.66	15.43	20.09	17.76	25.89	23.10	24.50	35.82	33.45	34.64	37.53	37.50	37.52
V_4	5.23	5.81	5.52	9.40	11.39	10.40	16.34	14.80	15.57	19.00	18.00	18.50	20.45	20.17	20.31
V_5	4.98	7.39	6.18	9.42	12.71	11.06	18.95	16.97	17.96	23.52	21.50	22.51	24.65	25.73	25.19
V_6	7.68	5.20	6.44	12.47	11.22	11.84	20.45	17.37	18.91	29.33	33.07	31.20	33.25	35.09	34.17
V_7	4.50	6.67	5.58	8.50	8.72	8.61	11.50	11.47	11.64	14.88	14.62	14.75	16.07	15.70	15.89
V_8	4.23	8.40	6.32	10.47	10.40	10.43	13.37	12.37	12.87	18.07	17.78	17.92	19.03	19.03	19.03
CD (0.05)			**1.46**			**1.46**			**1.56**			**2.17**			**2.68**

Table 12b. Performance of different varieties of strawberry on plant spread at High ranges of Kerala

Varieties (V)	High ranges Plant spread (cm)														
	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	Seasons		Mean	Seasons		Mean	Seasons		Mean	Seasons		Mean	Seasons		Mean
	I	II		I	II		I	II		I	II		I	II	
V_1	21.67	22.60	22.13	26.12	23.77	24.94	27.30	25.27	26.28	55.62	48.18	51.90	41.70	38.80	40.25
V_2	18.77	19.16	18.96	24.28	21.83	23.06	26.25	25.83	26.04	34.90	32.37	33.64	32.99	30.59	31.79
V_3	16.30	19.67	17.98	24.39	21.63	23.01	27.72	26.77	27.24	32.80	33.20	33.00	27.98	22.97	25.47
V_4	16.87	16.53	16.70	25.73	20.13	22.93	32.47	23.63	28.05	35.27	34.23	34.75	31.56	31.45	31.51
V_5	15.50	16.20	15.85	18.93	18.27	18.60	27.33	21.32	24.33	29.93	27.03	28.48	25.79	24.58	25.19
V_6	20.53	20.30	20.42	30.30	25.07	27.68	32.90	26.90	29.90	39.83	35.97	37.90	34.13	28.80	31.47
V_7	7.40	7.85	7.63	10.37	10.60	10.48	15.23	15.07	15.15	18.77	18.07	18.42	19.38	19.37	19.37
V_8	8.93	9.80	9.37	14.79	18.25	16.52	17.83	19.90	18.87	23.62	23.63	23.63	23.27	23.44	23.36
CD (0.05)			**2.06**			**3.97**			**3.47**			**5.96**			**4.72**

recorded the maximum number of leaves (37.82). It was followed by V_3 (30.78), V_1 (21.27), V_5 (20.39), V_2 (19.50), V_8 (17.08), V_4 (15.60) and V_7 (12.72).

4.1.1.3 Plant spread

Analysis of the data corresponding to the plant spread of strawberry at two locations *viz*., Central mid-lands and High ranges of Kerala are presented in Tables 12a and 12b.

Central mid-lands of Kerala

At 1 MAP, V_1 recorded the maximum plant spread (12.69 cm) which was followed by V_3 (9.66 cm), V_6 (6.44 cm), V_8 (6.32 cm), V_5 (6.18 cm), V_2 (5.85 cm), V_7 (5.58 cm) and V_4 (5.52 cm). At 2 MAP, V_1 recorded the maximum plant spread (18.79 cm) which was on par with V_3 (17.76 cm). It was followed by V_6 (11.84 cm), V_5 (11.06 cm), V_2 (10.47 cm), V_8 (10.43 cm), V_4 (10.40 cm) and V_7 (8.61 cm). At 3 MAP, V_3 recorded the maximum plant spread (24.50 cm) which was on par with V_1 (24.41 cm). It was followed by V_6 (18.91 cm), V_5 (17.96 cm), V_4 (15.57 cm), V_2 (14.98 cm), V_8 (12.87 cm) and V_7 (11.64 cm). At 4 MAP, V_3 recorded the maximum plant spread (34.64 cm) which was followed by V_6 (31.20 cm), V_1 (28.48 cm), V_5 (22.51 cm), V_2 (19.12 cm), V_4 (18.50 cm), V_8 (17.92 cm) and V_7 (14.75 cm). At 5 MAP, V_3 recorded the maximum plant spread (37.52 cm) which was followed by V_6 (34.17 cm), V_1 (29.77 cm), V_5 (25.19 cm), V_2 (20.36 cm), V_4 (20.31 cm), V_8 (19.03 cm) and V_7 (15.89 cm).

High ranges of Kerala

At 1 MAP, V_1 recorded the maximum plant spread (22.13 cm) which was on par with V_6 (20.42 cm). It was followed by V_2 (18.96 cm), V_3 (17.98 cm), V_4 (16.70 cm), V_5 (15.85 cm), V_8 (9.37 cm) and V_7 (7.63 cm). At 2 MAP, V_6 recorded the maximum plant spread (27.68 cm) which was followed by V_1 (24.94 cm), V_2 (23.06 cm), V_3 (23.01 cm), V_4 (22.93 cm), V_5 (18.60 cm), V_8 (16.52 cm) and V_7 (10.48 cm).

Table 13a. Performance of different varieties of strawberry on number of crowns at Central midlands of Kerala

Varieties (V)	Central midlands														
	Number of crowns														
	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	Seasons		Mean	Seasons		Mean	Seasons		Mean	Seasons		Mean	Seasons		Mean
	I	II		I	II		I	II		I	II		I	II	
V_1	1	1	1	1.00	1.11	1.06	1.11	1.22	1.17	1.31	1.22	1.27	1.38	1.55	1.47
V_2	1	1	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V_3	1	1	1	2.27	2.53	2.40	3.03	3.03	3.03	3.22	3.40	3.31	3.22	3.60	3.41
V_4	1	1	1	1.00	1.27	1.13	1.00	1.27	1.13	1.07	1.27	1.17	1.13	1.27	1.20
V_5	1	1	1	1.00	1.29	1.14	1.20	1.33	1.27	1.27	1.42	1.34	1.33	1.42	1.38
V_6	1	1	1	2.27	2.53	2.40	2.60	2.67	2.63	3.20	3.40	3.30	3.57	4.20	3.88
V_7	1	1	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.07	1.03	1.07	1.07	1.07
V_8	1	1	1	1.00	1.00	1.00	1.00	1.00	1.00	1.11	1.20	1.16	1.11	1.20	1.16
CD (0.05)			**NS**			**0.16**			**0.16**			**0.26**			**0.4**

Table 13b. Performance of different varieties of strawberry on number of crowns at High ranges of Kerala

Varieties (V)	High ranges														
	Number of crowns														
	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	Seasons		Mean	Seasons		Seasons	Seasons		Mean	Seasons		Mean	Seasons		Mean
	I	II		I	I		I	II		I	II		I	II	
V_1	1	1	1	1.00	1.07	1.03	1.20	1.33	1.27	3.07	3.33	3.20	3.20	3.47	3.33
V_2	1	1	1	1.00	1.00	1.00	2.00	2.20	2.10	3.00	3.33	3.17	3.07	3.40	3.23
V_3	1	1	1	1.20	1.73	1.47	2.27	2.27	2.27	4.60	4.73	4.67	4.67	4.80	4.73
V_4	1	1	1	1.07	1.27	1.17	1.67	1.87	1.77	2.60	3.87	3.23	2.67	3.93	3.30
V_5	1	1	1	1.00	1.00	1.00	1.20	1.53	1.37	1.80	2.13	1.97	1.87	2.33	2.10
V_6	1	1	1	1.00	1.07	1.03	1.80	1.73	1.77	4.60	4.60	4.60	4.73	4.87	4.80
V_7	1	1	1	1.00	1.00	1.00	1.00	1.07	1.03	1.07	1.13	1.10	1.13	1.20	1.17
V_8	1	1	1	1.00	1.00	1.00	1.13	1.20	1.17	1.33	1.47	1.40	1.40	1.60	1.50
CD (0.05)			**NS**			**0.14**			**0.14**			**0.47**			**0.49**

At 3 MAP, V_6 recorded the maximum plant spread (29.90 cm) which was on par with V_4 (28.05 cm) and V_3 (27.24 cm). It was followed by V_1 (26.28 cm), V_2 (26.04 cm), V_5 (24.33 cm), V_8 (18.87 cm) and V_7 (15.15 cm). At 4 MAP, V_1 recorded the maximum plant spread (51.90 cm). It was followed by V_6 (37.90 cm), V_4 (34.75 cm), V_2 (33.64 cm), V_3 (33.00 cm), V_5 (28.48 cm), V_8 (23.63 cm) and V_7 (18.42 cm). At 5 MAP, V_1 recorded the maximum plant spread (40.25 cm) which was followed by V_2 (31.79 cm), V_4 (31.51 cm), V_6 (31.47 cm), V_3 (25.47 cm), V_5 (25.19 cm), V_8 (23.36 cm) and V_7 (19.37 cm).

4.1.1.4 Number of crowns

Analysis of the data corresponding to the number of crowns of strawberry at two locations viz., Central mid-lands and High ranges of Kerala are presented in Tables 13a and 13b.

Central mid-lands of Kerala

At 1 MAP, all varieties were recorded only one crown per plant. At 2 MAP, V_3 and V_6 recorded the same number of crowns (2.40) which was followed by V_5 (1.14), V_4 (1.13), V_1 (1.06), V_2 (1.00), V_7 (1.00) and V_8 (1.00). At 3 MAP, V_3 recorded the maximum number of crowns (3.03) which was followed by V_6 (2.63), V_5 (1.27), V_1 (1.17), V_4 (1.13), V_2 (1.00), V_7 (1.00) and V_8 (1.00). At 4 MAP, V_3 recorded the maximum number of crowns (3.31) which was on par with V_6 (3.30). It was followed by V_5 (1.34), V_1 (1.27), V_4 (1.11), V_8 (1.16), V_7 (1.03) and V_2 (1.00). At 5 MAP, V_6 recorded the maximum number of crowns (3.88). It was followed by V_3 (3.41), V_1 (1.47), V_5 (1.38), V_4 (1.20), V_8 (1.16), V_7 (1.07) and V_2 (1.00).

High ranges of Kerala

At 1 MAP, varieties recorded same number of crowns (1) per plant. At 2 MAP, V_3 recorded the maximum number of crowns (1.47). It was followed by V_4 (1.17), V_1

(1.03), V_6 (1.03), V_2 (1.00), V_5 (1.00), V_7 (1.00) and V_8 (1.00). At 3 MAP, V_3 recorded the maximum number of crowns (2.27) which was followed by V_2 (2.10), V_4 (1.77), V_6 (1.77), V_5 (1.37), V_1 (1.27), V_8 (1.17) and V_7 (1.03). At 4 MAP, V_3 recorded the maximum number of crowns (4.67) which was on par with V_6 (4.60). It was followed by V_4 (3.23), V_1 (3.20), V_2 (3.17), V_5 (1.97), V_8 (1.40) and V_7 (1.10). At 5 MAP, V_6 recorded the maximum number of crowns (4.80) which was on par with V_3 (4.73). It was followed by V_1 (3.33), V_4 (3.30), V_2 (3.23), V_5 (2.10), V_8 (1.50) and V_7 (1.17).

4.1.2 Flowering attributes

4.1.2.1 Days to first flowering

Analysis of the data corresponding to days to first flowering at two locations *viz.*, Central mid-lands and High ranges of Kerala are presented in Table 14.

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that V_6 recorded significantly minimum number of days to first flowering (49.00 days) which was followed by V_5 (55.83 days), V_1 (75.33 days), V_3 (90.83 days), V_2 (93.00 days), V_7 (96.33 days), V_4 (101.17 days) and V_8 (101.50 days).

High ranges of Kerala

The pooled mean over the two seasons revealed that V_7 recorded significantly minimum number of days to first flowering (42.33 days) which was followed by V_3 (50.50 days), V_8 (51.00 days), V_1 (58.17 days), V_6 (60.00 days), V_2 (70.67 days), V_4 (70.83 days) and V_5 (71.83 days).

Table 14. Performance of different varieties of strawberry on days to first flowering at Central midlands and High ranges of Kerala

Days to first flowering (days)						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	75.67	75.00	75.33	57.67	58.67	58.17
V_2	93.00	93.00	93.00	70.33	71.00	70.67
V_3	90.67	91.00	90.83	50.33	50.67	50.50
V_4	101.33	101.00	101.17	67.67	74.00	70.83
V_5	55.67	56.00	55.83	71.67	72.00	71.83
V_6	49.00	49.00	49.00	64.67	55.33	60.00
V_7	96.00	96.67	96.33	42.00	42.67	42.33
V_8	101.67	101.33	101.50	40.00	62.00	51.00
CD (0.05)			**1.02**			**2.01**

Table 15. Performance of different varieties of strawberry on number of clusters at Central midlands and High ranges of Kerala

Number of clusters						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	1.33	2.00	1.67	10.27	9.97	10.12
V_2	0.00	0.00	0.00	9.47	9.33	9.40
V_3	3.33	3.00	3.17	11.00	10.93	10.97
V_4	0.33	0.00	0.17	5.33	5.50	5.42
V_5	0.00	0.00	0.00	8.87	8.00	8.43
V_6	5.67	5.67	5.67	12.30	12.83	12.57
V_7	0.00	0.00	0.00	2.40	2.57	2.48
V_8	0.00	0.00	0.00	7.23	8.23	7.73
CD (0.05)			**0.48**			**1.17**

Table 16. Performance of different varieties of strawberry on number of flowers at Central midlands and High ranges of Kerala

Number of flowers						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	2.67	2.60	2.63	20.37	20.27	20.32
V_2	1.20	1.33	1.27	18.47	19.30	18.88
V_3	5.07	4.20	4.63	21.97	22.00	21.98
V_4	2.03	1.07	1.55	11.63	11.87	11.75
V_5	1.47	1.53	1.50	15.40	15.52	15.46
V_6	8.23	8.03	8.13	24.87	24.37	24.62
V_7	1.13	1.07	1.10	7.07	6.20	6.63
V_8	1.00	1.4	1.20	11.83	12.40	12.12
CD (0.05)			**0.37**			**0.7**

4.1.2.2 Number of clusters per plant

Analysis of the data corresponding to number of clusters of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala are presented in Table 15.

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that V_6 recorded significantly maximum number of clusters (5.67) per plant. It was followed by V_3 (3.17), V_1 (1.67) and V_4 (0.17). However V_2, V_5, V_7 and V_8 had no clustering of flowers.

High ranges of Kerala

The pooled mean over the two seasons revealed that V_6 recorded significantly higher number of clusters per plant (12.57). It was followed by V_3 (10.97), V_1 (10.12), V_2 (9.40), V_5 (8.43), V_8 (7.73), V_4 (5.42) and V_7 (2.48).

4.1.2.3 Number of flowers per plant

Analysis of the data corresponding to number of flowers of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala are presented in Table 16.

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that V_6 recorded significantly higher number of flowers per plant (8.13) which was followed by V_3 (4.63), V_1 (2.63), V_4 (1.55), V_5 (1.50), V_2 (1.27), V_8 (1.20) and V_7 (1.10).

High ranges of Kerala

The pooled mean over the two seasons revealed that V_6 recorded significantly higher number of flowers per plant (24.62) which was followed by V_3 (21.98), V_1 (20.32), V_2 (18.88), V_5 (15.46), V_8 (12.12), V_4 (11.75) and V_7 (6.63).

4.1.3. Yield attributes

4.1.3.1 Number of fruits per plant

Analysis of the data corresponding to number of fruits per plant of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala are presented in Table 17.

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that V_6 recorded significantly maximum number of fruits per plant (4.85) which was followed by V_3 (3.57), V_1 (2.38), V_5 (1.17), V_2 (0.90), V_4 (0.90), V_8 (0.87) and V_7 (0.73).

High ranges of Kerala

The pooled mean over the two seasons revealed that V_6 recorded the maximum number of fruits per plant (13.68) which was followed by V_3 (12.45), V_1 (11.12), V_2 (10.30), V_5 (9.44), V_8 (6.40), V_4 (5.93) and V_7 (3.22).

4.1.3.2 Fruit length

Analysis of the data corresponding to fruit length of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala are presented in Table 18.

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that V_6 recorded significantly maximum fruit length (4.55 cm) which was followed by V_3 (3.88 cm), V_2 (3.17 cm), V_1 (2.98 cm), V_5 (2.60 cm), V_4 (2.52 cm), V_8 (2.22 cm) and V_8 (1.93 cm).

Table 17. Performance of different varieties of strawberry on number of fruits at Central midlands and High ranges of Kerala

Number of fruits						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	2.40	2.37	2.38	11.57	10.67	11.12
V_2	0.93	0.87	0.90	10.97	9.63	10.30
V_3	3.53	3.60	3.57	12.17	12.73	12.45
V_4	0.93	0.87	0.90	5.73	6.13	5.93
V_5	1.20	1.13	1.17	9.48	9.40	9.44
V_6	4.79	4.9	4.85	12.80	14.57	13.68
V_7	0.73	0.73	0.73	3.43	3.00	3.22
V_8	0.80	0.93	0.87	5.90	6.90	6.40
CD (0.05)			**0.26**			**0.69**

Table 18. Performance of different varieties of strawberry on fruit length at Central midlands and High ranges of Kerala

Fruit length (cm)						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	2.90	3.07	2.98	3.48	3.40	3.44
V_2	3.17	3.17	3.17	2.59	3.83	3.21
V_3	3.90	3.87	3.88	2.94	2.90	2.92
V_4	2.43	2.60	2.52	3.77	4.03	3.90
V_5	2.57	2.63	2.60	3.01	3.06	3.04
V_6	4.57	4.53	4.55	4.20	3.85	4.02
V_7	1.97	1.90	1.93	2.48	2.69	2.59
V_8	2.17	2.27	2.22	3.14	3.08	3.11
CD (0.05)			**0.37**			**0.33**

Table 19. Performance of different varieties of strawberry on fruit breadth at Central midlands and High ranges of Kerala

Fruit breadth (cm)						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	2.73	2.43	2.58	2.62	2.53	2.58
V_2	3.27	3.17	3.22	2.23	3.17	2.70
V_3	4.60	4.53	4.57	2.55	2.30	2.43
V_4	2.30	2.40	2.35	3.03	2.87	2.95
V_5	2.43	2.47	2.45	2.31	2.33	2.32
V_6	4.33	4.40	4.37	2.81	2.87	2.84
V_7	1.90	1.90	1.90	1.78	1.73	1.76
V_8	2.13	2.13	2.13	2.58	2.93	2.76
CD (0.05)			**0.28**			**0.25**

High ranges of Kerala

The pooled mean over the two seasons revealed that V_6 recorded significantly maximum fruit length (4.02 cm) which was on par with V_4 (3.90 cm). It was followed by V_1 (3.44 cm), V_2 (3.21 cm), V_8 (3.11 cm), V_5 (3.04 cm), V_3 (2.92 cm) and V_7 (2.59 cm).

4.1.3.3 Fruit breadth

Analysis of the data corresponding to fruit breadth of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala are presented in Table 19.

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that V_3 recorded significantly maximum fruit breadth (4.57 cm) which was on par with V_6 (4.37 cm). It was followed by V_2 (3.22 cm), V_1 (2.58 cm), V_5 (2.45 cm), V_4 (2.35 cm), V_8 (2.13 cm) and V_7 (1.90 cm).

High ranges of Kerala

The pooled mean over the two seasons revealed that V_4 recorded significantly maximum fruit breadth (2.95 cm) which was on par with V_6 (2.84 cm), V_8 (2.76 cm) and V_2 (2.70 cm). It was followed by V_1 (2.58 cm), V_3 (2.43 cm), V_5 (2.32 cm) and V_7 (1.76 cm).

4.1.3.4 Average fruit weight

Analysis of the data corresponding to average fruit weight of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala are presented in Table 20.

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that V_3 recorded significantly maximum average fruit weight (10.26 g) which was followed by V_6 (9.20 g), V_1 (8.15 g), V_8 (7.76 g), V_2 (6.58 g), V_5 (5.10 g), V_4 (2.85 g) and V_7 (2.24 g).

High ranges of Kerala

The pooled mean over the two seasons revealed that V_6 recorded significantly maximum average fruit weight (13.79 g) which was followed by V_3 (12.17 g), V_1 (12.14 g), V_5 (10.50 g), V_4 (10.29 g), V_2 (8.57 g), V_8 (7.57 g) and V_7 (4.45 g).

4.1.3.5 Days to first harvest

Analysis of the data corresponding to minimum number of days to first harvest at two locations *viz.,* Central mid-lands and High ranges of Kerala are presented in Table 21.

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that V_6 recorded significantly minimum number of days to first harvest (70.17 days) which was followed by V_5 (79.00 days), V_1 (102.00 days), V_2 (112.00 days), V_3 (114.00 days), V_7 (118.50 days), V_4 (121.67 days) and V_8 (124.33 days).

High ranges of Kerala

The pooled mean over the two seasons revealed that V_7 recorded minimum number of days to first harvest (65.33 days) which was followed by V_3 (73.00 days), V_8 (74.00 days), V_1 (81.17 days), V_6 (83.00 days), V_2 (93.67 days), V_4 (93.83 days) and V_5 (94.83 days).

Table 20. Performance of different varieties of strawberry on average fruit weight at Central midlands and High ranges of Kerala

Average fruit weight (g)						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	8.03	8.27	8.15	13.13	11.14	12.14
V_2	6.50	6.67	6.58	8.05	9.09	8.57
V_3	10.67	9.86	10.26	14.31	10.03	12.17
V_4	2.94	2.77	2.85	9.98	10.60	10.29
V_5	5.38	4.83	5.10	10.15	10.85	10.50
V_6	8.59	9.80	9.20	14.47	13.10	13.79
V_7	2.36	2.12	2.24	4.78	4.12	4.45
V_8	7.82	7.71	7.76	7.99	7.14	7.57
CD (0.05)			**0.93**			**0.95**

Table 21. Performance of different varieties of strawberry on days to first harvest at Central midlands and High ranges of Kerala

Days to first harvest (days)						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	100.67	103.33	102.00	80.67	81.67	81.17
V_2	112.00	112.00	112.00	93.33	94.00	93.67
V_3	113.67	114.33	114.00	72.33	73.67	73.00
V_4	122.00	121.33	121.67	90.67	97.00	93.83
V_5	79.00	79.00	79.00	94.67	95.00	94.83
V_6	70.00	70.33	70.17	87.67	78.33	83.00
V_7	118.67	118.33	118.50	65.00	65.67	65.33
V_8	124.67	124.00	124.33	63.00	85.00	74.00
CD (0.05)			**1.61**			**2.01**

Table 22. Performance of different varieties of strawberry on days to final harvest at Central midlands and High ranges of Kerala

Days to final harvest (days)						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	173.33	171.33	172.33	185.00	183.33	184.17
V_2	165.67	165.33	165.50	180.00	180.00	180.00
V_3	173.00	165.33	169.17	184.67	184.67	184.67
V_4	150.33	153.00	151.67	170.00	166.67	168.33
V_5	158.33	158.67	158.50	160.00	160.00	160.00
V_6	172.67	172.67	172.67	185.00	185.00	185.00
V_7	150.00	150.00	150.00	151.67	151.67	151.67
V_8	152.00	152.67	152.33	155.33	153.33	154.33
CD (0.05)			**9.14**			**1.91**

4.1.3.6 Days to final harvest

Analysis of the data corresponding to maximum number of days to final harvest of strawberry at two locations *viz.,* Central mid-lands and High ranges of Kerala are presented in Table 22.

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that V_6 recorded significantly maximum number of days to final harvest (172.67 days) which was on par with V_1 (172.33 days), V_3 (169.17 days) and V_2 (165.50 days). It was followed by V_5 (158.50 days), V_8 (152.33 days), V_4 (151.67 days) and V_7 (150.00 days).

High ranges of Kerala

The pooled mean over the two seasons revealed that V_6 recorded significantly maximum number of days to final harvest (185.00 days) which was on par with V_3 (184.67 days) and V_1 (184.17 days). It was followed by V_2 (180.00 days), V_4 (168.33 days), V_5 (160.00 days), V_8 (154.33 days) and V_7 (151.67 days).

4.1.3.7 Yield per plant

Analysis of the data corresponding to yield of strawberry at two locations *viz.,* Central mid-lands and High ranges of Kerala are presented in Tables 23.

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that V_6 recorded significantly maximum yield (44.53 g) which was followed by V_3 (36.29 g), V_1 (19.41 g), V_8 (6.73 g), V_2 (5.93 g), V_5 (5.93 g), V_4 (2.59 g) and V_7 (1.65 g).

High ranges of Kerala

The pooled mean over the two seasons revealed that V_6 recorded significantly maximum yield per plant (187.89 g) which was followed by V_3 (150.65 g), V_1 (135.34 g), V_5 (99.10 g), V_2 (87.86 g), V_4 (61.10 g), V_8 (48.20 g) and V_7 (14.42 g).

4.1.4 Quality attributes

4.1.4.1 TSS

Analysis of the data corresponding to TSS of strawberry at two locations *viz.* Central mid-lands and High ranges of Kerala are presented in Table 24.

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that V_7 recorded significantly higher TSS (7.07 ^{0}B) which was on par with V_2 (6.97 ^{0}B) and this was followed by V_6 (6.17 ^{0}B), V_3 (5.37 ^{0}B), V_8 (5.18 ^{0}B), V_5 (5.08 ^{0}B), V_1 (5.05 ^{0}B) and V_4 (4.43 ^{0}B).

High ranges of Kerala

The pooled mean over the two seasons revealed that the maximum TSS was recorded by V_1 (9.37 ^{0}B) which was on par with V_2 (9.34 ^{0}B). It was followed by V_8 (8.75 ^{0}B), V_8 (7.77 ^{0}B), V_3 (7.60 ^{0}B), V_6 (7.56 ^{0}B), V_4 (7.22 ^{0}B) and V_5 (6.63 ^{0}B).

4.1.4.2 Acidity

Analysis of the data corresponding to acidity of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala are presented in Table 25.

Table 23. Performance of different varieties of strawberry on yield at Central midlands and High ranges of Kerala

Yield (g)						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	19.26	19.56	19.41	151.70	118.98	135.34
V_2	6.06	5.79	5.93	88.16	87.56	87.86
V_3	37.48	35.11	36.29	174.13	127.18	150.65
V_4	2.77	2.40	2.59	57.20	65.00	61.10
V_5	6.36	5.49	5.93	96.17	102.04	99.10
V_6	41.06	48.01	44.53	185.07	190.71	187.89
V_7	1.75	1.54	1.65	16.47	12.36	14.42
V_8	6.26	7.19	6.73	47.19	49.20	48.20
CD (0.05)			**4.09**			**12.36**

Table 24. Performance of different varieties of strawberry on TSS at Central midlands and High ranges of Kerala

TSS (^{0}Brix)						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	5.17	4.93	5.05	9.25	9.50	9.37
V_2	7.13	6.80	6.97	9.18	9.50	9.34
V_3	5.43	5.30	5.37	7.83	7.36	7.60
V_4	4.40	4.47	4.43	7.21	7.23	7.22
V_5	5.07	5.10	5.08	6.63	6.63	6.63
V_6	6.13	6.20	6.17	7.59	7.53	7.56
V_7	7.00	7.13	7.07	8.86	8.65	8.75
V_8	5.20	5.17	5.18	7.73	7.80	7.77
CD (0.05)			**0.35**			**0.38**

Table 25. Performance of different varieties of strawberry on acidity at Central midlands and High ranges of Kerala

Acidity (%)						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	0.54	0.59	0.56	0.71	0.85	0.78
V_2	0.43	0.47	0.45	0.78	0.71	0.75
V_3	0.64	0.68	0.66	0.71	0.85	0.78
V_4	0.85	0.85	0.85	0.64	0.85	0.75
V_5	0.85	0.85	0.85	1.00	1.07	1.03
V_6	1.14	1.14	1.14	1.28	1.14	1.21
V_7	0.56	0.57	0.57	0.85	0.92	0.89
V_8	0.75	0.78	0.77	1.42	1.49	1.46
CD (0.05)			**0.07**			**0.12**

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that V_2 recorded significantly lower acidity (0.45 %) which was followed by V_1 (0.56 %), V_7 (0.57 %), V_3 (0.66 %), V_8 (0.77 %), V_4 (0.85 %), V_5 (0.85 %) and V_6 (1.14 %).

High ranges of Kerala

The pooled mean over the two seasons revealed that, the minimum acidity was recorded by V_2 and V_4 (0.75 %) which was on par with V_1 (0.71 %) and V_3 (0.71 %). It was followed by V_7 (0.89 %), V_5 (1.03 %), V_6 (1.21 %), and V_8 (1.46 %)

4.1.4.3 TSS/acidity

Analysis of the data corresponding to TSS/acidity of strawberry at two locations *viz.,* Central mid-lands and High ranges of Kerala are presented in Table 26.

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that V_2 recorded significantly maximum TSS/acidity (15.68) which was followed by V_7 (12.53), V_1 (9.02), V_3 (8.18), V_8 (6.78), V_5 (5.98), V_6 (5.46) and V_4 (5.22).

High ranges of Kerala

The pooled mean over the two seasons revealed that, the maximum TSS/acidity was recorded by V_2 (13.02) which was on par with V_1 (11.95). It was followed by V_3 and V_7 (9.95), V_4 (9.89), V_5 (6.47), V_6 (6.30) and V_8 (5.35).

4.1.4.4 Total sugars

Analysis of the data corresponding to total sugars content of strawberry at two locations *viz.,* Central mid-lands and High ranges of Kerala are presented in Table 27.

Table 26. Performance of different varieties of strawberry on TSS/acidity at Central midlands and High ranges of Kerala

TSS/acidity						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	9.57	8.47	9.02	12.72	11.17	11.95
V_2	16.59	14.77	15.68	12.42	13.61	13.02
V_3	8.49	7.86	8.18	11.24	8.66	9.95
V_4	5.18	5.25	5.22	11.26	8.51	9.89
V_5	5.96	6.00	5.98	6.75	6.20	6.47
V_6	5.44	5.49	5.46	5.93	6.66	6.30
V_7	12.59	12.47	12.53	10.42	9.48	9.95
V_8	6.93	6.63	6.78	5.46	5.23	5.35
CD (0.05)			**0.92**			**1.41**

Table 27. Performance of different varieties of strawberry on total sugars content at Central midlands and High ranges of Kerala

Total sugars (%)						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	3.84	3.84	3.84	5.86	5.91	5.89
V_2	5.38	5.41	5.40	6.08	6.10	6.09
V_3	6.30	6.12	6.21	4.48	5.16	4.82
V_4	2.70	2.93	2.82	5.35	5.13	5.24
V_5	6.36	5.85	6.11	5.06	4.79	4.93
V_6	5.04	4.97	5.00	5.23	4.54	4.89
V_7	5.22	5.19	5.21	6.36	6.27	6.32
V_8	5.37	5.31	5.34	4.26	4.33	4.30
CD (0.05)			**0.23**			**0.26**

Table 28. Performance of different varieties of strawberry on ascorbic acid content at Central midlands and High ranges of Kerala

	Ascorbic acid (mg 100 g^{-1})					
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	55.70	53.59	54.65	61.01	68.90	64.96
V_2	42.55	42.63	42.59	40.33	44.67	42.50
V_3	44.30	43.41	43.85	62.32	63.33	62.82
V_4	33.73	33.86	33.80	55.15	58.36	56.75
V_5	41.67	45.60	43.63	74.83	73.77	74.30
V_6	56.73	58.89	57.81	67.48	65.33	66.41
V_7	40.91	41.91	41.41	43.09	42.33	42.71
V_8	52.87	55.07	53.97	72.89	70.10	71.50
CD (0.05)			**1.61**			**1.09**

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that V_3 recorded maximum total sugars content (6.21 %) which was on par with V_5 (6.11 %). It was followed by V_2 (5.40 %), V_8 (5.34 %), V_7 (5.21 %), V_6 (5.00 %), V_1 (3.84 %) and V_4 (2.82 %).

High ranges of Kerala

The pooled mean over the two seasons revealed that the maximum total sugars was recorded in V_7 (6.32 %) which was on par with V_2 (6.09 %). It was followed by V_1 (5.89 %), V_4 (5.24 %), V_5 (4.93 %), V_6 (4.89 %), V_3 (4.82 %) and V_8 (4.30 %).

4.1.4.5 Ascorbic acid

Analysis of the data corresponding to ascorbic acid content of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala are presented in Table 28.

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that V_6 recorded significantly higher ascorbic acid content (57.81 mg 100 g^{-1}) which was followed by V_1 (54.65 mg 100 g^{-1}), V_8 (53.97 mg 100 g^{-1}), V_3 (43.85 mg 100 g^{-1}), V_5 (43.63 mg 100 g^{-1}), V_2 (42.59 mg 100 g^{-1}), V_7 (41.41 mg 100 g^{-1}) and V_4 (33.80 mg 100 g^{-1}).

High ranges of Kerala

The pooled mean over the two seasons revealed that V_5 recorded significantly higher ascorbic acid content (74.30 mg 100 g^{-1}) which was followed by V_8 (71.50 mg 100 g^{-1}), V_6 (66.41 mg 100 g^{-1}), V_1 (64.96 mg 100 g^{-1}), V_3 (62.82 mg 100 g^{-1}), V_4 (56.75 mg 100 g^{-1}), V_7 (42.71 mg 100 g^{-1}), and V_2 (42.50 mg 100 g^{-1}).

4.1.4.6 Anthocyanin

Analysis of the data corresponding to anthocyanin content of strawberry at two locations *viz.,* Central mid-lands and High ranges of Kerala are presented in Table 29.

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that V_5 recorded significantly maximum anthocyanin content (38.95 mg 100 g^{-1}) which was followed by V_8 (35.68 mg 100 g^{-1}), V_1 (32.43 mg 100 g^{-1}), V_6 (31.97 mg 100 g^{-1}), V_2 (22.29 mg 100 g^{-1}), V_7 (21.48 mg 100 g^{-1}), V_4 (19.80 mg 100 g^{-1}) and V_3 (15.67 mg 100 g^{-1}).

High ranges of Kerala

The pooled mean over the two seasons revealed that V_5 recorded significantly maximum anthocyanin content (41.35 mg 100 g^{-1}) which was followed by V_6 (35.98 mg 100 g^{-1}), V_1 (35.35 mg 100 g^{-1}), V_8 (26.68 mg 100 g^{-1}), V_2 (25.95 mg 100 g^{-1}), V_7 (21.42 mg 100 g^{-1}), V_3 (19.37 mg 100 g^{-1}) and V_4 (18.03 mg 100 g^{-1}).

4.1.4.7 β -Carotene

Analysis of the data corresponding to β-carotene content of strawberry at two locations *viz.,* Central mid-lands of Kerala and High ranges of Kerala are presented in Table 30.

Central mid-lands of Kerala

The pooled mean over the two seasons revealed that the highest β - carotene content was observed in V_3 (3.15 µg 100g^{-1}) which was on par with V_8 (2.83 µg 100g^{-1}). It was followed by V_6 (2.69 µg 100g^{-1}), V_2 (2.59 µg 100g^{-1}), V_5 (2.40 µg 100g^{-1}), V_7 (2.07 µg 100g^{-1}), V_4 (1.92 µg 100g^{-1}) and V_1 (1.85 µg 100g^{-1}).

Table 29. Performance of different varieties of strawberry on Anthocyanin at Central midlands and High ranges of Kerala

Anthocyanin (mg 100 g^{-1})						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	33.98	30.87	32.43	35.93	34.77	35.35
V_2	23.29	21.29	22.29	26.63	25.27	25.95
V_3	16.20	15.13	15.67	19.63	19.10	19.37
V_4	18.80	20.80	19.80	18.40	17.67	18.03
V_5	37.80	40.10	38.95	41.27	41.43	41.35
V_6	31.87	32.07	31.97	35.93	36.03	35.98
V_7	22.07	20.90	21.48	21.40	21.43	21.42
V_8	34.67	36.70	35.68	26.40	26.97	26.68
CD (0.05)			**1.71**			**0.62**

Table 30. Performance of different varieties of strawberry on β-Carotene at Central midlands and High ranges of Kerala

B-Carotene (µg 100g^{-1})						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	1.62	2.08	1.85	2.67	3.79	3.23
V_2	2.79	2.39	2.59	3.10	2.72	2.91
V_3	4.20	2.10	3.15	2.14	2.06	2.10
V_4	1.95	1.89	1.92	1.75	1.52	1.63
V_5	2.90	1.90	2.40	2.93	2.32	2.63
V_6	2.75	2.62	2.69	3.29	2.01	2.65
V_7	2.20	1.94	2.07	2.55	2.01	2.28
V_8	2.98	2.68	2.83	1.74	1.77	1.76
CD (0.05)			**0.42**			**0.31**

Table 31. Performance of different varieties of strawberry on Shelf life at Central midlands and High ranges of Kerala

Shelf life (days)						
Varieties (V)	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
V_1	3	3	3	3	3	3
V_2	3	3	3	3	3	3
V_3	3	3	3	3	3	3
V_4	3	3	3	3	3	3
V_5	4	4	4	4	4	4
V_6	3	3	3	3	3	3
V_7	3	3	3	3	3	3
V_8	3	3	3	3	3	3

High ranges of Kerala

The pooled mean over the two seasons revealed that the maximum β - carotene content was recorded by V_1 (3.23 µg $100g^{-1}$) which was on par with V_2 (2.91 µg $100g^{-1}$), V_6 (2.65 µg $100g^{-1}$), V_5 (2.63 µg $100g^{-1}$), V_7 (2.28 µg $100g^{-1}$), V_3 (2.10 µg $100g^{-1}$), V_8 (1.76 µg $100g^{-1}$) and V_4 (1.63 µg $100g^{-1}$).

4.1.4.8 Shelf life

The data on shelf life of strawberry is presented in Table 31. The varieties have no significant effect on shelf life of strawberry. Variety V_5 has a shelf life of 4 days except all the other varieties which have a shelf life of 3 days in both locations. It is evident that most of the strawberry varieties have a maximum shelf life of 3 days when stored in room temperature after harvest at 75 per cent ripened stage.

4.1.4.9 Colour

The data on colour of fruit skin is presented in Table 32. The skin colour was described using Universal Colour Language (UCL) and it was deep purplish pink (61 D) for all treatments except V_5, where it was deep purplish pink (67 C).

4.1.4.8 Sensory evaluation

Data corresponding to the sensory evaluation of strawberry fruits grown at two locations viz., Central mid-lands and High ranges of Kerala are presented in Tables 33a and 33b.

In strawberry, the sensory evaluation was carried out on a nine point hedonic scale using score card for eight attributes *viz.,* appearance, colour, texture, flavour, 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 carried out on the same day of harvest by panel of judges.

Central mid-lands of Kerala

During first year, the highest score for appearance was recorded by V_5 (8.6) and the lowest score by V_8 (6.6). The highest score for colour was recorded by V_5 (8.6) and the lowest score was by V_8 (6.7). The highest score for taste was recorded by V_6 (7.4) and the lowest score was by V_8 (5.6). Highest score for flavour was recorded by V_3 (7.4) and the lowest was recorded by V_5 (6.0). Highest score for aroma was recorded by V_2 (7.3) and the lowest score was recorded by V_1 (6.4). Highest score for texture was recorded by V_3 (7.8) and V_7 (7.8). Lowest score for texture was recorded by V_1 (6.0). V_3 and V_6 recorded highest score for after taste (7.5). Lowest score for after taste was recorded by V_5 (6.4). Highest score for acceptability was recorded by V_6 (7.9). The highest total sensory score was recorded by V_3 and V_6 (52.9) and the lowest total sensory score was recorded by V_1 (45.7).

However during second year, the highest score for appearance was recorded by V_5 (8.7) and the lowest score was by V_8 (6.0). The highest score for colour was recorded by V_5 (8.8) and the lowest score by V_8 (6.0). The highest score for taste was scored by V_3 (7.5) and the lowest score for taste was by V_5 (5.8). The highest score for flavour was recorded by V_3 (7.6) and the lowest score for flavour was by V_5 (5.7). The highest score for aroma was recorded by V_6 (7.3) and the lowest score for aroma was recorded by V_1 (6.5) and V_4 (6.5). V_6 (8.3) recorded the highest score for texture. V_8 (6.0) recorded lowest score for texture. V_6 (7.6) recorded the highest score for after taste while the lowest score for after taste was recorded by V_5 (6.6). Highest score for acceptability was recorded by V_6 (8.3). The highest total sensory score was recorded by V_6 (53.5) and the lowest total sensory score was recorded by V_8 (44.8).

High ranges of Kerala

During first year, the highest score for appearance was recorded by V_5 (8.7) and the lowest score by V_8 (6.9). The highest score for colour was recorded by V_5 (8.7) and

Table 32. Performance of different varieties of strawberry on Colour at Central midlands and High ranges of Kerala

Varieties (V)	Central mid-lands	High ranges
V_1	Deep Purplish Pink - 61D	Deep Purplish Pink - 61D
V_2	Deep Purplish Pink - 61D	Deep Purplish Pink - 61D
V_3	Deep Purplish Pink - 61D	Deep Purplish Pink - 61D
V_4	Deep Purplish Pink - 61D	Deep Purplish Pink - 61D
V_5	Deep Purplish Pink - 67C	Deep Purplish Pink - 67C
V_6	Deep Purplish Pink - 61D	Deep Purplish Pink - 61D
V_7	Deep Purplish Pink - 61D	Deep Purplish Pink - 61D
V_8	Deep Purplish Pink - 61D	Deep Purplish Pink - 61D

Table 33a. Sensory evaluation (Central mid-lands of Kerala)

Treatments (T)	Appearance		Colour		Taste		Flavour		Aroma		Texture		After taste		Overall acceptability		Total score	
	Years		Years		Years		Years		Years		Years		Years		Years		Years	
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
V_1	7.3	7.5	7.0	7.2	6.0	5.9	6.4	6.4	6.4	6.5	6.0	6.5	6.6	6.7	45.7	46.7	7.1	6.9
V_2	7.5	7.3	7.6	8.2	6.6	7.1	7.3	7.1	**7.3**	7.1	7.0	7.0	6.5	6.7	49.8	50.6	7.5	7.8
V_3	7.9	7.8	8.1	8.1	7.0	**7.5**	**7.4**	**7.6**	7.2	7.1	**7.8**	8.0	**7.5**	7.2	**52.9**	53.3	7.6	8.0
V_4	6.9	7.3	7.0	7.2	6.5	6.6	6.4	6.7	6.5	6.5	6.4	6.8	6.8	7.4	46.5	48.5	6.6	6.5
V_5	**8.6**	**8.7**	**8.6**	**8.8**	5.7	5.8	6.0	5.7	6.5	6.7	6.2	6.5	6.4	6.6	48	48.8	7.3	7.5
V_6	8.2	8.0	7.9	7.7	**7.4**	7.4	7.1	7.2	7.2	**7.3**	7.6	**8.3**	**7.5**	**7.6**	**52.9**	**53.5**	**7.9**	**8.3**
V_7	7.0	7.4	6.9	7.6	7.1	7.1	7.0	7.5	7.1	7.2	**7.8**	7.4	7.4	7.7	50.3	51.9	7.0	7.4
V_8	6.6	6.0	6.7	6.0	5.6	6.7	6.8	6.0	6.7	6.6	6.9	6.0	7.4	7.5	46.7	44.8	6.4	6.5

Table 33b. Sensory evaluation (High ranges of Kerala)

Treatments (T)	Appearance		Colour		Taste		Flavour		Aroma		Texture		After taste		Overall acceptability		Total score	
	Years		Years		Years		Years		Years		Years		Years		Years		Years	
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
V_1	8.4	**8.8**	8.3	8.1	7.9	**8.1**	7.5	7.4	7.6	7.5	**7.9**	**8.2**	7.0	7.4	54.6	55.5	8.1	7.9
V_2	8.6	**8.8**	8.2	8.5	**8.2**	7.8	**8.2**	7.8	7.9	8.1	7.7	7.9	7.2	7.3	**55.7**	**56.5**	**8.3**	**8.0**
V_3	8.4	8.1	8.2	8.1	7.8	**8.1**	7.4	7.4	7.1	7.3	7.8	7.2	**7.7**	7.1	54.4	53.3	7.9	7.7
V_4	7.9	7.3	7.4	7.1	6.6	6.9	6.1	6.6	6.5	6.3	7.0	6.5	7.4	7.0	48.9	47.7	7.2	6.6
V_5	**8.7**	8.5	**8.7**	**9.0**	5.8	6.6	6.0	6.7	6.8	6.6	7.6	7.0	6.5	7.0	50.1	51.4	7.6	6.9
V_6	8.0	8.2	7.9	8.1	7.4	7.4	7.3	7.1	7.3	7.5	7.6	7.9	**7.8**	**8.0**	53.4	54.2	8.0	7.9
V_7	7.5	7.4	6.9	7.8	7.2	7.5	7.6	**7.9**	7.1	7.2	**7.3**	7.7	7.5	7.4	50.3	52.9	7.9	7.5
V_8	6.9	7.0	6.7	7.2	6.8	6.5	6.9	6.7	6.7	6.3	6.9	6.7	7.6	7.5	46.7	47.9	7.3	7.0

the lowest score was by V_4 (7.4). The highest score for taste was recorded by V_2 (8.2) and the lowest score was by V_5 (5.8). Highest score for flavour was recorded by V_2 (8.2) and the lowest was recorded by V_5 (6.0). Highest score for aroma was recorded by V_2 (7.9) and the lowest score was recorded by V_4 (6.5). Highest score for texture was recorded by V_1 (7.9) and the lowest score for texture was recorded by V_8 (6.9). V_6 recorded highest score for after taste (7.8). Lowest score for after taste was recorded by V_5 (6.5). Highest score for acceptability was recorded by V_2 (8.3) and the lowest score was by V_4 (7.2). The highest total sensory score was recorded by V_2 (55.7) and the lowest total sensory score was recorded by V_4 (48.9).

However during second year, the highest score for appearance was recorded by V_1 (8.8) and V_2 (8.8) and the lowest score was by V_8 (7.0). The highest score for colour was recorded by V_5 (9.0) and the lowest score by V_4 (7.1). The highest score for taste was scored by V_3 (8.1) and V_1 (8.1). The lowest score for taste was by V_8 (6.5). The highest score for flavour was recorded by V_7 (7.9) and the lowest score for flavour was by V_4 (6.6). The highest score for aroma was recorded by V_2 (8.1) and the lowest score for aroma was recorded by V_4 (6.3) and V_8 (6.3). V_1 (8.2) recorded the highest score for texture. V_4 (6.5) recorded lowest score for texture. V_6 (8.0) recorded the highest score for after taste while the lowest score for after taste was recorded by V_4 (7.0) and V_5 (7.0). Highest score for acceptability was recorded by V_2 (8.0) and the lowest was by V_4 (6.6). The highest total sensory score was recorded by V_2 (56.5) and the lowest total sensory score was recorded by V_4 (47.7).

4.1.5 Pest and disease incidence and severity

Central mid-lands of Kerala

During the entire period of study, termite was a severe pest which attacked the fibrous roots that would lead to the sudden death of plants within 4-5 days. It was controlled by soil drenching with Chlorpyriphos @ 4ml per litre. Other pests such as Black looper

Table 34a. Benefit Cost Ratio of different varieties in Location I (Central mid-lands) -100 m^2 for six months

Varieties (V)	**Total cost incurred (Rs)**	**Total benefit (Rs)**	**B/C Ratio**
V_1	16987.48	3991.35	0.23
V_2	16987.48	1215.65	0.07
V_3	16987.48	7439.45	0.44
V_4	16987.48	530.95	0.03
V_5	16987.48	1215.65	0.07
V_6	16987.48	9128.65	**0.54**
V_7	16987.48	338.25	0.02
V_8	16987.48	1379.65	0.08

Table 34b. Benefit Cost Ratio of different varieties in Location II (High ranges) - 100 m^2 for six months

Varieties (V)	Total cost incurred (Rs)	Total benefit (Rs)	B/C Ratio
V_1	16987.48	27744.7	1.63
V_2	16987.48	18011.3	1.06
V_3	16987.48	30883.25	1.82
V_4	16987.48	12525.5	0.74
V_5	16987.48	20315.5	1.20
V_6	16987.48	38517.45	**2.27**
V_7	16987.48	2956.1	0.17
V_8	16987.48	9881	0.58

- *Hyposidra talaca* (Family: Geometridae), Hairy caterpillar- *Orgyia postica* (Lymantidae), Leaf tip roller – *Archis semiferanus* (Family: Torticidae) and Fruit borer were only minor pests and there severity is less than 1%. These pests were controlled by spraying with Quinalphos 25% EC@ 2ml per litre.

During the entire period of study, disease was not a severe problem. Nearly 3 % plants got lost because of Fusarium crown rot. Other diseases which was of minor importance was *Alternaria alternata* leaf spot and *Pestalotiopsis longisetula* leaf spot which was controlled by the soil drenching with Copper Hydroxide @ 2 g per litre.

High ranges of Kerala

During the entire period of study, there was not much incidence of pests and diseases. Peats such as looper, fruit borer were only minor pests there.

Disease incidence and severity was very low, nearly less than 1%. Only *Alternaria alternata* leaf spot was a minor disease there.

4.1.6. Economics of cultivation

Data corresponding to the economics of cultivation of strawberry fruits grown at two locations viz., Central mid-lands and High ranges of Kerala are presented in Tables 34a and 34b.

In Central mid-lands, the B/C (Benefit: Cost ratio) was highest in V_6 (0.54).The lowest B/C ratio was recorded in V_7 (0.02). In High ranges, the B/C ratio was recorded highest in V_6 (2.27) and the lowest B/C ratio was recorded in V_7 (0.17).

Experiment -II

4.2. Nutrient management in strawberry

This study pertains to the nutrient management of strawberry (*Fragaria x ananassa* Duch.) under the agro climatic conditions of Thrissur. The influence of different nutrient combinations on the vegetative, flowering, yield and quality attributes of strawberry were studied and presented below.

4.2.1 Vegetative characters

Observations on vegetative growth attributes of strawberry during two seasons *viz.*, September 2016-March 2017 and September 2017-March 2018 at Central mid-lands of Kerala are presented in Tables 33 to 36.

4.2.1.1 Plant height

Analysis of the data corresponding to the plant height of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 35.

At 1 MAP, maximum plant height was recorded by T_6 (9.38 cm) which was on par with T_1 (9.26 cm), T_9 (8.88 cm), T_4 (8.85 cm), T_8 (8.73 cm) and T_7 (8.20 cm) which was followed by T_2 (7.75 cm), T_5 (7.27 cm), T_{10} (6.59 cm) and T_3 (5.85 cm). At 2 MAP, maximum plant height was recorded by T_1 (12.86 cm) which was on par with T_8 (12.42 cm), T_9 (12.08 cm), T_4 (12.02 cm), T_7 (11.61 cm), T_6 (11.57 cm). It was followed by T_2 (11.56 cm), T_5 (10.65 cm), T_3 (9.89 cm) and T_{10} (9.63 cm). At 3 MAP, maximum plant height was recorded by T_8 (15.24 cm) which was on par with T_9 (15.22 cm), T_1 (14.95 cm), T_4 (14.46 cm) and T_7 (14.34 cm). It was followed by T_3 (13.82 cm), T_6 (13.60 cm), T_5 (12.86 cm), T_2 (12.55 cm) and T_{10} (11.68 cm). At 4 MAP, maximum plant height was recorded by T_9 (17.72 cm) which was on par with T_8 (17.63 cm). It was followed by T_1 (16.71 cm), T_4 (15.92 cm), T_7 (15.88 cm), T_6 (15.24 cm), T_3 (15.22 cm), T_5 (13.99

cm), T_2 (13.92 cm) and T_{10} (13.64 cm). At 5 MAP, maximum plant height was recorded by T_8 (19.39 cm) which was on par with T_9 (18.65 cm). It was followed by T_1 (18.10 cm), T_6 (17.04 cm), T_3 (16.93 cm), T_7 (16.84 cm), T_4 (16.76 cm), T_5 (15.82 cm), T_2 (15.37 cm) and T_{10} (15.36 cm).

4.2.1.2 Number of leaves per plant

Analysis of the data corresponding to the number of leaves per plant of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 36.

At 1 MAP, maximum number of leaves per plant was recorded by T_3 (7.37) which was on par with T_1 (7.28), T_5 (7.15), T_6 (7.02), T_4 (6.41), T_7 (6.40), T_9 (6.30). It was followed by T_8 (6.23), T_2 (6.19) and T_{10} (4.60). At 2 MAP, maximum number of leaves per plant was recorded by T_9 (19.70). It was followed by T_5 (16.44), T_7 (16.28), T_2 (15.44), T_3 (14.80), T_1 (13.61), T_4 (13.45), T_6 (12.69), T_8 (12.62) and T_{10} (10.48). At 3 MAP, maximum number of leaves per plant was recorded by T_9 (32.18) which was on par with T_8 (31.31). It was followed by T_2 (28.25), T_4 (26.91), T_6 (24.99), T_5 (24.53), T_7 (22.00), T_3 (20.70), T_1 (20.51) and T_{10} (15.29). At 4 MAP, maximum number of leaves per plant was recorded by T_8 (43.68) which was on par with T_9 (42.36) and this was followed by T_4 (36.94), T_6 (36.79), T_2 (36.02), T_5 (32.79), T_1 (27.16), T_7 (26.34), T_3 (25.19) and T_{10} (19.00). At 5 MAP, maximum number of leaves per plant was recorded by T_8 (47.76). It was followed by T_9 (44.03), T_4 (42.39), T_2 (40.59), T_6 (39.68), T_5 (33.12), T_7 (29.36), T_3 (27.39), T_1 (26.49) and T_{10} (18.84).

4.2.1.3 Plant spread

Analysis of the data corresponding to the plant spread of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 37.

Table 35. Effect of different levels of nutrients on plant height of strawberry

Treatments (T)	Plant height (cm)														
	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II		I	II		I	II	
T_1	9.44	9.07	9.26	12.26	13.47	12.86	15.11	14.8	14.95	16.96	16.46	16.71	18.5	17.7	18.1
T_2	6.33	9.18	7.75	10.19	12.93	11.56	12.97	12.13	12.55	14.91	12.93	13.92	16.65	14.1	15.37
T_3	3.8	7.9	5.85	7.73	12.05	9.89	13.31	14.33	13.82	15.33	15.11	15.22	17.16	16.69	16.93
T_4	9.24	8.47	8.85	12.27	11.77	12.02	15.03	13.89	14.46	16.45	15.39	15.92	17.19	16.33	16.76
T_5	7.26	7.29	7.27	10.9	10.39	10.65	13.4	12.32	12.86	14.59	13.4	13.99	16.25	15.4	15.82
T_6	9.17	9.59	9.38	11.24	11.89	11.57	13.36	13.83	13.6	15.6	14.87	15.24	17.43	16.65	17.04
T_7	7.59	8.81	8.2	11.13	12.09	11.61	14.2	14.48	14.34	15.98	15.77	15.88	17.21	16.47	16.84
T_8	8.66	8.8	8.73	12.64	12.21	12.42	15.77	14.72	15.24	18.16	17.1	17.63	20.34	18.43	19.39
T_9	8.77	8.99	8.88	12.27	11.88	12.08	15.43	15.01	15.22	17.83	17.6	17.72	18.75	18.55	18.65
T_{10}	5.97	7.22	6.59	8.81	10.44	9.63	11.44	11.91	11.68	13.25	14.03	13.64	15.4	15.31	15.36
CD (0.05)			**1.26**			**1.29**			**1.1**			**0.88**			**0.88**

Table 36. Effect of different levels of nutrients on number of leaves of strawberry

Treatments (T)	Number of leaves														
	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II		I	II		I	II	
T_1	9.62	4.93	7.28	15.56	11.66	13.61	22.08	18.93	20.51	29.31	25.01	27.16	27.07	25.92	26.49
T_2	7.70	4.67	6.19	19.34	11.53	15.44	30.94	25.56	28.25	38.72	33.42	36.07	40.41	40.76	40.59
T_3	8.14	6.60	7.37	13.07	16.53	14.80	20.17	21.23	20.70	23.85	26.53	25.19	27.03	27.74	27.39
T_4	8.42	4.40	6.41	15.50	11.40	13.45	24.28	29.53	26.91	36.95	36.94	36.94	41.77	43.01	42.39
T_5	8.69	5.60	7.15	13.78	19.10	16.44	22.85	26.21	24.53	30.46	35.11	32.79	33.14	33.10	33.12
T_6	8.96	5.07	7.02	15.32	10.07	12.69	26.46	23.51	24.99	37.33	36.24	36.79	39.11	40.25	39.68
T_7	6.41	6.40	6.40	11.60	20.97	16.28	17.15	26.85	22.00	23.24	29.44	26.34	28.60	30.12	29.36
T_8	6.93	5.53	6.23	15.81	9.43	12.62	27.79	34.84	31.31	39.16	48.20	43.68	47.00	48.51	47.76
T_9	7.74	4.87	6.30	18.70	20.70	19.70	29.92	34.43	32.18	38.55	46.17	42.36	43.75	44.31	44.03
T_{10}	4.93	4.27	4.60	9.72	11.23	10.48	14.10	16.49	15.29	17.16	20.84	19.00	18.85	18.83	18.84
CD (0.05)			**1.10**			**3.25**			**3.25**			**3.1**			**3.24**

At 1 MAP, maximum plant spread was recorded by T_5 (13.17 cm) which was on par with T_1 (12.97 cm), T_7 (12.47 cm), T_3 (12.33 cm), T_6 (12.29 cm), T_9 (12.15 cm), T_8 (12.03 cm) and T_4 (11.85 cm). It was followed by T_2 (11.64 cm) and T_{10} (8.88 cm). At 2 MAP, maximum plant spread was recorded by T_1 (18.78 cm) which was on par with T_5 (18.06 cm), T_8 (18.03 cm), T_4 (17.78 cm), T_6 (17.51 cm), T_9 (17.34 cm) and T_3 (17.01 cm). It was followed by T_7 (16.77 cm), T_2 (15.00 cm) and T_{10} (11.58 cm). At 3 MAP, maximum plant spread was recorded by T_8 (23.76 cm) which was on par with T_4 (22.69 cm), T_1 (22.50 cm) and T_9 (21.71 cm). It was followed by T_6 (21.16 cm), T_5 (21.15 cm), T_3 (20.68 cm), T_7 (20.22 cm), T_2 (17.66 cm) and T_{10} (14.83 cm). At 4 MAP, maximum plant spread was recorded by T_4 (29.96 cm). It was followed by T_8 (27.78 cm), T_1 (27.75 cm). T_9 (27.39 cm), T_5 (26.16 cm), T_6 (25.47 cm), T_3 (25.09 cm), T_7 (22.78 cm), T_2 (19.71 cm) and T_{10} (18.87 cm). At 5 MAP, maximum plant spread was recorded by T_8 (30.64 cm) which was on par with T_4 (30.24 cm), T_9 (29.39 cm) and T_1 (29.26 cm). It was followed by T_5 (28.62 cm), T_3 (28.06 cm), T_6 (27.59 cm), T_7 (24.67 cm), T_2 (21.48 cm) and T_{10} (20.48 cm).

4.2.1.4 Number of crowns

Analysis of the data corresponding to the number of crowns per plant of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 38.

At 1 MAP, different nutrient combinations had no significant effect on the number of crowns per plant. All the treatments recorded the maximum number of crowns as 1.00. At 2 MAP, there was no significant effect on the number of crowns of strawberry by different nutrient combinations. Maximum number of crowns was recorded by T_5 (1.47) which was followed by T_6 (1.47), T_8 (1.43), T_3 (1.40), T_7 (1.37), T_4 (1.33), T_1 (1.27), T_2 (1.23), T_{10} (1.20) and T_9 (1.17). At 3 MAP, maximum number of crowns per plant was recorded by T_5 (3.10) which was on par with T_7 (2.90) and T_9 (2.70). It was followed by T_3 (2.63), T_2 (2.50), T_6 (2.40), T_8 (2.17), T_4 (2.10), T_1 (2.03) and T_{10} (1.60). At 4 MAP, maximum number of crowns per plant was recorded by T_8

Table 37. Effect of different levels of nutrients on plant spread of strawberry

Treatments (T)	Plant spread (cm)														
	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II		I	II		I	II	
T_1	11.41	14.53	12.97	18.34	19.22	18.78	22.86	22.13	22.50	27.56	27.93	27.75	28.45	30.06	29.26
T_2	10.19	13.10	11.64	15.36	14.64	15.00	18.36	16.97	17.66	20.95	18.46	19.71	22.94	20.02	21.48
T_3	9.63	15.03	12.33	14.27	19.75	17.01	17.91	23.45	20.68	24.05	26.13	25.09	27.98	28.13	28.06
T_4	10.40	13.30	11.85	17.91	17.64	17.78	24.35	21.02	22.69	30.16	29.76	29.96	30.28	30.20	30.24
T_5	13.05	13.30	13.17	19.02	17.11	18.06	22.53	19.77	21.15	26.97	25.34	26.16	30.65	26.60	28.62
T_6	12.31	12.27	12.29	18.08	16.93	17.51	22.67	19.65	21.16	26.37	24.56	25.47	28.94	26.23	27.59
T_7	12.14	12.80	12.47	17.45	16.08	16.77	21.77	18.67	20.22	23.32	22.23	22.78	25.05	24.30	24.67
T_8	10.22	13.83	12.03	17.54	18.52	18.03	24.36	23.16	23.76	28.35	27.21	27.78	30.47	30.80	30.64
T_9	11.10	13.20	12.15	18.46	16.22	17.34	23.54	19.87	21.71	28.90	25.87	27.39	30.49	28.30	29.39
T_{10}	7.12	10.63	8.88	10.17	12.99	11.58	13.83	15.83	14.83	18.04	19.70	18.87	19.93	21.03	20.48
CD (0.05)			**1.36**			**1.98**			**2.11**			**1.94**			**1.74**

Table 38. Effect of different levels of nutrients on number of crowns per plant of strawberry

Treatments (T)	Number of crowns														
	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II		I	II		I	II	
T_1	1.00	1.00	1.00	1.20	1.33	1.27	2.00	2.07	2.03	3.40	3.67	3.53	4.80	5.27	5.03
T_2	1.00	1.00	1.00	1.27	1.20	1.23	2.40	2.60	2.50	3.73	3.97	3.85	5.07	5.33	5.20
T_3	1.00	1.00	1.00	1.33	1.47	1.40	2.53	2.73	2.63	3.20	3.27	3.23	3.87	3.80	3.83
T_4	1.00	1.00	1.00	1.40	1.27	1.33	2.13	2.07	2.10	4.70	4.77	4.73	7.27	7.47	7.37
T_5	1.00	1.00	1.00	1.40	1.53	1.47	2.87	3.33	3.10	4.23	4.50	4.37	5.40	5.67	5.53
T_6	1.00	1.00	1.00	1.33	1.60	1.47	2.47	2.33	2.40	4.10	4.33	4.22	5.27	6.33	5.80
T_7	1.00	1.00	1.00	1.27	1.47	1.37	2.73	3.07	2.90	4.20	4.57	4.38	5.67	6.07	5.87
T_8	1.00	1.00	1.00	1.60	1.27	1.43	2.20	2.13	2.17	5.03	5.23	5.13	7.87	8.33	8.10
T_9	1.00	1.00	1.00	1.20	1.13	1.17	2.60	2.80	2.70	4.67	4.73	4.70	6.73	6.93	6.83
T_{10}	1.00	1.00	1.00	1.13	1.27	1.20	1.47	1.73	1.60	2.40	2.53	2.47	3.33	3.47	3.40
CD (0.05)			**NS**			**NS**			**0.43**			**0.39**			**0.77**

Table 39. Effect of different levels of nutrients on days to first flowering, number of clusters and number of flowers per plant of strawberry

Treatments (T)	Days to first flowering			Number of clusters			Number of flowers		
	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II	
T_1	50.47	50.40	50.43	3.7	3.60	3.65	5.40	5.63	5.52
T_2	49.67	49.73	49.70	5.17	5.23	5.20	6.77	6.83	6.80
T_3	50.67	50.53	50.60	4.80	4.93	4.87	5.60	5.83	5.72
T_4	50.17	50.00	50.08	5.67	5.70	5.68	7.60	7.57	7.58
T_5	50.53	50.33	50.43	5.37	5.43	5.40	6.20	6.30	6.25
T_6	50.00	50.40	50.20	5.17	5.20	5.18	6.50	6.70	6.60
T_7	49.93	49.87	49.90	4.70	4.83	4.77	5.70	5.88	5.79
T_8	50.13	50.00	50.07	5.83	5.87	5.85	8.63	8.78	8.71
T_9	50.20	50.40	50.30	5.92	5.97	5.94	8.20	8.38	8.29
T_{10}	50.67	50.33	50.50	1.78	2.70	2.24	3.80	3.47	3.64
CD (0.05)			NS			0.17			0.19

Table 40. Effect of different levels of nutrients on number of fruits, fruit length and fruit breadth of strawberry

Treatments (T)	Number of fruits			Fruit length (cm)			Fruit breadth (cm)		
	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II	
T_1	3.40	3.50	3.45	3.37	3.20	3.28	3.50	3.33	3.42
T_2	4.77	4.83	4.80	2.93	3.00	2.97	2.90	2.93	2.92
T_3	3.60	3.90	3.75	2.93	2.70	2.82	3.07	2.77	2.92
T_4	5.43	5.57	5.50	3.13	3.17	3.15	3.23	3.03	3.13
T_5	4.20	4.30	4.25	3.13	3.33	3.23	3.17	2.87	3.02
T_6	4.50	4.70	4.60	2.77	3.00	2.88	3.03	3.17	3.10
T_7	4.40	6.10	5.25	3.07	2.70	2.88	3.07	2.67	2.87
T_8	6.20	6.63	6.42	2.80	3.33	3.07	3.17	3.43	3.30
T_9	6.63	5.72	6.18	3.23	3.43	3.33	3.37	3.27	3.32
T_{10}	1.90	1.47	1.68	2.40	2.33	2.37	2.37	2.23	2.30
CD (0.05)			0.25			0.38			0.26

(5.13). It was followed by T_4 (4.73), T_9 (4.70), T_7 (4.38), T_5 (4.37), T_6 (4.22), T_2 (3.85), T_1 (3.53), T_3 (3.23) and T_{10} (2.47). At 5 MAP, maximum number of crowns per plant was recorded by T_8 (8.10) which was on par with T_4 (7.37). It was followed by T_9 (6.83), T_7 (5.87), T_6 (5.80), T_5 (5.53), T_2 (5.20), T_1 (5.03), T_3 (3.83) and T_{10} (3.40).

4.2.2 Flowering attributes

4.2.2.1 Days to first flowering

Analysis of the data corresponding to days to first flowering of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 39.

The pooled mean over the two years revealed that T_2 recorded minimum number of days to first flowering (49.70 days) which was followed by T_7 (49.90 days), T_8 (50.07 days), T_4 (50.08 days), T_6 (50.20 days), T_9 (50.30 days), T_5 (50.43 days), T_1 (50.43 days), T_{10} (50.50 days) and T_3 (50.60 days).

4.1.2.2 Number of clusters per plant

Analysis of the data corresponding to number of clusters of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 39.

The pooled mean over the two years revealed that T_9 recorded maximum number of clusters per plant (5.94) which was on par with T_8 (5.85). It was followed by T_4 (5.68), T_5 (5.40), T_2 (5.20), T_6 (5.18), T_3 (4.87), T_7 (4.77), T_1 (3.65) and T_{10} (2.24).

4.1.2.3 Number of flowers per plant

Analysis of the data corresponding to number of flowers per plant at Central mid-lands of Kerala in two seasons are presented in Table 39.

The pooled mean over the two seasons revealed that T_8 recorded maximum number of flowers per plant (8.71). It was followed by T_9 (8.29), T_4 (7.58), T_2 (6.80), T_6 (6.60), T_5 (6.25), T_7 (5.79), T_3 (5.72), T_1 (5.52) and T_{10} (3.64).

4.2.3. Yield attributes

4.2.3.1 Number of fruits

Analysis of the data corresponding to number of fruits per plant of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 40.

The pooled mean over the two seasons revealed that T_8 recorded maximum number of fruits per plant (6.42) which was on par with T_9 (6.18). It was followed by T_4 (5.50), T_7 (5.25), T_2 (4.80), T_6 (4.60), T_5 (4.25), T_3 (3.75), T_1 (3.45) and T_{10} (1.68).

4.1.3.2 Fruit length

Analysis of the data corresponding to fruit length of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 40.

The pooled mean over the two seasons revealed that T_9 recorded maximum fruit length (3.33 cm) which was on par with T_1 (3.28 cm), T_5 (3.23 cm), T_4 (3.15 cm), T_8 (3.07 cm) and T_2 (2.97 cm). It was followed by T_6 (2.88 cm), T_7 (2.88 cm), T_3 (2.82 cm) and T_{10} (2.37 cm).

4.2.3.3 Fruit breadth

Analysis of the data corresponding to fruit breadth of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 40.

The pooled mean over the two seasons revealed that T_1 recorded maximum fruit breadth (3.42 cm) which was on par with T_9 (3.32 cm) and T_8 (3.30 cm). It was followed by T_4 (3.13 cm), T_6 (3.10 cm), T_5 (3.02 cm), T_2 (2.92 cm), T_3 (2.92 cm), T_7 (2.87 cm) and T_{10} (2.30 cm).

4.2.3.4 Average fruit weight

Analysis of the data corresponding to average fruit weight of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 41.

The pooled mean over the two seasons revealed that T_1 recorded maximum average fruit weight (12.93 g) which was on par with T_8 (12.41 g), T_6 (12.06 g), T_2 (12.02 g), T_9 (11.91 g), T_7 (11.85 g) and T_3 (11.64 g). It was followed by T_4 (10.91 g), T_5 (10.14 g) and T_{10} (6.35 g).

4.2.3.5 Days to first harvest

Analysis of the data corresponding to the number of days to first harvest at Central mid-lands of Kerala in two seasons are presented in Table 41.

The pooled mean over the two seasons revealed that T_8 recorded minimum number of days to first harvest (71.25 days) which was followed by T_9 (72.97 days), T_7 (73.20 days), T_6 (73.37 days), T_2 (73.70 days), T_1 (73.86 days) and T_3 (74.21 days), T_4 (74.33 days), T_5 (74.58 days) and T_{10} (76.61 days).

4.2.3.6 Days to final harvest

Analysis of the data corresponding to the number of days to final harvest of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 41.

The pooled mean over the two seasons revealed that T_3 recorded the maximum number of days to final harvest (179.33 days). It was followed by T_5 (177.33 days), T_2 (176.17 days), T_8 (174.50 days), T_4 (174.00 days), T_9 (171.33 days), T_7 (170.83 days), T_1 (170.67 days), T_6 (169.17 days) and T_{10} (165.67 days).

Table 41. Effect of different levels of nutrients on average fruit weight per plant, days to first harvest, days to final harvest and yield per plant of strawberry

Treatments (T)	Average fruit weight per plant (g)			Days to first harvest (days)			Days to final harvest (days)			Yield per plant (g)		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II		I	II	
T_1	12.46	13.39	12.93	74.00	73.72	73.86	170.00	171.33	170.67	42.27	46.99	44.63
T_2	11.70	12.34	12.02	74.67	72.73	73.70	177.00	175.33	176.17	55.73	59.61	57.67
T_3	11.16	12.13	11.64	73.63	74.79	74.21	180.00	178.67	179.33	40.12	47.36	43.74
T_4	12.26	9.55	10.91	73.67	75.00	74.33	174.33	173.67	174.00	67.03	53.17	60.10
T_5	10.13	10.14	10.14	74.83	74.33	74.58	178.00	176.67	177.33	42.62	43.60	43.11
T_6	11.13	12.98	12.06	73.00	73.73	73.37	170.00	168.33	169.17	50.07	61.03	55.55
T_7	11.69	12.00	11.85	72.93	73.47	73.20	170.00	171.67	170.83	51.55	73.11	62.33
T_8	11.25	13.56	12.41	70.50	72.00	71.25	174.00	175.00	174.50	69.75	90.09	79.92
T_9	11.75	12.07	11.91	72.87	73.07	72.97	172.00	170.67	171.33	77.86	73.94	75.90
T_{10}	7.08	5.61	6.35	76.97	76.25	76.61	165.00	166.33	165.67	13.51	8.09	10.80
CD (0.05)			1.51			0.83			0.62			8.09

Table 42. Effect of different levels of nutrients on TSS, Acidity, TSS/Acidity and total sugars of strawberry

Treatments (T)	T.S.S (^{0}Brix)			Acidity (%)			T.S.S/Acidity			Total sugars (%)		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II		I	II	
T_1	6.7	6.30	6.50	0.82	0.98	0.90	8.20	6.52	7.36	3.89	3.98	3.94
T_2	7.6	7.17	7.38	1.05	0.84	0.94	7.24	8.57	7.90	3.46	3.53	3.49
T_3	7.3	7.73	7.52	0.77	0.93	0.85	9.69	8.86	9.28	4.73	4.86	4.80
T_4	6.83	6.67	6.75	0.78	0.82	0.80	8.75	8.19	8.47	3.89	3.93	3.91
T_5	6.43	6.50	6.47	0.92	1.06	0.99	7.10	6.53	6.82	4.22	4.78	4.50
T_6	7.00	7.07	7.03	0.75	0.89	0.82	9.41	8.50	8.96	3.93	4.00	3.97
T_7	7.23	7.43	7.33	0.70	0.77	0.74	10.61	9.76	10.19	5.00	5.13	5.07
T_8	7.67	7.70	7.68	0.66	0.78	0.72	11.62	10.04	10.83	5.11	5.09	5.10
T_9	7.13	7.33	7.23	0.69	0.84	0.77	10.30	9.13	9.72	5.27	5.18	5.23
T_{10}	5.40	5.67	5.53	0.74	0.97	0.86	7.36	6.63	6.99	3.36	3.03	3.20
CD (0.05)			0.32			NS			1.72			0.20

4.2.3.7 Yield

Analysis of the data corresponding to yield of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 41.

The pooled mean over the two seasons revealed that T_8 recorded significantly maximum yield per plant (79.92 g) which was on par with T_9 (75.90 g). It was followed by T_7 (62.33 g), T_4 (60.10 g), T_2 (57.67 g), T_6 (55.55 g), T_1 (44.63 g), T_3 (43.74 g), T_5 (43.11 g) and T_{10} (10.80 g).

4.2.4 Quality attributes

4.2.4.1 TSS

Analysis of the data corresponding to TSS of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 42.

The pooled mean over the two seasons revealed that T_8 (7.68 ^{0}Brix) recorded maximum TSS which was on par with T_3 (7.52 ^{0}Brix) and T_2 (7.38 ^{0}Brix). It was followed by T_7 (7.33 ^{0}Brix), T_9 (7.23 ^{0}Brix), T_6 (7.03 ^{0}Brix), T_4 (6.75 ^{0}Brix), T_1 (6.50 ^{0}Brix), T_5 (6.47 ^{0}Brix) and T_{10} (5.53 ^{0}Brix).

4.2.4.2 Acidity

Analysis of the data corresponding to acidity of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 42.

The pooled mean over the two seasons revealed that treatment combinations had no significant effect on acidity of strawberry. However T_8 (0.72 %) recorded lowest acidity which was followed by T_7 (0.74 %), T_9 (0.77 %), T_4 (0.80 %), T_6 (0.82 %), T_3 (0.85 %), T_{10} (0.86 %), T_1 (0.90 %), T_2 (0.94 %) and T_5 (0.99 %).

4.2.4.3 TSS/acidity

Analysis of the data corresponding to TSS/acidity of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 42.

The pooled mean over the two seasons revealed that T_8 recorded the maximum TSS/acidity (10.83) which was on par withT_7 (10.19), T_9 (9.72), T_3 (9.28). It was followed by T_6 (8.96), T_4 (8.47), T_2 (7.90), T_1 (7.36), T_{10} (6.99) and T_5 (6.82).

4.2.4.4 Total sugars

Analysis of the data corresponding to total sugars content of strawberry at Central mid-lands in two seasons are presented in Table 42.

The pooled mean over the two seasons revealed that T_9 recorded the maximum total sugars content (5.23 %) which was on par with T_8 (5.10 %) and T_7 (5.07 %). It was followed by T_3 (4.80 %), T_5 (4.50 %), T_6 (3.97 %), T_1 (3.94 %), T_4 (3.91 %), T_2 (3.49%) and T_{10} (3.20 %).

4.2.4.5 Ascorbic acid

Analysis of the data corresponding to ascorbic acid content at Central mid-lands of Kerala in two seasons are presented in Table 43.

The pooled mean over the two seasons revealed that T_9 recorded maximum ascorbic acid content (52.22 mg 100 g^{-1}). It was followed by T_6 (43.47 mg 100 g^{-1}), T_3 (38.00 mg 100 g^{-1}), T_8 (31.50 mg 100 g^{-1}), T_5 (28.18 mg 100 g^{-1}), T_2 (25.32 mg 100 g^{-1}), T_7 (25.21 mg 100 g^{-1}), T_4 (23.67 mg 100 g^{-1}), T_1 (19.88 mg 100 g^{-1}) and T_{10} (17.15 mg 100 g^{-1}).

Table 43. Effect of different levels of nutrients on ascorbic acid, anthocyanin content, β - Carotene and shelf life of strawberry

Treatments (T)	Ascorbic acid (mg/100g)			Anthocyanin content (mg/100g)			β – Carotene (µg/100g)			Shelf life (days)		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II		I	II	
T_1	19.73	20.03	19.88	14.03	21.97	18.00	1.41	2.52	1.96	3	3	3
T_2	25.80	24.83	25.32	32.20	33.70	32.95	2.32	2.38	2.35	3	3	3
T_3	37.37	38.63	38.00	18.50	18.40	18.45	4.25	1.67	2.96	4	4	4
T_4	24.00	23.35	23.67	41.20	39.53	40.37	2.72	1.45	2.09	3	3	3
T_5	27.70	28.67	28.18	31.07	30.87	30.97	1.89	2.47	2.18	3	3	3
T_6	41.43	45.50	43.47	35.47	34.80	35.13	2.19	2.94	2.57	3	3	3
T_7	25.38	25.03	25.21	49.47	46.83	48.15	2.47	1.88	2.18	3	3	3
T_8	32.60	30.40	31.50	43.57	45.90	44.73	3.13	2.24	2.68	3	3	3
T_9	50.73	53.70	52.22	42.37	43.40	42.88	3.02	1.94	2.48	3	3	3
T_{10}	15.57	18.73	17.15	36.57	29.47	33.02	2.86	1.86	2.36	3	3	3
CD (0.05)			1.48			0.81			0.05			

4.2.4.6 Anthocyanin

Analysis of the data corresponding to anthocyanin content at Central mid-lands of Kerala in two seasons are presented in Table 43.

The pooled mean over the two seasons revealed that T_7 recorded the highest anthocyanin content (48.15 mg 100 g^{-1}). It was followed by T_8 (44.73 mg 100 g^{-1}), T_9 (42.88 mg 100 g^{-1}), T_4 (40.37 mg 100 g^{-1}), T_6 (35.13 mg 100 g^{-1}), T_{10} (33.02 mg 100 g^{-1}), T_2 (32.95 mg 100 g^{-1}), T_5 (30.97 mg 100 $g^{-}1$), T_3 (18.45 mg 100 g^{-1}) and T_1 (18.00 mg 100 g^{-1}).

4.2.4.7 β - Carotene

Analysis of the data corresponding to β - carotene content (μg $100g^{-1}$) of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 43.

The pooled mean over the two seasons revealed that T_3 recorded maximum β - carotene content (2.96 μg $100g^{-1}$). It was followed by T_8 (2.68 μg $100g^{-1}$), T_6 (2.57 μg $100g^{-1}$), T_9 (2.48 μg $100g^{-1}$), T_{10} (2.36 μg $100g^{-1}$), T_2 (2.35 μg $100g^{-1}$), T_5 (2.18 μg $100g^{-1}$), T_7 (2.18 μg $100g^{-1}$), T_4 (2.09 μg $100g^{-1}$) and T_1 (1.96 μg $100g^{-1}$).

4.2.4.8 Shelf life

The data on shelf life of strawberry is presented in Table 43. The treatments had no significant effect on shelf life of strawberry. Fruits harvested from all the treatments have a shelf life of 3 days during both seasons of growth except T_3 which recorded shelf life of 4 days.

4.2.4.9 Colour

The data on colour of fruit skin is presented in Table 44. The skin colour was described using Universal Colour Language (UCL) and it was deep purplish pink (61

Table 44. Effect of different levels of nutrients on colour of strawberry fruit

Treatments (T)	Years	
	I	II
T_1	Deep Purplish Pink -61D	Deep Purplish Pink -61D
T_2	Deep Purplish Pink -61D	Deep Purplish Pink -61D
T_3	Deep Purplish Pink -61D	Deep Purplish Pink -61D
T_4	Deep Purplish Pink -61D	Deep Purplish Pink -61D
T_5	Deep Purplish Pink -61D	Deep Purplish Pink -61D
T_6	Deep Purplish Pink -61D	Deep Purplish Pink -61D
T_7	Deep Purplish Pink -61D	Deep Purplish Pink -61D
T_8	Deep Purplish Pink -61D	Deep Purplish Pink -61D
T_9	Deep Purplish Pink -61D	Deep Purplish Pink -61D
T_{10}	Deep Purplish Pink -61D	Deep Purplish Pink -61D

Table 45. Sensory evaluation of strawberry

Treatments (T)	Appearance		Colour		Taste		Flavour		Aroma		Texture		After taste		Overall acceptability		Total score	
	Years		Years		Years		Years		Years		Years		Years		Years		Years	
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
T_1	6.6	7.16	7.16	7.26	6.6	6.63	6.73	6.63	7.03	6.93	7.20	7.4	6.50	6.57	7.57	7.7	55.39	56.28
T_2	6.4	6.5	6.5	6.66	6.63	6.9	6.86	6.97	6.9	6.72	7.83	7.87	6.93	7.40	7.40	7.4	55.45	56.42
T_3	6.0	6.26	6.8	6.93	7.13	7.13	6.94	6.83	6.8	6.93	8.33	8.46	7.03	7.20	8.00	8.0	57.03	57.74
T_4	6.3	6.43	6.73	6.93	6.53	7.10	7.06	7.13	7.39	7.53	7.5	8.10	7.55	7.65	8.26	8.4	57.32	59.27
T_5	6.6	6.66	6.23	6.63	6.73	7.20	7.56	7.36	7.80	8.10	8.10	8.30	7.87	7.93	8.27	8.2	59.16	60.38
T_6	7.7	7.6	7.66	7.53	7.56	7.30	7.56	7.50	7.73	7.76	8.13	8.13	7.67	7.60	8.30	8.4	62.31	61.82
T_7	6.7	6.76	7.16	7.03	7.10	6.76	7.3	7.20	7.46	7.66	8.53	8.56	7.90	7.80	8.36	8.4	60.51	60.17
T_8	6.4	6.33	6.46	6.33	8.0	7.93	8.43	8.60	7.33	7.47	8.50	8.60	8.0	7.86	8.13	8.2	61.25	61.32
T_9	6.7	6.63	6.86	6.73	7.6	8.03	7.8	8.20	7.97	7.97	8.27	8.46	7.97	8.20	8.37	8.5	61.54	62.72
T_{10}	6.7	6.9	6.96	6.33	5.7	5.76	6.26	5.96	7.40	7.60	8.30	8.50	8.13	8.13	8.10	8.4	57.55	57.58

D) for all treatments. The treatments had no significant influence on the colour of strawberry.

4.2.4.10 Sensory evaluation

Data corresponding to the sensory evaluation of strawberry fruits grown at Central mid-lands of Kerala are presented in Tables 45.

In strawberry, the sensory evaluation was carried out on a nine point hedonic scale using score card for eight attributes namely appearance, colour, texture, flavour, 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 carried out on the same day of harvest by panel of judges.

During first year, the highest score for appearance was recorded by T_6 (7.7) and the lowest score by T_3 (6.0). The highest score for colour was recorded by T_6 (7.66) and the lowest score was by T_5 (6.23). The highest score for taste was recorded by T_8 (8.0). Highest score for flavour was recorded by T_8 (8.43). Highest score for aroma was recorded by T_9 (7.97). Highest score for texture was recorded by T_7 (8.53). T_{10} (8.13) recorded highest score for after taste. Highest score for overall acceptability was recorded by T_9 (8.37). The highest total sensory score was recorded by T_6 (62.31) and the lowest total sensory score was recorded by T_1 (55.39).

However during second year, the highest score for appearance was recorded by T_6 (7.6). The highest score for colour was recorded by T_6 (7.53). The highest score for taste was scored by T_9 (8.03). The highest score for flavour was recorded by T_8 (8.60). The highest score for aroma was recorded by T_5 (8.10). T_8 (8.60) recorded the highest score for texture. T_9 (8.20) recorded the highest score for after taste while T_9 (8.5) recorded the highest score for overall acceptability.T_9 (62.72) scored the highest total sensory score and the lowest total sensory score was recorded in T_1 (56.28).

4.2.5 Physiological attributes

4.2.5.1 Photosynthetic rate

The photosynthetic rate measured during 60, 120 and 180 days after planting for all the treatments during two seasons are given in Table 46.

At 60 days after planting, photosynthetic rate was ranged from 6.63 µmol m^{-2} $sec^{-1}$to 0.91 µmol m^{-2} sec^{-1}. T_1 recorded the highest value of 6.63 µmol m^{-2} sec^{-1} which was followed by T_4 (6.32 µmol m^{-2} sec^{-1}), T_2 (6.08 µmol m^{-2} sec^{-1}), T_8 (5.65 µmol m^{-2} sec^{-1}), T_3 (5.42 µmol m^{-2} sec^{-1}), T_5 (4.77 µmol m^{-2} sec^{-1}), T_6 (2.21 µmol m^{-2} sec^{-1}), T_7 (2.05 µmol m^{-2} sec^{-1}), T_9 (0.91 µmol m^{-2} sec^{-1}) and T_{10} (0.91 µmol m^{-2} sec^{-1}).

At 120 days after planting, the photosynthetic rate among all the treatments were ranged from 23.02 µmol m^{-2} sec^{-1} to 6.31 µmol m^{-2} sec^{-1}. T_4 (23.02 µmol m^{-2} sec^{-}1) recorded the maximum photosynthetic rate which was followed by T_8 (19.07 µmol m^{-2} sec^{-}1), T_{10} (16.55 µmol m^{-2} sec^{-}1), T_3 (15.63 µmol m^{-2} sec^{-}1), T_6 (10.24 µmol m^{-2} sec^{-}1), T_2 (9.63 µmol m^{-2} sec^{-}1), T_1 (9.24 µmol m^{-2} sec^{-}1), T_7 (8.91 µmol m^{-2} sec^{-}1), T_5 (8.56 µmol m^{-2} sec^{-}1) and T_9 (6.31 µmol m^{-2} sec^{-}1).

At 180 days after planting, the photosynthetic rate among all the different treatments were ranged from 11.59 µmol m^{-2} sec^{-1} to 8.80 µmol m^{-2} sec^{-1}. T_1 (11.59 µmol m^{-2} sec^{-1}) recorded the maximum photosynthetic rate which was followed by T_{10} (11.47 µmol m^{-2} sec^{-1}), T_7 (11.42 µmol m^{-2} sec^{-1}), T_6 (11.30 µmol m^{-2} sec^{-1}), T_8 (11.30 µmol m^{-2} sec^{-1}), T_4 (11.20 µmol m^{-2} sec^{-1}), T_5 (10.95 µmol m^{-2} sec^{-1}), T_2 (10.91 µmol m^{-2} sec^{-1}), T_3 (10.20 µmol m^{-2} sec^{-1}) and T_9 (8.80 µmol m^{-2} sec^{-1}).

4.2.5.2 Stomatal conductance

The stomatal conductance measured during 60, 120 and 180 days after planting for all the treatments during two seasons are given in Table 47.

Table 46. Effect of different levels of nutrients on photosynthetic rate of strawberry

Treatments (T)	Photosynthetic rate (µmol m^2 sec^{-1})								
	2 MAP			4 MAP			6 MAP		
	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II	
T_1	6.80	6.47	6.63	9.08	9.40	9.24	11.7	11.47	11.59
T_2	6.20	5.97	6.08	9.40	9.87	9.63	11.13	10.68	10.91
T_3	5.54	5.30	5.42	15.30	15.97	15.63	10.30	10.10	10.20
T_4	6.58	6.07	6.32	23.20	22.83	23.02	11.30	11.10	11.20
T_5	4.81	4.73	4.77	8.26	8.86	8.56	11.10	10.80	10.95
T_6	2.02	2.40	2.21	9.42	11.07	10.24	11.40	11.20	11.30
T_7	1.99	2.10	2.05	8.82	9.00	8.91	11.53	11.30	11.42
T_8	5.80	5.50	5.65	19.23	18.90	19.07	11.40	11.20	11.30
T_9	0.81	1.01	0.91	6.13	6.50	6.31	8.99	8.61	8.80
T_{10}	1.01	0.82	0.91	16.30	16.80	16.55	11.60	11.13	11.47
C.D (0.05)			0.11			0.09			0.03

Table 47. Effect of different levels of nutrients on stomatal conductance of strawberry

Treatments (T)	Stomatal conductance (m µmol m^{-2} sec^{-1})								
	2 MAP			4 MAP			6 MAP		
	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II	
T_1	0.13	0.14	0.13	0.01	0.01	0.01	0.007	0.008	0.008
T_2	0.12	0.13	0.12	0.01	0.01	0.01	0.007	0.007	0.007
T_3	0.10	0.11	0.11	0.21	0.21	0.21	0.006	0.006	0.006
T_4	0.15	0.16	0.15	0.24	0.24	0.24	0.007	0.007	0.007
T_5	0.23	0.24	0.23	0.01	0.01	0.01	0.007	0.007	0.007
T_6	0.22	0.23	0.22	0.01	0.01	0.01	0.007	0.007	0.007
T_7	0.14	0.15	0.14	0.01	0.01	0.01	0.007	0.007	0.007
T_8	0.20	0.21	0.20	0.22	0.21	0.215	0.006	0.007	0.007
T_9	0.13	0.14	0.13	0.01	0.01	0.01	0.006	0.006	0.006
T_{10}	0.19	0.20	0.19	0.25	0.24	0.25	0.006	0.006	0.006
C.D (0.05)			0.01			NS			NS

At 60 days after planting, stomatal conductance among all the different treatments were ranged from 0.23µmol m^{-2} $sec^{-1}$to 0.11 µmol m^{-2} sec^{-1}. T_5 recorded the highest value of 0.23 µmol m^{-2} sec^{-1} which was followed by T_6 (0.22 µmol m^{-2} sec^{-1}), T_8 (0.20 µmol m^{-2} sec^{-1}), T_{10} (0.19 µmol m^{-2} sec^{-1}), T_4 (0.15 µmol m^{-2} sec^{-1}), T_7 (0.14 µmol m^{-2} sec^{-1}), T_1 (0.13 µmol m^{-2} sec^{-1}), T_9 (0.13 µmol m^{-2} sec^{-1}), T_2 (0.12 µmol m^{-2} sec^{-1}) and T_3 (0.11 µmol m^{-2} sec^{-1}).

At 120 days after planting, the stomatal conductance among all the different treatments were ranged from 0.25 µmol m^{-2} sec^{-1} to 0.01 µmol m^{-2} sec^{-1}. T_{10} (0.25 µmol m^{-2} sec^{-1}) recorded the maximum stomatal conductance which was followed by T_4 (0.24 µmol m^{-2} sec^{-1}), T_8 (0.22 µmol m^{-2} sec^{-1}) T_3 (0.21 µmol m^{-2} sec^{-1}) T_1 (0.01 µmol m^{-2} sec^{-1}) T_2 (0.01 µmol m^{-2} sec^{-1}) T_5 (0.01 µmol m^{-2} sec^{-1}) T_6 (0.01 µmol m^{-2} sec^{-1}) T_7 (0.01 µmol m^{-2} sec^{-1}) and T_9 (0.01 µmol m^{-2} sec^{-1}).

At 180 days after planting, the stomatal conductance among all the treatments were ranged from 0.008 µmol m^{-2} sec^{-1} to 0.006 µmol m^{-2} sec^{-1}. T_1 recorded the maximum stomatal conductance (0.008 µmol m^{-2} sec^{-1}). T_2, T_4, T_5, T_6 T_7 and T_8 recorded the stomatal conductance of 0.007 µmol m^{-2} sec^{-1} while T_{10}, T_9 and T_3 recorded the stomatal conductance of 0.006 µmol m^{-2} sec^{-1}.

4.2.5.3 Transpiration rate

The transpiration rate measured during 60, 120 and 180 days after planting for all the treatments during two seasons are given in Table 48.

At 60 days after planting, transpiration rate for all the treatments was ranged from 9.77 µmol m^{-2} sec^{-1} to 2.61 µmol m^{-2} sec^{-1}. Among the treatments, T_4 recorded the highest value of 9.77 µmol m^{-2} sec^{-1} which was followed by T_1 (9.58 µmol m^{-2} sec^{-1}), T_6 (9.07 µmol m^{-2} sec^{-1}), T_5 (8.55 µmol m^{-2} sec^{-1}), T_2 (8.28 µmol m^{-2} sec^{-1}), T_{10} (7.54 µmol m^{-2} sec^{-1}), T_7 (6.25 µmol m^{-2} sec^{-1}), T_3 (5.34 µmol m^{-2} sec^{-1}), T_8 (4.89 µmol m^{-2} sec^{-1}) and T_9 (2.61 µmol m^{-2} sec^{-1}). At 120 days after planting, the transpiration rate

Table 48. Effect of different levels of nutrients on transpiration rate of strawberry

Treatments (T)	Transpiration rate (µmol m^{-2} sec^{-1})								
	2 MAP			4 MAP			6 MAP		
	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II	
T_1	10.60	8.57	9.58	0.52	0.32	0.42	0.31	0.32	0.31
T_2	9.20	7.37	8.28	0.41	0.21	0.31	0.28	0.30	0.29
T_3	6.77	3.91	5.34	6.09	5.89	5.99	0.23	0.25	0.24
T_4	10.43	9.10	9.77	7.44	7.25	7.35	0.28	0.30	0.29
T_5	8.49	8.60	8.55	0.41	0.21	0.31	0.29	0.31	0.30
T_6	9.20	8.93	9.07	0.40	0.20	0.30	0.28	0.30	0.29
T_7	7.23	5.27	6.25	0.49	0.29	0.39	0.33	0.34	0.34
T_8	5.33	4.45	4.89	7.63	7.43	7.53	0.27	0.28	0.28
T_9	2.55	2.67	2.61	0.34	0.14	0.24	0.21	0.23	0.22
T_{10}	8.88	6.20	7.54	8.84	8.64	8.74	0.28	0.30	0.29
C.D (0.05)			0.08			0.02			0.01

Table 49. Effect of different levels of nutrients on leaf area index of strawberry

Treatments (T)	LAI					
	90 DAT			180 DAT		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	0.07	0.08	0.07	0.21	0.20	0.20
T_2	0.04	0.04	0.04	0.12	0.12	0.12
T_3	0.11	0.10	0.10	0.25	0.25	0.25
T_4	0.08	0.08	0.08	0.28	0.28	0.28
T_5	0.09	0.07	0.08	0.32	0.24	0.28
T_6	0.11	0.08	0.09	0.24	0.24	0.24
T_7	0.05	0.05	0.05	0.26	0.22	0.24
T_8	0.07	0.11	0.09	0.32	0.29	0.30
T_9	0.11	0.11	0.11	0.37	0.38	0.37
T_{10}	0.02	0.02	0.02	0.10	0.09	0.09
C.D (0.05)			0.02			0.04

among all the treatments were ranged from 8.74 µmol m^{-2} sec^{-1} to 0.24 µmol m^{-2} sec^{-1}. T_{10} (8.74 µmol m^{-2} sec^{-1}) recorded the maximum transpiration rate which was followed by T_8 (7.53 µmol m^{-2} sec^{-1}), T_4 (7.35 µmol m^{-2} sec^{-1}) T_3 (5.99 µmol m^{-2} sec^{-1}) T_1 (0.42 µmol m^{-2} sec^{-1}) T_7 (0.39 µmol m^{-2} sec^{-1}) T_2 (0.31 µmol m^{-2} sec^{-1}) T_5 (0.31 µmol m^{-2} sec^{-1}) T_6 (0.30 µmol m^{-2} sec^{-1}) and T_9 (0.24 µmol m^{-2} sec^{-1}). At 180 days after planting, the transpiration rate among all the treatments were ranged from 0.34 µmol m^{-2} sec^{-1} to 0.22 µmol m^{-2} sec^{-1}. T_7 recorded the maximum transpiration rate (0.34 µmol m^{-2} sec^{-1}) which was followed by T_1 (0.31 µmol m^{-2} sec^{-1}), T_5 (0.30 µmol m^{-2} sec^{-1}), T_2 (0.29 µmol m^{-2} sec^{-1}), T_4 (0.29 µmol m^{-2} sec^{-1}), T_6 (0.29 µmol m^{-2} sec^{-1}), T_{10} (0.29 µmol m^{-2} sec^{-1}), T_8 (0.28 µmol m^{-2} sec^{-1}), T_3 (0.24 µmol m^{-2} sec^{-1}) and T_9 (0.22 µmol m^{-2} sec^{-1}).

4.2.5.4 Leaf area index

Analysis of data corresponding to the leaf area index of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 49.

At 90 days after planting, different nutrient combinations had significant effect on leaf area index. T_9 recorded maximum leaf area index (0.11) which was on par with T_3 (0.1), T_6 (0.09) and T_8 (0.09). It was followed by T_4 (0.08), T_5 (0.08), T_1 (0.07), T_7 (0.05), T_2 (0.04) and T_{10} (0.02).

At 180 days after planting also, different nutrient combinations had significant effect on leaf area index. T_9 recorded maximum leaf area index (0.37) which was followed by T_8 (0.30), T_4 (0.28), T_5 (0.28), T_3 (0.25), T_6 (0.24), T_7 (0.24), T_1 (0.20), T_2 (0.12), T_{10} (0.09).

4.2.5.5 Crop growth rate

Analysis of data corresponding to the crop growth rate of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 50.

Different treatment combinations had significant effect on crop growth rate of strawberry. T_4 recorded maximum crop growth rate (2.30 g m^{-2} day^{-1}) which was followed by T_8 (1.99 g m^{-2} day^{-1}), T_9 (1.79 g m^{-2} day^{-1}), T_3 (1.63 g m^{-2} day^{-1}), T_7 (1.61 g m^{-2} day^{-1}), T_1 (1.44 g m^{-2} day^{-1}), T_5 (1.30 g m^{-2} day^{-1}), T_2 (1.16 g m^{-2} day^{-1}), T_6 (1.12 g m^{-2} day^{-1}) and T_{10} (0.60 g m^{-2} day^{-1}).

4.2.5.6 Relative growth rate

Analysis of data corresponding to the relative growth rate at Central mid-lands of Kerala in two seasons are presented in Table 50.

Different treatment combinations had significant effect on relative growth rate of strawberry. T_4 and T_8 recorded maximum relative growth rate (0.04 g g^{-1} day^{-1}) and was followed by T_9 (0.03 g g^{-1} day^{-1}), T_7 (0.03 g g^{-1} day^{-1}), T_1 (0.03 g g^{-1} day^{-1}), T_2 (0.03 g g^{-1} day^{-1}), T_3 (0.03 g g^{-1} day^{-1}) T_5 (0.03 g g^{-1} day^{-1}), T_6 (0.03 g g^{-1} day^{-1}) and T_{10} (0.02 g g^{-1} day^{-1}).

4.2.5.7 Net assimilation rate

Analysis of data corresponding to the net assimilation rate at Central mid-lands of Kerala in two seasons are presented in Table 50.

Different treatment**s** had significant effect on net assimilation rate T_2 recorded significantly higher net assimilation rate (9.75 g g^{-1} day^{-1}) which was followed by T_1 (7.20 g g^{-1} day^{-1}), T_8 (6.57 g g^{-1} day^{-1}), T_3 (6.53 g g^{-1} day^{-1}), T_7 (6.52 g g^{-1} day^{-1}), T_9 (6.44 g g^{-1} day^{-1}) T_{10} (6.41 g g^{-1} day^{-1}), T_4 (6.18 g g^{-1} day^{-1}), T_6 (4.81 g g^{-1} day^{-1}), T_5 (4.78 g g^{-1} day^{-1}).

Table 50. Effect of different levels of nutrients on crop growth rate, relative growth rate and net assimilation rate of strawberry

Treatments (T)	Crop growth rate (g m^{-2} day^{-1})			Relative growth rate (g m^{-2} day^{-1})			Net assimilation rate (g m^{-2} day^{-1})		
	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II	
T_1	1.36	1.52	1.44	0.03	0.03	0.03	6.68	7.72	7.20
T_2	1.16	1.15	1.16	0.03	0.03	0.03	9.53	9.96	9.75
T_3	1.64	1.61	1.63	0.03	0.03	0.03	6.58	6.47	6.53
T_4	2.38	2.22	2.30	0.04	0.04	0.04	6.45	5.90	6.18
T_5	1.17	1.43	1.30	0.03	0.03	0.03	3.71	5.86	4.78
T_6	0.96	1.28	1.12	0.03	0.03	0.03	4.17	5.44	4.81
T_7	1.94	1.27	1.61	0.03	0.03	0.03	7.38	5.67	6.52
T_8	1.75	2.22	1.99	0.03	0.04	0.04	5.51	7.63	6.57
T_9	2.03	1.55	1.79	0.04	0.03	0.03	7.35	5.53	6.44
T_{10}	0.61	0.59	0.60	0.02	0.02	0.02	6.29	6.54	6.41
CD (0.05)			0.30			0.003			0.99

Table 51. Effect of different levels of nutrients on chlorophyll a, chlorophyll b and total chlorophyll content of strawberry

Treatments	Chlorophyll a (mg g^{-1})			Chlorophyll b (mg g^{-1})			Total Chlorophyll (mg g^{-1})		
	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II	
T_1	0.92	1.17	1.05	0.29	0.34	0.32	2.82	2.51	2.66
T_2	1.60	1.55	1.58	0.56	0.40	0.48	3.87	3.25	3.56
T_3	0.79	0.88	0.84	0.34	0.43	0.39	1.88	2.05	1.96
T_4	1.77	1.90	1.84	0.64	0.56	0.60	4.56	4.11	4.33
T_5	1.69	1.72	1.71	0.49	0.40	0.45	4.12	3.77	3.95
T_6	1.10	1.18	1.14	0.45	0.58	0.52	3.96	3.53	3.75
T_7	1.35	1.45	1.40	0.50	0.51	0.51	3.70	3.22	3.46
T_8	2.29	2.05	2.17	0.80	0.71	0.75	4.97	4.51	4.74
T_9	1.70	1.80	1.75	0.42	0.58	0.50	4.28	3.91	4.10
T_{10}	0.73	0.86	0.79	0.28	0.32	0.30	1.45	1.92	1.68
C.D (0.05)			0.15			0.11			0.31

4.2.6 Analysis of plant sample

Analysis of the data corresponding to chlorophyll a, chlorophyll b and total chlorophyll content of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 51.

4.2.6.1 Chlorophyll a

The pooled mean over the two seasons revealed that different treatment combinations had significant effect on chlorophyll a content of strawberry. T_8 recorded maximum chlorophyll a content (2.17 mg g^{-1}). It was followed by T_4 (1.84 mg g^{-1}), T_9 (1.75 mg g^{-1}), T_5 (1.71 mg g^{-1}), T_2 (1.58 mg g^{-1}), T_7 (1.40 mg g^{-1}), T_6 (1.14 mg g^{-1}), T_1 (1.05 mg g^{-1}), T_3 (0.84 mg g^{-1}) and T_{10} (0.79 mg g^{-1}).

4.2.6.2 Chlorophyll b

The pooled mean over the two seasons revealed that different treatment combinations had significant effect on chlorophyll b content of strawberry.

Among all the treatment combinations, T_8 recorded maximum chlorophyll b content of 0.75 mg g^{-1}). It was followed by T_4 (0.60 mg g^{-1}), T_6 (0.52 mg g^{-1}), T_7 (0.51 mg g^{-1}), T_9 (0.50 mg g^{-1}), T_2 (0.48 mg g^{-1}), T_5 (0.45 mg g^{-1}), T_3 (0.39 mg g^{-1}), T_1 (0.32 mg g^{-1}) and T_{10} (0.30 mg g^{-1}).

4.2.6.3 Total Chlorophyll

The pooled mean over the two seasons revealed that different treatments had significant effect on total chlorophyll content.

T_8 recorded maximum total chlorophyll content (4.74 mg g^{-1}). It was followed by T_4 (4.33 mg g^{-1}), T_9 (4.10 mg g^{-1}), T_5 (3.95 mg g^{-1}), T_6 (3.75 mg g^{-1}), T_2 (3.56 mg g^{-1}), T_7 (3.46 mg g^{-1}), T_1 (2.66 mg g^{-1}), T_3 (1.96 mg g^{-1}) and T_{10} (1.68 mg g^{-1}).

Table 52. Effect of different levels of nutrients on plant nutrient uptake of strawberry (kg ha^{-1})

Treatments	N			P			K			Ca			Mg			S		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II		I	II		I	II		I	II	
T_1	33.09	37.29	35.19	0.008	0.008	0.008	0.056	0.058	0.057	0.034	0.037	0.036	0.012	0.013	0.013	0.001	0.001	0.001
T_2	26.97	28.63	27.80	0.006	0.006	0.006	0.046	0.047	0.046	0.020	0.020	0.020	0.009	0.009	0.009	0.001	0.001	0.001
T_3	40.01	40.12	40.06	0.008	0.008	0.008	0.061	0.06	0.061	0.033	0.035	0.034	0.014	0.014	0.014	0.002	0.002	0.002
T_4	56.63	60.66	58.65	0.012	0.011	0.012	0.087	0.085	0.086	0.048	0.044	0.046	0.017	0.017	0.017	0.003	0.003	0.003
T_5	31.15	28.86	30.01	0.008	0.008	0.008	0.060	0.056	0.058	0.032	0.032	0.032	0.014	0.013	0.013	0.003	0.003	0.003
T_6	29.57	31.78	30.67	0.007	0.008	0.007	0.050	0.055	0.053	0.023	0.026	0.025	0.010	0.011	0.011	0.002	0.002	0.002
T_7	31.77	23.28	27.53	0.010	0.008	0.009	0.055	0.045	0.050	0.017	0.014	0.015	0.014	0.011	0.012	0.002	0.002	0.002
T_8	44.65	46.66	45.66	0.011	0.014	0.012	0.074	0.081	0.077	0.022	0.023	0.022	0.015	0.017	0.016	0.002	0.002	0.002
T_9	44.14	38.97	41.56	0.015	0.012	0.013	0.080	0.065	0.072	0.030	0.026	0.028	0.015	0.012	0.013	0.003	0.003	0.003
T_{10}	10.13	11.19	10.66	0.003	0.003	0.003	0.021	0.022	0.022	0.013	0.013	0.013	0.004	0.005	0.005	0.000	0.001	0.001
C.D (0.05)			5.72			0.002			0.011			0.004			0.002			NS

Table 53. Effect of different levels of nutrients on plant nutrient uptake of strawberry (kg ha^{-1}) Contd..

Treatments	Cu			Fe			Zn			Mn			B		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II		I	II		I	II	
T_1	0.00	0.00	0.00	0.007	0.005	0.006	0.00	0.00	0.00	0.001	0.001	0.001	0.001	0.001	0.001
T_2	0.00	0.00	0.00	0.007	0.007	0.007	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.00	0.000
T_3	0.00	0.00	0.00	0.010	0.014	0.012	0.00	0.00	0.00	0.001	0.001	0.001	0.001	0.001	0.001
T_4	0.00	0.00	0.00	0.013	0.010	0.012	0.00	0.00	0.00	0.001	0.001	0.001	0.001	0.001	0.001
T_5	0.00	0.00	0.00	0.010	0.008	0.009	0.00	0.00	0.00	0.001	0.001	0.001	0.001	0.001	0.001
T_6	0.00	0.00	0.00	0.005	0.005	0.005	0.00	0.00	0.00	0.001	0.001	0.001	0.000	0.001	0.001
T_7	0.00	0.00	0.00	0.011	0.011	0.011	0.00	0.00	0.00	0.001	0.001	0.001	0.001	0.001	0.001
T_8	0.00	0.00	0.00	0.008	0.007	0.008	0.00	0.00	0.00	0.001	0.001	0.001	0.001	0.001	0.001
T_9	0.00	0.00	0.00	0.013	0.010	0.011	0.00	0.00	0.00	0.001	0.001	0.001	0.001	0.001	0.001
T_{10}	0.00	0.00	0.00	0.002	0.002	0.002	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
C.D (0.05)			**NS**			**0.003**			**NS**			**NS**			**NS**

4.2.6.4 Uptake of nutrients

Analysis of the data corresponding to uptake of nutrients of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 52 and 53.

The pooled mean over the two seasons revealed that different treatment combinations had significant effect on uptake of N content of strawberry. T_4 recorded maximum uptake of N with 58.65 kg ha^{-1} which was followed by T_8 (45.66 kg ha^{-1}), T_9 (41.56 kg ha^{-1}), T_3 (40.06 kg ha^{-1}), T_1 (35.19 kg ha^{-1}), T_6 (30.67 kg ha^{-1}), T_5 (30.01 kg ha^{-1}), T_2 (27.80 kg ha-1), T_7 (27.53 kg ha^{-1}), T_{10} (10.66 kg ha^{-1}).

The pooled mean over the two seasons revealed that different treatment combinations had significant effect on uptake of P content of strawberry. T_9 recorded maximum uptake of P with 0.013 kg ha^{-1} which was on par with T_4 and T_8 (0.012 kg ha^{-1}). It was followed by T_7 (0.009 kg ha^{-1}), T_1 (0.008 kg ha^{-1}), T_3 (0.008 kg ha^{-1}), T_5 (0.008 kg ha^{-1}), T_6 (0.007 kg ha^{-1}), T_2 (0.006 kg ha^{-1}) and T_{10} (0.003 kg ha^{-1}).

The pooled mean over the two seasons revealed that different treatments had significant effect on uptake of K content of strawberry. T_4 recorded maximum uptake of K with 0.09 kg ha^{-1} which was on par with T_8 (0.08 kg ha^{-1}). It was followed by T_9 (0.07 kg ha^{-1}), T_3 (0.06 kg ha^{-1}), T_5 (0.06 kg ha^{-1}), T_1 (0.06 kg ha^{-1}), T_6 (0.05 kg ha^{-1}), T_7 (0.05 kg ha^{-1}), T_2 (0.05 kg ha^{-1}) and T_{10} (0.02 kg ha^{-1}).

The pooled mean over the two seasons revealed that different treatment combinations had significant effect on uptake of Ca content of strawberry. T_4 recorded maximum uptake of Ca with 0.05 kg ha^{-1} which was followed by T_1 (0.04 kg ha^{-1}, T_3 (0.03 kg ha^{-1}), T_5 (0.03 kg ha^{-1}), T_9 (0.03 kg ha^{-1}), T_6 (0.03 kg ha^{-1}), T_8 (0.02 kg ha^{-1}), T_2 (0.02 kg ha-1), T_7 (0.02 kg ha^{-1}) and T_{10} (0.01 kg ha^{-1}).

The pooled mean over the two seasons revealed that different treatment combinations had significant effect on uptake of Mg content of strawberry. T_4 recorded maximum uptake of Mg with 0.02 kg ha^{-1} which was on par with T_8 (0.02 kg ha^{-1}). It was followed by T_3 (0.01 kg ha^{-1}), T_1 (0.01 kg ha^{-1}), T_5 (0.01 kg ha^{-1}), T_9 (0.01 kg ha^{-1}), T_7 (0.01 kg ha^{-1}), T_6 (0.01 kg ha-1), T_2 (0.01 kg ha^{-1}) and T_{10} (0.01 kg ha^{-1}).

The pooled mean over the two seasons revealed that different treatment combinations had no significant effect on uptake of S content of strawberry. All the treatments recorded no uptake of S content.

The pooled mean over the two seasons revealed that different treatment combinations had no significant effect on uptake of Cu content of strawberry. All the treatments recorded no uptake of Cu content.

The pooled mean over the two seasons revealed that different treatment combinations had significant effect on uptake of Fe content. All the treatments recorded an uptake of 0.01 kg ha^{-1} except T_{10} which recorded no uptake.

The pooled mean over the two seasons revealed that different treatment combinations had no significant effect on uptake of Zn content of strawberry. All the treatments recorded no uptake of Zn content.

The pooled mean over the two seasons revealed that different treatment combinations had no significant effect on uptake of Mn content of strawberry. All the treatments recorded no uptake of Mn content.

The pooled mean over the two seasons revealed that different treatment combinations had no significant effect on uptake of B content of strawberry. All the treatments recorded no uptake of B content.

4.2.7. Content of nutrients in strawberry fruits

Analysis of the data corresponding to nutrient content in fruits of strawberry at Central mid-lands of Kerala in two seasons are presented in Table 54 and 55.

Table 54. Effect of different levels of nutrients on nutrient content of strawberry fruits

Treatments	N (%)			P (mg l^{-1})			K (mg l^{-1})			Ca (mg l^{-1})			Mg (mg l^{-1})			S (mg l^{-1})		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II		I	II		I	II		I	II	
T_1	3.56	4.04	3.80	9.31	9.59	9.45	66.51	71.95	69.23	9.73	11.46	10.60	6.98	7.84	7.41	1.68	2.26	1.97
T_2	4.50	4.79	4.64	9.87	10.34	10.11	75.30	77.42	76.36	9.91	11.12	10.52	7.00	8.33	7.67	1.79	2.29	2.04
T_3	3.68	4.03	3.86	9.76	10.54	10.15	73.99	75.73	74.86	11.88	12.88	12.38	6.76	8.75	7.76	2.05	2.68	2.36
T_4	3.50	3.80	3.65	10.69	11.22	10.96	72.38	74.38	73.38	9.96	10.38	10.17	7.12	8.11	7.61	1.89	2.00	1.95
T_5	2.86	3.45	3.16	11.94	11.86	11.90	70.21	72.75	71.48	11.12	13.27	12.20	7.58	8.67	8.12	2.74	3.02	2.88
T_6	2.83	3.15	2.99	10.39	10.80	10.60	71.87	77.10	74.49	11.39	13.39	12.39	8.25	8.81	8.53	2.83	3.05	2.94
T_7	2.99	3.45	3.22	10.56	10.89	10.72	69.16	70.49	69.82	4.90	6.79	5.85	7.32	8.24	7.78	2.56	2.85	2.71
T_8	2.85	3.21	3.03	10.25	10.91	10.58	71.42	75.55	73.48	4.40	5.23	4.82	7.42	8.53	7.98	1.66	2.23	1.95
T_9	3.68	3.97	3.83	12.58	12.73	12.65	72.11	77.88	75.00	10.64	14.02	12.33	7.77	9.24	8.51	1.48	1.88	1.68
T_{10}	2.30	2.32	2.31	8.49	10.82	9.65	61.64	73.55	67.60	12.33	16.09	14.21	5.91	8.69	7.30	1.18	2.18	1.68
C.D (0.05)			0.54			1.05			4.04			2.97			0.80			0.33

Table 55. Effect of different levels of nutrients on nutrient content of strawberry fruits Contd..

Treatments	Cu (mg l^{-1})			Fe (mg l^{-1})			Zn (mg l^{-1})			Mn (mg l^{-1})			B (mg l^{-1})		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II		I	II		I	II	
T_1	0.03	0.03	0.03	1.22	1.34	1.28	0.19	0.21	0.20	0.12	0.16	0.14	0.54	0.67	0.61
T_2	0.03	0.03	0.03	1.78	2.12	1.95	0.15	0.17	0.16	0.20	0.24	0.22	0.61	0.66	0.64
T_3	0.03	0.04	0.03	1.36	1.44	1.40	0.14	0.17	0.15	0.21	0.24	0.23	0.63	0.72	0.67
T_4	0.03	0.04	0.03	1.43	1.74	1.59	0.13	0.19	0.16	0.20	0.21	0.21	0.64	0.51	0.58
T_5	0.03	0.04	0.04	1.09	1.17	1.13	0.16	0.23	0.19	0.18	0.21	0.20	0.27	0.34	0.30
T_6	0.03	0.03	0.03	1.06	1.13	1.10	0.11	0.14	0.13	0.25	0.26	0.26	0.52	0.63	0.58
T_7	0.03	0.03	0.03	0.94	1.02	0.98	0.09	0.10	0.10	0.21	0.22	0.21	0.70	0.73	0.72
T_8	0.03	0.03	0.03	1.12	1.29	1.21	0.10	0.11	0.10	0.22	0.22	0.22	0.61	0.67	0.64
T_9	0.04	0.04	0.04	1.25	1.32	1.29	0.10	0.10	0.10	0.20	0.21	0.20	0.58	0.64	0.61
T_{10}	0.02	0.05	0.03	1.11	1.38	1.25	0.08	0.11	0.09	0.19	0.21	0.20	0.48	0.89	0.68
C.D (0.05)			NS			0.34			0.03			0.03			0.14

The pooled mean over the two seasons revealed that T_2 recorded the maximum nitrogen content (4.64 %) which was followed by T_3 (3.86 %), T_9 (3.83 %), T_1 (3.80 %), T_4 (3.65 %), T_7 (3.22 %), T_5 (3.16 %), T_8 (3.03 %), T_6 (2.99 %) and T_{10} (2.31 %).

The pooled mean over the two seasons revealed that T_9 recorded the maximum phosphorus content (12.65 mg l^{-1}) which was on par with T_5 (11.90 mg l^{-1}). It was followed by T_4 (10.96 mg l^{-1}), T_7 (10.72 mg l^{-1}), T_6 (10.60 mg l^{-1}), T_8 (10.58 mg l^{-1}), T_3 (10.15 mg l^{-1}), T_2 (10.11 mg l^{-1}), T_{10} (9.65 mg l^{-1}) and T_1 (9.45 mg l^{-1}).

The pooled mean over the two seasons revealed that T_2 recorded the maximum potassium content (76.36 mg l^{-1}) which was on par with T_9 (75.00 mg l^{-1}), T_3 (74.86 mg l^{-1}), T_6 (74.49 mg l^{-1}), T_8 (73.48 mg l^{-1}), T_4 (73.38 mg l^{-1}). It was followed by T_5 (71.48 mg l^{-1}), T_7 (69.82 mg l^{-1}), T_1 (69.23 mg l^{-1}) and T_{10} (67.60 mg l^{-1}).

The pooled mean over the two seasons revealed that T_2 recorded the maximum calcium content (14.21 mg l^{-1}) which was on par with T_6 (12.39 mg l^{-1}), T_3 (12.38 mg l^{-1}), T_9 (12.33 mg l^{-1}), T_5 (12.20 mg l^{-1}). It was followed by T_1 (10.60 mg l^{-1}), T_2 (10.52 mg l^{-1}), T_4 (10.17 mg l^{-1}), T_7 (5.85 mg l^{-1}) and T_8 (4.82 mg l^{-1}).

The pooled mean over the two seasons revealed that T_6 recorded the maximum magnesium content (8.53 mg l^{-1}) which was on par with T_9 (8.51 mg l^{-1}), T_5 (8.12 mg l^{-1}), T_8 (7.98 mg l^{-1}), T_7 (7.78 mg l^{-1}) and T_3 (7.76 mg l^{-1}). It was followed by T_2 (7.67 mg l^{-1}), T_4 (7.61 mg l^{-1}), T_1 (7.41 mg l^{-1}) and T_{10} (7.30 mg l^{-1}).

The pooled mean over the two seasons among treatments revealed that T_6 recorded the maximum sulphur content (2.94 mg l^{-1}) of strawberry fruits which was on par with T_5 (2.88 mg l^{-1}) and T_7 (2.71 mg l^{-1}). It was followed by T_3 (2.36 mg l^{-1}), T_2 (2.04 mg l^{-1}), T_1 (1.97 mg l^{-1}), T_4 and T_8 (1.95 mg l^{-1}), T_9 and T_{10} (1.68 mg l^{-1}).

The pooled mean over the two seasons revealed that different treatments had no significant effect on copper content of strawberry fruits.

The pooled mean over the two seasons revealed that T_2 recorded the maximum iron content (1.95 mg l^{-1}) which was followed by T_4 (1.59 mg l^{-1}) and T_3 (1.40 mg l^{-1}), T_9 (1.29 mg l^{-1}), T_1 (1.28 mg l^{-1}), T_{10} (1.25 mg l^{-1}), T_8 (1.21 mg l^{-1}), T_5 (1.13 mg l^{-1}), T_6 (1.10 mg l^{-1}) and T_7 (0.98 mg l^{-1}).

The pooled mean over the two seasons revealed that T_1 recorded the maximum zinc content (0.20 mg l^{-1}) which was on par with T_5 (0.19 mg l^{-1}). It was followed by T_4 and T_2 (0.16 mg l^{-1}), T_3 (0.15 mg l^{-1}), T_6 (0.13 mg l^{-1}), T_7, T_8 and T_9 (0.10 mg l^{-1}) and T_{10} (0.09 mg l^{-1}).

The pooled mean over the two seasons revealed that T_6 recorded the maximum manganese content (0.26 mg l^{-1}) which was on par with T_3 (0.23 mg l^{-1}). It was followed by T_8 and T_2 (0.22 mg l^{-1}), T_7 and T_4 (0.21 mg l^{-1}), T_5, T_9 and T_{10} (0.20 mg l^{-1}) and T_1 (0.14 mg l^{-1}).

The pooled mean over the two seasons revealed that T_7 recorded the maximum boron content (0.72 mg l^{-1}) which was on par with T_{10} (0.68 mg l^{-1}), T_3 (0.67 mg l^{-1}), T_8 and T_2 (0.64 mg l^{-1}), T_1 and T_9 (0.61 mg l^{-1}), T_6 and T_4 (0.58 mg l^{-1}). It was followed by T_5 (0.30 mg l^{-1}).

4.2.8. Soil analysis

The important physical and chemical properties of soil before and after the experiment are presented in tables 56 and 57, respectively.

4.2.8.1. Soil pH

Soil samples were collected from the site before planting of the crop and recorded a pH of 4.8. After the final harvest, T_8 recorded the highest pH of 5.9 which was followed by T_5 and T_7 (5.6), T_9 (5.5), T_1, T_3, T_4 (5.4), T_6 and T_{10} (5.3) and T_2 (5.2).

Table 56. Chemical properties of the soil at the experimental site before experiment

Parameters	Quantity
pH	4.8
Electrical conductivity (dS m^{-1})	0.04
Organic Carbon (%)	0.83
Available nitrogen (kg ha^{-1})	8.2
Available phosphorus (kg ha^{-1})	11.2
Available potassium (kg ha^{-1})	324.80
Available calcium (mg kg^{-1})	342.63
Available magnesium (mg kg^{-1})	97.13
Available sulphur (mg kg^{-1})	11.93

Table 57. Chemical properties of the soil at the experimental site after experiment

Treatments	pH	EC (dS m^{-1})	Organic Carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available Ca (mg kg^{-1})	Available Mg (mg kg^{-1})	Available S (mg kg^{-1})
10: 50: 20: 50	5.4	0.15	2.0	20.1	147.6	738.53	926.47	285.63	11.41
10: 75:40:75	5.2	0.29	1.84	18.3	118.51	1240.4	834.25	251.63	19.06
10:100:80:100	5.4	0.18	2.0	20.3	181.54	1026.3	918.32	277.32	11.72
20:50:40:100	5.4	0.21	1.95	19.4	150.46	825.94	859.94	260.94	13.6
20:75:80:50	5.6	0.22	2.17	21.6	232.66	848.46	951.47	305.00	20.47
20;100:20:75	5.3	0.21	1.99	19.7	196.35	923.56	755.76	257.69	12.19
30:50:80:75	5.6	0.26	2.28	22.7	352.61	915.49	895.32	343.25	21.88
30:75:20:100	5.9	0.30	2.59	25.6	319.50	1217.78	1228.55	453.82	16.25
30:100:40:50	5.5	0.26	1.98	19.7	265.48	879.16	956.43	307.01	18.29
Control	5.3	0.12	1.63	16.1	70.59	650.72	797.57	228.69	7.35

4.2.8.2. Soil EC

Before planting EC recorded was 0.04 dS m^{-1} and after the final harvest, the highest EC was noted for T_8 (0.30 dS m^{-1}) which was followed by T_2 (0.29 dS m^{-1}), T_9 and T_7 (0.26 dS m^{-1}). The least EC was recorded with T_{10} (0.12 dS m^{-1}).

4.2.8.3. Organic Carbon

The organic carbon content of the soil before planting was 0.83 %. After the final harvest, the highest organic carbon content was recorded in T_8 (2.59 %) followed by T_7 (2.28 %) and T_5 (2.17%). The least organic carbon content was recorded in T_{10} (1.63 %).

4.2.8.4. Available N

Soil samples were collected from the site before planting of the crop and recorded the nitrogen content of 8.2 kg ha^{-1}. After the final harvest, T_8 recorded the maximum available N content of 25.6 kg ha^{-1}which was followed by T_7 (22.7 kg ha^{-1}) and T_5 (21.6 kg ha^{-1}). The least nitrogen content was recorded with T_{10} (16.1 kg ha^{-1})

4.2.8.5. Available P

Soil samples were collected from the site before planting of the crop and recorded the phosphorous content of 11.2 kg ha^{-1}. After the final harvest, T_7 recorded the maximum available P content of 352.61 kg ha^{-1}which was followed by T_8 (319.5 kg ha^{-1}) and T_9 (265.48 kg ha^{-1}). The least phosphorus content was recorded with T_{10} (70.59 kg ha^{-1}).

4.2.8.6. Available K

Before planting available K recorded was 324.80 kg ha^{-1} and after the final harvest, the highest available K content was noted for T_2 (1240.4 kg ha^{-1}) which was followed by T_8 (1217.78 kg ha^{-1}) and T_3 (1026.3 kg ha^{-1}). The least available K was recorded with T_{10} (650.72 kg ha^{-1}).

4.2.8.7. Available Ca

The available Ca content of the soil before planting was recorded as 342.63 mg kg^{-1}. After the final harvest, the maximum available calcium content was recorded in T_8 (1228.55 mg kg^{-1}) followed by T_9 (956.53 mg kg^{-1}) and T_5 (951.47 mg kg^{-1}). The least calcium content was recorded in T_6 (755.76 mg kg^{-1}) which was followed by T_{10} (797.57 mg kg^{-1}).

4.2.8.8. Available Mg

Soil samples were collected from the site before planting of the crop and recorded the available magnesium content of 97.13 mg kg^{-1}. After the final harvest, T_8 recorded the maximum available Mg content of 453.82 mg kg^{-1} which was followed by T_7 (343.25 mg kg^{-1}) and T_9 (307.01 mg kg^{-1}). The least magnesium content was recorded in T_{10} (228.69 mg kg^{-1}).

4.2.8.9. Available S

Before planting available S recorded was 11.93 mg kg^{-1} and after the final harvest, the highest available S content was noted for T_7 (21.88 mg kg^{-1}) which was followed by T_5 (20.47 mg kg^{-1}) and T_2 (19.06 mg kg^{-1}). The least available S was recorded in T_{10} (7.35 mg kg^{-1}).

Table 58. Economics of cultivation of strawberry under different nutrient combinations (100 m^2)

Treatments (T)	Total cost incurred (Rs.)	Total benefit (Rs.)	B/C Ratio
10: 50: 20: 50	15,612.6	9,149.15	0.59
10: 75:40:75	16,092.45	11,822.35	0.73
10:100:80:100	17,037.91	8,966.7	0.53
20:50:40:100	17,109.55	12,320.5	0.72
20:75:80:50	17,987.48	8,837.55	0.49
20;100:20:75	16,644.73	11,387.75	0.68
30:50:80:75	19,005.81	12,777.65	0.67
30:75:20:100	17,926.02	16,383.6	**0.91**
30:100:40:50	18,992.4	15,559.5	0.82
Control	14,090	2,214	0.16

4.2.9. Economics of cultivation

Data corresponding to the economics of cultivation of strawberry fruits grown at Central mid-lands of Kerala are presented in Table 58.

The B/C (Benefit: Cost ratio) was highest in T_8 (0.91) which was followed by T_9 (0.82). The lowest B/C ratio was recorded in T_{10} (0.16).

Experiment -III

4.3. Effect of spacing on growth and yield

This study pertains to the effect of spacing on the growth and yield of strawberry (*Fragaria x ananassa* Duch.) under two agro climatic conditions *viz.*, Central mid-lands and High ranges of Kerala. The influence of different treatments on the vegetative, flowering, yield and quality attributes of strawberry were studied. The main effects of the different spacings i.e., T_1 (30 cm x 60 cm), T_2 (30 cm x 50 cm), T_3 (30 cm x 40 cm), T_4 (30 cm x 30 cm), T_5 (30 cm x 20 cm), T_6 (20 cm x 20 cm) were studied and presented below.

4.3.1 Vegetative characters

Various observations on growth of strawberry under open condition during two seasons *viz.*, September 2016-March 2017 and September 2017-March 2018 at two locations *viz.*, Central mid-lands and High ranges of Kerala are presented in Tables 59a to 62b.

4.3.1.1 Plant height

Analysis of the data corresponding to the plant height of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala are presented in Tables 59a and 59b.

Table 59a. Effect of different spacings on plant height of strawberry at Central mid-lands of Kerala

Treatments (T)	Plant height (cm)														
	1MAP			2MAP			3MAP			4MAP			5MAP		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II	I	II	II		I	II	
T_1	7.86	8.25	8.05	10.18	11.55	10.87	12.89	13.90	13.39	15.01	15.51	15.26	16.42	16.58	16.50
T_2	8.83	8.76	8.79	11.09	11.85	11.47	13.38	13.30	13.34	15.56	15.15	15.36	17.08	16.43	16.75
T_3	8.16	9.75	8.95	10.83	12.83	11.83	13.51	14.45	13.98	15.83	15.95	15.89	17.74	16.86	17.30
T_4	8.95	9.42	9.18	10.90	12.60	11.75	13.93	14.40	14.17	16.50	15.82	16.16	18.02	17.14	17.58
T_5	8.90	8.19	8.54	11.46	11.83	11.64	14.39	14.60	14.49	16.40	15.88	16.14	17.92	17.70	17.81
T_6	8.01	9.37	8.69	11.58	12.95	12.27	14.16	14.95	14.55	16.27	16.36	16.31	18.35	17.94	18.15
CD			NS			NS			NS			0.66			0.59

Table 59b. Effect of different spacings on plant height of strawberry at High ranges of Kerala

Treatments (T)	Plant height (cm)														
	1MAP			2MAP			3MAP			4MAP			5MAP		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II		I	II		I	II	
T_1	7.85	11.00	9.42	11.75	11.75	11.75	14.02	13.35	13.69	16.03	16.10	16.06	18.23	17.30	17.76
T_2	8.43	11.40	9.92	11.08	12.30	11.69	14.94	13.30	14.12	16.92	13.45	15.19	18.38	14.70	16.54
T_3	8.15	11.05	9.60	12.52	13.05	12.78	15.14	13.45	14.30	18.23	15.30	16.76	20.41	16.45	18.43
T_4	8.82	10.90	9.86	12.24	12.65	12.44	14.69	13.10	13.89	17.14	14.90	16.02	18.66	15.45	17.06
T_5	8.38	12.60	10.49	12.88	12.85	12.86	16.55	13.90	15.22	19.25	15.05	17.15	20.90	15.95	18.42
T_6	8.70	11.45	10.07	12.11	12.85	12.48	16.58	14.60	15.59	19.78	16.15	17.96	22.09	18.65	20.37
CD			NS			NS			NS			NS			NS

Central mid-lands of Kerala

At first, second and third months after planting, the spacing did not have significant effect on plant height of strawberry. At 4 MAP, T_6 recorded the maximum height of 16.31 cm which was on par with T_4 (16.16 cm), T_5 (16.14 cm) and T_3 (15.89 cm). It was followed by T_2 (15.36 cm) and T_1 (15.26 cm). At 5 MAP, T_6 recorded the maximum height of 18.15 cm which was on par with T_5 (17.81 cm) and T_4 (17.58 cm). It was followed by T_3 (17.30 cm), T_2 (16.75 cm) and T_1 (16.50 cm).

High ranges of Kerala

The spacing did not have significant effect on plant height of strawberry.

4.3.1.2 Number of leaves

The data depicting the number of leaves of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala are presented in Tables 60a and 60b.

Central mid-lands of Kerala

At 1 MAP, T_6 recorded the maximum number of leaves (8.26) which was on par with T_4 (7.61) and T_1 (7.35). It was followed by T_2 (7.03), T_5 (6.96) and T_3 (6.27). At 2 MAP, T_5 recorded the maximum number of leaves (14.55) which was on par with T_6 (13.29). It was followed by T_1 (12.88), T_4 (12.46), T_3 (12.22) and T_2 (11.71). At 3 MAP, T_5 recorded the maximum number of leaves (22.39) which was on par with T_6 (22.04). It was followed by T_4 (20.35), T_2 (20.21), T_3 (19.85) and T_1 (19.81). At 4 MAP, T_6 recorded the maximum number of leaves (29.42) which was on par with T_5 (29.18). It was followed by T_4 (27.05), T_1 (25.60), T_3 (24.96) and T_2 (24.78). At 5 MAP, T_6 recorded the maximum number of leaves (31.80) which was on par with T_5 (31.40). It was followed by T_4 (29.46), T_1 (28.04), T_3 (27.62) and T_2 (27.59).

Table 60a. Effect of different spacings on number of leaves per plant of strawberry at Central mid-lands of Kerala

Treatments (T)	Number of leaves														
	1MAP			2MAP			3MAP			4MAP			5MAP		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II	I	II	II		I	II	
T_1	9.40	5.30	7.35	13.63	12.13	12.88	20.61	19.02	19.81	25.09	26.12	25.60	27.62	28.46	28.04
T_2	8.36	5.70	7.03	12.13	11.28	11.71	20.72	19.69	20.21	23.91	25.65	24.78	27.56	27.62	27.59
T_3	7.23	5.30	6.27	12.61	11.83	12.22	19.19	20.51	19.85	23.91	26.01	24.96	26.46	28.78	27.62
T_4	8.56	6.65	7.61	12.84	12.08	12.46	19.96	20.74	20.35	26.55	27.55	27.05	28.82	30.10	29.46
T_5	7.63	6.30	6.96	15.69	13.42	14.55	21.87	22.92	22.39	28.47	29.89	29.18	30.60	32.20	31.40
T_6	8.46	8.05	8.26	12.10	14.48	13.29	20.85	23.24	22.04	28.62	30.22	29.42	30.91	32.70	31.80
CD			1.10			1.5			1.72			1.32			1.25

Table 60b. Effect of different spacings on number of leaves per plant of strawberry at High ranges of Kerala

Treatments (T)	Number of leaves														
	1MAP			2MAP			3MAP			4MAP			5MAP		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II		I	II		I	II	
T_1	4.37	7.53	5.95	9.61	8.25	8.93	16.56	17.20	16.88	20.97	21.90	21.44	19.50	18.10	18.80
T_2	4.68	7.55	6.12	8.63	8.05	8.34	13.60	14.40	14.00	20.27	19.25	19.76	18.70	18.35	18.53
T_3	4.60	7.75	6.17	8.30	9.00	8.65	14.68	16.90	15.79	22.32	23.75	23.03	22.33	14.35	18.34
T_4	5.58	7.70	6.64	10.63	10.35	10.49	13.66	15.54	14.60	18.06	17.75	17.91	21.72	16.75	19.24
T_5	5.53	6.95	6.24	8.61	7.60	8.11	15.94	14.05	14.99	20.21	16.65	18.43	21.55	20.03	20.79
T_6	5.40	7.45	6.42	10.53	8.60	9.56	21.54	17.65	19.59	24.16	22.40	23.28	22.73	21.40	22.07
CD			NS			1.36			3.43			3.28			NS

High ranges of Kerala

At 1 MAP, different spacings had no significant effect on number of leaves per plant. At 2 MAP, T_4 recorded the maximum number of leaves per plant (10.49) which was on par with T_6 (9.56). It was followed by T_1 (8.93). T_3 (8.65), T_2 (8.34) and T_5 (8.11). At 3 MAP, T_6 recorded the maximum number of leaves (19.59) which was on par with T_1 (16.88). It was followed by T_3 (15.79), T_5 (14.99), T_4 (14.60) and T_2 (14.00). At 4 MAP, T_6 recorded the maximum number of leaves (23.28) which was on par with T_3 (23.03) and T_1 (21.44). It was followed by T_2 (19.76), T_5 (18.43) and T_4 (17.91). At 5 MAP, different spacings had no significant effect on number of leaves per plant.

4.3.1.3 Plant spread

The data depicting the plant spread of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala are presented in Tables 61a and 61b.

Central mid-lands of Kerala

At 1 MAP, the different spacings had no significant effect on plant spread. At 2 MAP, T_6 recorded the maximum plant spread (19.58 cm) which was followed by T_4 (16.82 cm), T_5 (16.65 cm), T_2 (15.79 cm), T_3 (15.78 cm) and T_1 (15.49 cm). At 3 MAP, T_6 recorded the maximum plant spread (23.79 cm) which was on par with T_4 (22.91 cm). It was followed by T_5 (20.69 cm), T_2 (20.53 cm), T_1 (20.33 cm) and T_3 (20.02 cm). At 4 MAP, T_4 recorded the maximum plant spread (28.21 cm) which was on par with T_6 (27.08 cm). It was followed by T_5 (25.74 cm), T_1 (25.16 cm), T_3 (25.00 cm), T_2 (24.77 cm). At 5 MAP, T_4 recorded the maximum plant spread (32.67 cm) which was followed by T_6 (30.12 cm), T_5 (29.78 cm), T_1 (29.62 cm), T_2 (29.51 cm) and T_3 (29.28 cm).

Table 61a. Effect of different spacings on plant spread of strawberry at Central mid-lands of Kerala

Treatments (T)	Plant spread (cm)														
	1MAP			2MAP			3MAP			4MAP			5MAP		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II	I	II	II		I	II	
T_1	11.16	13.40	12.28	15.64	15.33	15.49	20.18	20.47	20.33	24.80	25.53	25.16	28.56	30.69	29.62
T_2	10.58	14.40	12.49	15.19	16.40	15.79	20.81	20.24	20.53	25.48	24.07	24.77	29.35	29.67	29.51
T_3	11.22	10.66	10.94	16.23	15.33	15.78	21.47	18.58	20.02	26.79	23.21	25.00	30.35	28.21	29.28
T_4	11.23	10.36	10.80	15.96	17.68	16.82	21.67	24.15	22.91	26.18	30.24	28.21	30.94	34.39	32.67
T_5	11.37	11.23	11.30	15.71	17.60	16.65	19.96	21.43	20.69	25.79	25.69	25.74	29.97	29.59	29.78
T_6	10.97	9.64	10.31	19.90	19.25	19.58	24.02	23.56	23.79	28.03	26.13	27.08	30.83	29.41	30.12
CD			NS			1.80			1.91			1.93			1.42

Table 61b. Effect of different spacings on plant spread of strawberry at High ranges of Kerala

Treatments (T)	Plant spread (cm)														
	1MAP			2MAP			3MAP			4MAP			5MAP		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II		I	II		I	II	
T_1	9.61	8.10	8.86	17.31	19.73	18.52	23.09	23.38	23.23	26.41	25.33	25.87	29.21	28.25	28.73
T_2	11.03	9.35	10.19	17.63	17.88	17.75	22.61	21.55	22.08	25.28	22.77	24.02	26.45	23.08	24.76
T_3	9.31	8.88	9.09	17.73	18.45	18.09	22.00	22.83	22.41	29.44	24.25	26.84	32.16	27.90	30.03
T_4	11.89	9.98	10.93	16.66	19.05	17.85	21.80	20.50	21.15	25.44	22.15	23.79	27.60	24.00	25.80
T_5	10.94	8.68	9.81	18.22	19.73	18.97	23.31	21.10	22.21	29.36	22.25	25.81	32.77	26.98	29.87
T_6	10.87	10.08	10.47	20.00	18.40	19.20	26.41	20.00	23.21	30.00	25.20	27.60	33.21	26.83	30.02
CD			1.28			NS			NS			NS			3.17

High ranges of Kerala

At 1 MAP, T_4 recorded the maximum plant spread (10.93 cm) which was on par with T_6 (10.47 cm), T_2 (10.19 cm) and T_5 (9.81 cm). It was followed by T_3 (9.09 cm) and T_1 (8.86 cm). At 2 MAP, 3 MAP and 4 MAP, different spacings had no significant effect on plant spread. At 5 MAP, T_3 recorded the maximum plant spread (30.03 cm) which was on par with T_6 (30.02 cm), T_5 (29.87 cm) and T_1 (28.73 cm). It was followed by T_4 (25.80 cm) and T_2 (24.76 cm).

4.3.1.4 Number of crowns

The data depicting the number of crowns of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala are presented in Tables 62a and 62b.

Central mid-lands of Kerala

At 1 MAP, different spacings had no significant effect on number of crowns of strawberry. At 2 MAP, T_6 recorded significantly highest number of crowns (1.53) which was on par with T_5 (1.38). It was followed by T_4 (1.30), T_1 (1.28), T_2 (1.20) and T_3 (1.13). At 3 MAP, T_6 recorded the maximum number of crowns (3.10) which was on par with T_5 (2.68). It was followed by T_4 (2.65), T_3 (2.50), T_1 (2.20) and T_2 (2.15). At 4 MAP, T_6 recorded the maximum number of crowns (4.63) which was on par with T_5 (4.15) and T_4 (3.98). It was followed by T_3 (3.48), T_2 (3.18) and T_1 (2.90). At 5 MAP, T_6 recorded the maximum number of crowns (5.65) and was on par with T_5 (5.43) and T_4 (5.23). It was followed by T_3 (4.45), T_2 (3.90) and T_1 (3.88).

High ranges of Kerala

At 1 MAP and 2 MAP, different spacings had no significant effect on the number of crowns. At 3 MAP, T_1 recorded the maximum number of crowns (2.60) which was on par with T_3 (2.50), T_6 (2.33) and T_4 (2.28). It was followed by T_5 (1.90)

Table 62a. Effect of different spacings on number of crowns per plant of strawberry at Central mid-lands of Kerala

Treatments (T)	Number of crowns														
	1MAP			2MAP			3MAP			4MAP			5MAP		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II	I	II	II		I	II	
T_1	1	1	1	1.15	1.40	1.28	1.80	2.60	2.20	2.60	3.20	2.90	3.80	3.95	3.88
T_2	1	1	1	1.15	1.25	1.20	1.65	2.65	2.15	3.00	3.35	3.18	3.65	4.15	3.90
T_3	1	1	1	1.15	1.10	1.13	2.60	2.40	2.50	3.55	3.40	3.48	4.45	4.45	4.45
T_4	1	1	1	1.20	1.40	1.30	2.50	2.80	2.65	4.15	3.80	3.98	5.20	5.25	5.23
T_5	1	1	1	1.30	1.45	1.38	2.55	2.80	2.68	4.00	4.30	4.15	5.30	5.55	5.43
T_6	1	1	1	1.40	1.65	1.53	3.40	2.80	3.10	4.90	4.35	4.63	5.55	5.75	5.65
CD			NS			0.21			0.43			0.64			0.68

Table 62b. Effect of different spacings on number of crowns per plant of strawberry at High ranges of Kerala

Treatments (T)	Number of crowns														
	1MAP			2MAP			3MAP			4MAP			5MAP		
	Years		Mean	Years		Mean	Years		Mean	Years		Mean	Years		Mean
	I	II		I	II		I	II	I	II	II		I	II	
T_1	1.00	1.00	1.00	1.45	1.40	1.43	2.50	2.70	2.60	2.70	2.50	2.60	3.35	3.25	3.30
T_2	1.00	1.00	1.00	1.30	1.30	1.30	1.65	1.70	1.68	2.90	2.65	2.78	3.40	3.30	3.35
T_3	1.00	1.00	1.00	1.40	1.50	1.45	2.55	2.45	2.50	3.30	3.35	3.33	4.10	4.15	4.13
T_4	1.00	1.00	1.00	1.30	1.30	1.30	2.30	2.25	2.28	2.20	2.05	2.13	2.95	2.85	2.90
T_5	1.00	1.00	1.00	1.50	1.25	1.38	1.95	1.85	1.90	2.55	2.45	2.50	3.05	2.85	2.95
T_6	1.00	1.00	1.00	1.20	1.20	1.20	2.50	2.15	2.33	3.25	2.85	3.05	3.80	3.55	3.68
CD			NS			NS			0.45			0.50			0.47

and T_2 (1.68). At 4 MAP, T_3 recorded the maximum number of crowns (3.33) which was on par with T_6 (3.05). It was followed by T_2 (2.78), T_1 (2.60), T_5 (2.50) and T_4 (2.13). At 5 MAP, T_3 recorded the maximum number of crowns (4.13) which was on par with T_6 (3.68). It was followed by T_2 (3.35), T_1 (3.30), T_5 (2.95) and T_4 (2.90).

4.3.2 Flowering attributes

4.3.2.1 Days to first flowering

Analysis of the data corresponding to days to first flowering of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala in two seasons are presented in Table 63.

Central mid-lands of Kerala

Days to first flowering did not vary significantly among different spacings. T_4 recorded the minimum number of days to first flowering (53.26 days). Maximum number of days to first flowering was recorded by T_3 (57.38 days).

High ranges of Kerala

Days to first flowering did not vary significantly among different spacings. T_5 recorded the minimum number of days to first flowering (64.88 days). Maximum number of days to first flowering was recorded by T_2 (72.88 days).

4.3.2.2 Number of clusters per plant

Analysis of the data corresponding to number of clusters per plant of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala in two locations are presented in Table 64.

Table 63. Effect of different spacings on days to first flowering of strawberry

Treatments (T)	Days to first flowering (Days)					
	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	58.75	55.50	57.13	73.25	69.50	71.38
T_2	57.45	53.76	55.61	73.25	72.50	72.88
T_3	59.00	55.75	57.38	69.25	72.00	70.63
T_4	55.13	51.40	53.26	69.50	69.75	69.63
T_5	58.00	54.88	56.44	64.00	65.75	64.88
T_6	55.95	50.78	53.37	71.75	69.50	70.63
CD			NS			NS

Table 64.Effect of different spacings on number of clusters per plant of strawberry

Treatments (T)	Number of clusters per plant					
	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	5.43	5.20	5.31	6.30	7.65	6.98
T_2	5.50	5.43	5.46	8.06	4.65	6.36
T_3	4.98	4.88	4.93	10.89	10.92	10.90
T_4	5.65	5.73	5.69	10.17	9.96	10.06
T_5	6.38	6.53	6.45	11.25	11.05	11.15
T_6	6.63	6.73	6.68	12.24	11.93	12.08
CD			0.30			1.13

Table 65. Effect of different spacings on number of flowers per plant of strawberry

Treatments (T)	Number of flowers per plant					
	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	8.70	8.31	8.50	21.95	19.88	20.91
T_2	7.45	7.23	7.34	19.65	19.10	19.38
T_3	8.10	8.22	8.16	22.30	22.60	22.45
T_4	9.95	10.28	10.11	19.25	18.60	18.93
T_5	10.36	10.78	10.57	26.45	26.00	26.23
T_6	11.47	11.30	11.38	30.15	27.60	28.88
CD			0.33			4.3

Central mid-lands of Kerala

Among multiple spacings, T_6 recorded significantly maximum number of clusters per plant (6.68) which was on par with T_5 (6.45). It was followed by T_4 (5.69), T_2 (5.46), T_1 (5.31) and T_3 (4.93).

High ranges of Kerala

T_6 recorded significantly maximum number of clusters per plant (12.08) which was on par with T_5 (11.15). It was followed by T_3 (10.90), T_4 (10.06), T_1 (6.98) and T_2 (6.36).

4.3.2.3 Number of flowers per plant

Analysis of the data corresponding to number of flowers of strawberry at two locations *viz.,* Central mid-lands and High ranges of Kerala in two locations are presented in Tables 65.

Central mid-lands of Kerala

T_6 recorded significantly maximum number of flowers per plant (11.38) which was followed by T_5 (10.57), T_4 (10.11), T_1 (8.50), T_3 (8.16) and T_2 (7.34).

High ranges of Kerala

T_6 recorded maximum number of flowers per plant (28.88) which was on par with T_5 (26.23). It was followed by T_3 (22.45), T_1 (20.91), T_2 (19.38) and T_4 (18.93).

4.3.3. Yield attributes

4.3.3.1 Number of fruits per plant

Analysis of the data corresponding to number of fruits per plant of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala in two locations are presented in Tables 66.

Central mid-lands of Kerala

T_6 recorded significantly maximum number of fruits per plant (9.36) which was followed by T_5 (7.86), T_4 (6.37), T_3 (5.23), T_1 (4.72) and T_2 (4.45).

High ranges of Kerala

T_6 recorded significantly maximum number of fruits per plant (26.35) which was on par with T_5 (23.78). It was followed by T_3 (21.40), T_1 (18.28), T_2 (17.44) and T_4 (16.74).

4.3.3.2 Fruit length

Analysis of the data corresponding to fruit length of strawberry at two locations *viz.*, Central mid-lands (22.25 m above MSL) and High ranges (1000 m above MSL) of Kerala in two locations are presented in Tables 67.

Central mid-lands of Kerala

T_1 recorded significantly maximum fruit length (3.51 cm) which was on par with T_2 (3.46 cm). It was followed by T_6 (3.15 cm), T_4 (3.14 cm), T_5 (3.06 cm) and T_3 (3.05 cm).

Table 66. Effect of different spacings on number of fruits per plant of strawberry

Treatments (T)	Number of fruits per plant					
	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	4.83	4.62	4.72	18.50	18.05	18.28
T_2	4.28	4.63	4.45	17.85	17.03	17.44
T_3	5.08	5.38	5.23	21.70	21.10	21.40
T_4	6.41	6.33	6.37	17.40	16.08	16.74
T_5	7.81	7.90	7.86	24.20	23.35	23.78
T_6	9.35	9.38	9.36	27.75	24.95	26.35
CD			0.20			4.21

Table 67. Effect of different spacings on fruit length of strawberry

Treatments (T)	Fruit length (cm)					
	Central mid la nds			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	3.50	3.53	3.51	4.20	4.08	4.14
T_2	3.43	3.50	3.46	3.88	3.73	3.80
T_3	3.00	3.10	3.05	3.70	3.58	3.64
T_4	3.13	3.15	3.14	3.80	3.63	3.71
T_5	3.05	3.08	3.06	4.10	3.93	4.01
T_6	3.15	3.15	3.15	3.65	3.53	3.59
CD			0.30			0.30

Table 68. Effect of different spacings on fruit breadth of strawberry

Treatments (T)	Fruit breadth (cm)					
	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	3.13	3.10	3.11	3.40	3.35	3.38
T_2	3.53	3.65	3.59	3.43	3.35	3.39
T_3	2.98	3.13	3.05	3.43	3.25	3.34
T_4	3.25	3.33	3.29	3.28	3.13	3.20
T_5	2.83	3.03	2.93	3.23	3.18	3.20
T_6	3.20	3.28	3.24	3.20	3.18	3.19
CD			0.30			NS

High ranges of Kerala

T_1 recorded significantly maximum fruit length (4.14 cm) which was on par withT_5 (4.01 cm). It was followed by T_2 (3.80 cm), T_4 (3.71 cm), T_3 (3.64 cm) and T_6 (3.59 cm).

4.3.3.3 Fruit breadth

Analysis of the data corresponding to fruit breadth of strawberry at two locations *viz.,* Central mid-lands and High ranges of Kerala in two locations are presented in Tables 68.

Central mid-lands of Kerala

T_2 recorded significantly maximum fruit breadth (3.59 cm) which was on par with T_4 (3.29 cm). It was followed by T_6 (3.24 cm), T_1 (3.11 cm), T_3 (3.05 cm) and T_5 (2.93 cm).

High ranges of Kerala

Spacings had no significant effect on fruit breadth of strawberry.

4.3.3.4 Average fruit weight

Analysis of the data corresponding to fruit breadth of strawberry at two locations *viz.,* Central mid-lands and High ranges of Kerala in two locations are presented in Tables 69.

Central mid-lands of Kerala

T_1 recorded significantly maximum average fruit weight (13.04 g) which was followed by T_2 (11.66 g), T_4 (10.78 g), T_6 (10.68 g), T_3 (9.70 g) and T_5 (9.48 g).

High ranges of Kerala

T_1 recorded significantly maximum average fruit weight of 12.67 g which was on par with T_2 (12.31 g). It was followed by T_3 (10.48 g), T_4 (11.04 g), T_5 (10.01 g) and T_6 (10.38 g).

4.3.3.5 Days to first harvest

Analysis of the data corresponding to minimum number of days to first harvest at two locations *viz.,* Central mid-lands and High ranges of Kerala in two locations are presented in Tables 70.

Central mid-lands of Kerala

Spacings had no significant effect on number of days to first harvest of strawberry. However T_6 (77.37 days) recorded minimum number of days to first harvest and T_3 (81.38 days) recorded maximum number of days to first harvest.

High ranges of Kerala

Spacings had no significant effect on number of days to first harvest of strawberry. However T_5 (88.88 days) recorded minimum number of days to first harvest and T_2 (96.88 days) recorded maximum number of days to first harvest.

4.3.3.6 Days to final harvest

Analysis of the data corresponding to maximum number of days to final harvest of strawberry at two locations *viz.,* Central mid-lands (22.25 m above MSL) and High ranges (1000 m above MSL) of Kerala in two locations are presented in Tables 71.

Central mid-lands of Kerala

Spacings had no significant effect on number of days to final harvest of strawberry.

Table 69. Effect of different spacings on average fruit weight of strawberry

Treatments (T)	Average fruit weight (g)					
	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	12.98	13.09	13.04	12.85	12.48	12.67
T_2	11.76	11.57	11.66	12.56	12.06	12.31
T_3	9.72	9.69	9.70	10.85	10.11	10.48
T_4	10.78	10.79	10.78	11.47	10.61	11.04
T_5	9.47	9.49	9.48	10.33	9.69	10.01
T_6	10.65	10.71	10.68	10.96	9.81	10.38
CD			0.59			0.54

Table 70. Effect of different spacings on days to first harvest of strawberry

Treatments (T)	Days to first harvest (days)					
	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	82.75	79.50	81.13	97.25	93.50	95.38
T_2	81.45	77.95	79.70	97.25	96.50	96.88
T_3	83.00	79.75	81.38	93.25	96.00	94.63
T_4	79.13	76.00	77.56	93.50	93.75	93.63
T_5	82.00	78.88	80.44	88.00	89.75	88.88
T_6	79.95	74.78	77.37	90.75	93.50	92.13
CD			NS			NS

Table 71. Effect of different spacings on days to final harvest of strawberry

Treatments (T)	Days to final harvest (days)					
	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	182.00	182.00	182.00	180.00	180.00	180.00
T_2	182.00	182.00	182.00	180.00	180.00	180.00
T_3	182.00	182.00	182.00	180.00	180.00	180.00
T_4	182.00	182.00	182.00	180.00	180.00	180.00
T_5	182.00	182.00	182.00	180.00	180.00	180.00
T_6	182.00	182.00	182.00	180.00	180.00	180.00
CD			NS			NS

High ranges of Kerala

Spacings had no significant effect on number of days to final harvest of strawberry.

4.3.3.7 Yield

Analysis of the data corresponding to yield of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala in two locations are presented in Tables 72.

Central mid-lands of Kerala

T_6 recorded significantly higher yield of 100.03 g which was followed by T_5 (74.47 g), T_4 (68.63 g), T_1 (61.40 g), T_2 (51.88 g) and T_3 (50.71 g).

High ranges of Kerala

T_6 recorded significantly maximum yield of 271.69 g which was on par with T_5 (237.85 g) and T_1 (231.47 g). It was followed by T_3 (223.87 g), T_2 (214.54 g) and T_4 (186.15 g).

4.3.4 Quality attributes

4.3.4.1 TSS

Analysis of the data corresponding to TSS of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala in two seasons are presented in Table 73.

Central mid-lands of Kerala

T_2 recorded significantly higher TSS of 7.58 ^{0}B which was followed by T_3 (6.24 ^{0}B), T_1 (6.04 ^{0}B), T_5 (4.84 ^{0}B), T_6 (4.81 ^{0}B) and T_4 (4.64 ^{0}B).

Table 72. Effect of different spacings on yield of strawberry

Treatments (T)	Yield (g)					
	Central midlan ds			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	62.40	60.39	61.40	237.89	225.05	231.47
T_2	50.28	53.48	51.88	223.92	205.17	214.54
T_3	49.49	51.93	50.71	234.53	213.22	223.87
T_4	69.03	68.23	68.63	200.49	171.81	186.15
T_5	73.93	75.01	74.47	249.01	226.69	237.85
T_6	99.65	100.41	100.03	299.77	243.62	271.69
CD			3.95			43.4

Table 73. Effect of different spacings on total soluble solids (TSS) of strawberry

Treatments (T)	TSS (^{0}B)					
	Central midlands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	6.98	5.10	6.04	8.32	6.90	7.61
T_2	7.95	7.20	7.58	6.75	6.75	6.75
T_3	6.36	6.11	6.24	8.19	5.40	6.80
T_4	5.16	4.11	4.64	9.38	6.18	7.78
T_5	5.08	4.60	4.84	10.01	7.08	8.54
T_6	4.98	4.65	4.81	8.81	5.48	7.14
CD			1.29			NS

Table 74. Effect of different spacings on acidity of strawberry

Treatments (T)	Acidity (%)					
	Central midlands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	0.53	0.58	0.55	0.48	0.51	0.50
T_2	0.64	0.56	0.60	0.71	0.58	0.64
T_3	1.02	0.88	0.95	0.58	0.37	0.47
T_4	0.59	0.54	0.57	0.64	0.57	0.60
T_5	0.65	0.50	0.57	0.68	0.52	0.60
T_6	0.64	0.63	0.63	0.64	0.64	0.64
CD			0.19			NS

High ranges of Kerala

Spacings had no significant effect on TSS of strawberry fruit.

4.3.4.2 Acidity

Analysis of the data corresponding to acidity of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala in two seasons are presented in Table 74.

Central mid-lands of Kerala

T_1 recorded significantly lower acidity (0.55 %) which was on par with T_4 and T_5 (0.57 %), T_2 (0.60 %) and T_6 (0.63 %). It was followed by T_3 (0.95 %).

High ranges of Kerala

Different spacings had no significant effect on acidity of strawberry fruits. However, the acidity was ranged from 0.47 % (T_3) to 0.64 % (T_2 and T_6).

4.3.4.3 TSS/acidity ratio

Analysis of the data corresponding to TSS/acidity ratio of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala in two seasons are presented in Table 75.

Central mid-lands of Kerala

T_2 recorded significantly higher TSS/acidity ratio of 12.79 which was on par with T_1 (11.32) and T_5 (10.55). It was followed by T_4 (8.65), T_6 (8.49) and T_3 (6.94).

High ranges of Kerala

Different spacings had no significant effect on TSS/acidity ratio of strawberry fruits.

Table 75. Effect of different spacings on TSS/Acidity of strawberry

Treatments (T)	TSS/Acidity					
	Central midlands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	13.78	8.87	11.32	18.05	15.94	16.99
T_2	12.73	12.85	12.79	9.78	12.50	11.14
T_3	6.53	7.35	6.94	14.50	15.81	15.15
T_4	9.85	7.46	8.65	15.27	10.99	13.13
T_5	10.22	10.89	10.55	14.97	15.12	15.05
T_6	9.48	7.50	8.49	15.85	8.58	12.21
CD			3.41			NS

Table 76. Effect of different spacings on total sugars of strawberry

Treatments (T)	Total sugars (%)					
	Central midlands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	5.50	5.60	5.55	5.62	5.12	5.37
T_2	6.53	5.65	6.09	5.13	5.39	5.26
T_3	5.40	5.35	5.38	4.90	4.80	4.85
T_4	5.68	5.98	5.83	4.50	4.76	4.63
T_5	5.00	5.11	5.06	5.14	5.29	5.21
T_6	5.68	5.73	5.70	5.15	5.50	5.33
CD			0.36			0.21

Table 77. Effect of different spacings on ascorbic acid of strawberry

Treatments (T)	Ascorbic acid (mg $100g^{-1}$)					
	Central midlands			High ranges		
	Years		Mean	Years		Mean
T_1	67.47	75.75	71.61	38.42	32.41	35.41
T_2	49.56	42.56	46.06	62.35	55.56	58.96
T_3	40.33	42.56	41.45	38.89	37.20	38.04
T_4	33.12	34.54	33.83	36.91	27.78	32.35
T_5	29.70	30.30	30.00	30.58	29.67	30.13
T_6	26.44	27.78	27.11	23.70	18.52	21.11
CD			1.93			0.94

4.3.4.4 Total Sugars

Analysis of the data corresponding to total sugars content of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala in two seasons are presented in Table 76.

Central mid-lands of Kerala

Among different spacings, T_2 recorded significantly higher total sugars content (6.09 %) which was on par with T_4 (5.83 %). It was followed by T_6 (5.70 %), T_1 (5.55 %), T_3 (5.38 %) and T_5 (5.06 %).

High ranges of Kerala

T_1 recorded significantly higher total sugars content (5.37 %) which was on par with T_6 (5.33 %), T_2 (5.26 %) and T_5 (5.21 %). It was followed by T_3 (4.85 %) and T_4 (4.63 %).

4.3.4.5 Ascorbic acid

Analysis of the data corresponding to ascorbic acid content of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala in two seasons are presented in Table 77.

Central mid-lands of Kerala

T_1 recorded significantly maximum ascorbic acid content (71.61 mg 100 g^{-1}) which was followed by T_2 (46.06 mg 100 g^{-1}), T_3 (41.45 mg 100 g^{-1}), T_4 (33.83 mg 100 g^{-1}), T_5 (30.00 mg 100 g^{-1}) and T_6 (27.11 mg 100 g^{-1}).

High ranges of Kerala

T_2 recorded significantly maximum ascorbic acid content (58.96 mg 100 g^{-1}) which was followed by T_3 (38.04 mg 100 g^{-1}), T_1 (35.41 mg 100 g^{-1}), T_4 (32.35 mg 100 g^{-1}), T_5 (30.13 mg 100 g^{-1}) and T_6 (21.11 mg 100 g^{-1}).

4.3.4.6 Anthocyanin

Analysis of the data corresponding to anthocyanin content of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala in two seasons are presented in Table 78.

Central mid-lands of Kerala

T_1 recorded significantly maximum anthocyanin content (32.66 mg 100 g^{-1}) which was followed by T_3 (30.08 mg 100 g^{-1}), T_4 (28.08 mg 100 g^{-1}), T_2 (23.63 mg 100 g^{-1}), T_6 (16.95 mg 100 g^{-1}) and T_5 (12.79 mg 100 g^{-1}).

High ranges of Kerala

T_4 recorded significantly maximum anthocyanin content (35.93 mg 100 g^{-1}) which was followed by T_5 (30.88 mg 100 g^{-1}), T_6 (29.56 mg 100 g^{-1}), T_2 (26.01 mg 100 g^{-1}), T_3 (24.61 mg 100 g^{-1}) and T_1 (19.94 mg 100 g^{-1}).

4.3.4.7 β - Carotene

Analysis of the data corresponding to β carotene content of strawberry at two locations *viz.*, Central mid-lands and High ranges of Kerala in two seasons are presented in Table 79.

Table 78. Effect of different spacings on anthocyanin content of strawberry

Treatments (T)	Anthocyanin content (mg $100g^{-1}$)					
	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	32.38	32.95	32.66	19.35	20.53	19.94
T_2	23.00	24.25	23.63	25.73	26.30	26.01
T_3	29.88	30.28	30.08	24.30	24.93	24.61
T_4	28.15	28.00	28.08	35.73	36.13	35.93
T_5	13.48	12.10	12.79	31.08	30.68	30.88
T_6	17.58	16.33	16.95	29.45	29.68	29.56
CD			0.5			0.31

Table 79. Effect of different spacings on β-Carotene of strawberry

Treatments (T)	β-Carotene (μg $100g^{-1}$)					
	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	0.66	2.27	1.47	2.01	2.16	2.08
T_2	2.07	2.86	2.46	2.25	2.46	2.36
T_3	2.42	3.18	2.80	1.23	1.58	1.41
T_4	3.31	2.77	3.04	1.63	1.82	1.72
T_5	2.52	2.16	2.34	2.11	2.18	2.15
T_6	2.24	2.49	2.37	2.18	2.41	2.30
CD			0.11			0.04

Table 80. Effect of different spacings on shelf life of strawberry

Treatments (T)	Shelf life (days)					
	Central mid-lands			High ranges		
	Years		Mean	Years		Mean
	I	II		I	II	
T_1	3	3	3	3	3	3
T_2	3	3	3	3	3	3
T_3	3	3	3	3	3	3
T_4	3	3	3	3	3	3
T_5	3	3	3	3	3	3
T_6	3	3	3	3	3	3

Table 81. Effect of different spacings on colour of strawberry fruits

Treatments (T)	Central mid-lands	High ranges
T1	Deep Purplish Pink - 61D	Deep Purplish Pink - 61D
T_1	Deep Purplish Pink - 61D	Deep Purplish Pink - 61D
T_2	Deep Purplish Pink - 61D	Deep Purplish Pink - 61D
T_3	Deep Purplish Pink - 61D	Deep Purplish Pink - 61D
T_4	Deep Purplish Pink - 61D	Deep Purplish Pink - 61D
T_5	Deep Purplish Pink - 61D	Deep Purplish Pink - 61D
T_6	Deep Purplish Pink - 61D	Deep Purplish Pink - 61D

Central mid-lands of Kerala

T_4 recorded significantly maximum β carotene content (3.04 µg $100g^{-1}$) which was followed by T_3 (2.80 µg $100g^{-1}$), T_2 (2.46 µg $100g^{-1}$), T_6 (2.37 µg $100g^{-1}$), T_5 (2.34 µg $100g^{-1}$) and T_1 (1.47 µg $100g^{-1}$).

High ranges of Kerala

T_2 recorded significantly maximum β carotene content (2.36 µg $100g^{-1}$) which was followed by T_6 (2.30 µg $100g^{-1}$), T_5 (2.15 µg $100g^{-1}$), T_1 (2.08 µg $100g^{-1}$), T_4 (1.72 µg $100g^{-1}$) and T_3 (1.41 µg $100g^{-1}$).

4.3.4.8 Shelf life

The data on shelf life of fruit is presented in Table 80. The treatments have no significant effect on shelf life of strawberry. Strawberry fruits in all the treatments have a shelf life of 3 days in both locations. It is evident that most of the strawberry varieties have a maximum shelf life of 3 days when stored in room temperature after harvest at 75 per cent ripened stage.

4.3.4.9 Colour

The data on colour of fruit skin is presented in Table 81. The skin colour was described using Universal Colour Language (UCL) and it was deep purplish pink (61 D) for all treatments.

4.3.4.10 Sensory evaluation

Data corresponding to the sensory evaluation of strawberry fruits grown at two locations *viz.*, Central mid-lands and High ranges of Kerala are presented in Tables 82a and 82b.

In strawberry, the sensory evaluation was carried out on a nine point hedonic scale using score card for eight attributes *viz.*, appearance, colour, texture, flavour, 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 carried out on the same day of harvest by panel of judges.

Central mid-lands of Kerala

During first year, the highest score for appearance was recorded by T_3 (7.2). The highest score for colour was recorded by T_1 (7.5). The highest score for taste was recorded by T_2 (7.43). Highest score for flavour was recorded by T_6 (7.10). Highest score for aroma was recorded by T_3 (6.95). T_6 recorded highest score for texture (6.98). T_2 recorded highest score of 7.30 for overall acceptability.

However during second year, the highest score for appearance was recorded by T_5 (7.43). The highest score for colour was recorded by T_1 (7.65). The highest score for taste was scored by T_2 (7.08). The highest score for flavour was recorded by T_2 (7.28). The highest score for aroma was recorded by T_3 (7.15). T_3 (7.08) recorded the highest score for texture. T_2 (7.05) recorded the highest score for after taste. T_1 recorded highest score of 7.30 for overall acceptability.

Considering total sensory score, T_2 recorded a high sensory score of 56.35 and 56.74 during first year and second year, respectively.

High ranges of Kerala

During first year, T_6 (8.4) recorded the highest score for appearance. Highest score for colour was recorded by T_4 (8.4). T_1 recorded the highest score of 7.8 for taste. Highest score for flavour was recorded by T_1 (7.4). Highest score for aroma was recorded by T_5 (7.1). The highest score for texture was recorded by T_4 (7.6). The

Table 82a. Sensory evaluation of fruits (Central mid-lands)

Treatments (T)	Appearance		Colour		Taste		Flavour		Aroma		Texture		After taste		Overall acceptability	
	Years		Years		Years		Years		Years		Years		Years		Years	
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
T_1	7.1	7.03	7.5	7.65	7.10	6.88	6.55	6.73	6.80	6.83	6.3	6.43	6.43	6.73	6.83	7.30
T_2	6.9	7.25	7.1	7.20	7.43	7.08	7.03	7.28	6.93	7.03	6.93	6.85	6.73	7.05	7.30	7.00
T_3	7.2	7.28	7.3	7.38	6.60	6.80	6.80	6.70	6.95	7.15	6.94	7.08	6.43	6.69	7.03	6.98
T_4	7.1	7.13	7.4	7.33	6.78	6.73	6.68	6.68	6.1	6.13	6.7	6.70	6.45	6.8	6.85	6.88
T_5	6.5	7.43	7.1	7.08	6.30	6.55	6.35	6.83	6.45	7.08	6.9	6.98	6.60	6.48	6.88	6.93
T_6	7.0	7.10	7.1	7.15	6.75	6.83	7.10	7.08	6.48	6.98	6.98	7.00	6.80	6.9	6.55	6.78

Table 82b. Sensory evaluation of fruits (High ranges)

Treatments (T)	Appearance		Colour		Taste		Flavour		Aroma		Texture		After taste		Overall acceptability	
	Years		Years		Years		Years		Years		Years		Years		Years	
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
T_1	8	7.93	7.2	7.10	7.8	7.17	7.4	6.4	6.9	6.67	7.4	7.07	7.7	6.9	8.70	7.83
T_2	7.9	7.60	7.4	7.53	6.7	6.8	6.6	6.8	6.8	6.80	6.5	6.73	7.1	7.2	7.47	7.30
T_3	7.3	7.40	7.3	7.43	6.6	6.9	7.1	6.8	5.9	6.80	6.6	6.70	6.6	6.9	7.20	7.17
T_4	7.4	7.10	8.4	7.80	7.1	7.0	6.9	6.8	6.5	7.40	7.6	6.80	7.3	6.9	7.70	7.50
T_5	8	7.70	8.2	8.10	7.3	7.4	7.1	7.3	7.1	7.20	7.4	7.30	6.8	7.1	7.60	7.40
T_6	8.4	8.20	7.6	7.50	6.6	7.0	6.5	6.9	6.9	6.90	6.5	6.80	6.3	7.1	7.30	7.20

highest score for after taste was recorded by T_1 (7.7). T_1 recorded the highest score of 8.7 for overall acceptability.

During second year, T_6 recorded the highest score of 8.2 for appearance. T_5 (8.1) recorded the maximum score for colour. T_5 (7.4) recorded maximum score for taste. T_5 (7.3) recorded maximum score for flavour. T_4 (7.4) recorded maximum score for aroma. T_5 recorded maximum score of 7.3 for texture. T_2 recorded maximum score of 7.2 for after taste. Highest score for overall acceptability was recorded by T_1 (7.83).

Considering total sensory score, T_1 recorded a high sensory score of 61.10 and 57.07 during first year and second year respectively.

4.3.5. Pest and disease incidence and severity

The incidence of pest and disease severity was shown in Table 83.

Central mid-lands of Kerala

During the entire period of study, termite was a severe pest which attacked the fibrous roots that would lead to the sudden death of plants within 4-5 days. It was controlled by soil drenching with Chlorpyriphos @ 4ml per litre. Other pests such as Black looper - *Hyposidra talaca* (Family: Geometridae), Hairy caterpillar- *Orgyia postica* (Lymantidae), Leaf tip roller – *Archis semiferanus* (Family: Torticidae) and Fruit borer were only minor pests and there severity is less than 1%. These pests were controlled by spraying with Quinalphos 25 %EC @ 2ml per litre. During the entire period of study, disease was not a severe problem. Nearly 3 % plants got lost because of Fusarium crown rot. Other diseases which was of minor importance was *Alternaria alternata* leaf spot and *Pestalotiopsis longisetula* leaf spot which was controlled by the soil drenching with Copper Hydroxide @ 2 g per litre.

Table 83. Pest and Disease incidence and severity

Sl. No.	Central mid-lands			High Ranges	
	Pests	Scale of attack (0-9)	Description	Scale of attack (0-9)	Description
1	Termites (*Coptotermes formosanus*)	7	High/severe attack	0	No attack
2	Black looper (*Hyposidra talaca*)	1	Very low or no visible sign of susceptability	1	Very low or no visible sign of susceptability
3	Hairy Caterpillar (*Orgyia postica*)	1	Very low or no visible sign of susceptability	0	No attack
4	Leaf tip roller (*Archis semiferanus*)	1	Very low or no visible sign of susceptability	0	No attack
5	Fruit borer (*Meridarchis scyrodes*)	0	No attack	1	Very low or no visible sign of susceptability
6	Mealy bug (*Pseudococcidae*)	3	Low	0	No attack
	Diseases				
7	Fusarium crown rot (*Fusarium oxysporum*)	7	High/severe attack	1	Very low or no visible sign of susceptability
8	Leaf spot (*Alternaria alternata*)	3	Low	3	Low
9	Leaf spot (*Pestalotiopsis longisetula*)	3	Low	0	No attack

Table 84a. Economics of cultivation of strawberry under different spacings (Central mid-lands)

Treatments (T)	Total cost incurred (Rs)	Total benefit (Rs)	B/C Ratio
T_1	16,987.48	12,587	0.74
T_2	16,987.48	10,635.4	0.63
T_3	16,987.48	10,395.55	0.61
T_4	16,987.48	14,069.15	0.83
T_5	16,987.48	15,266.35	0.90
T_6	16,987.48	20,506.15	**1.21**

Table 84b. Economics of cultivation of strawberry under different spacings (High ranges)

Treatments (T)	Total cost incurred (Rs)	Total benefit (Rs)	B/C Ratio
T_1	16,987.48	47,451.35	2.79
T_2	16,987.48	43,980.7	2.59
T_3	16,987.48	45,893.35	2.70
T_4	16,987.48	38,160.75	2.25
T_5	16,987.48	48,759.25	2.87
T_6	16,987.48	55,696.45	**3.28**

High ranges of Kerala

During the entire period of study, there was not much incidence of pests and diseases. Peats such as looper, fruit borer were only minor pests there.

Disease incidence and severity was very low, nearly less than 1%. Only *Alternaria alternata* leaf spot was a minor disease there.

4.3.6. Economics of cultivation

Data corresponding to the economics of cultivation of strawberry fruits grown at two locations *viz.,* Central mid-lands and High ranges of Kerala are presented in Table 84a and 84b.

In Central mid-lands, the B/C (Benefit: Cost ratio) was highest in T_6 (1.21) which was followed by T_5 (0.90). The lowest B/C ratio was recorded in T_3 (0.61).

In High ranges, the B/C (Benefit: Cost ratio) was highest in T_6 (3.28) which was followed by T_5 (2.87). The lowest B/C ratio was recorded in T_4 (2.25).

Experiment-IV

4.4 Evaluating different growing systems for home-gardening

This study pertains to the effect of growing systems and media on the growth and yield of strawberry (*Fragaria x ananassa* Duch.) under the agro climatic conditions of Central mid-lands of Kerala. The influence of different treatments on the vegetative, flowering, yield and quality attributes of strawberry were studied. Evaluation of different growing systems and growing media in the ratio of 1:1:1 i.e., S_1M_1 (Hanging pots with Soil: Cocopeat: FYM); S_1M_2 (Hanging pots with Soil: Cocopeat: Vermicompost); S_1M_3 (Hanging pots with Cocopeat: Perlite: FYM); S_1M_4 (Hanging pots with Cocopeat: Perlite: Vermicompost); S_2M_1 (Hanging pipes with Soil:

Cocopeat: FYM); S_2M_2 (Hanging pipes with Soil: Cocopeat: Vermicompost); S_2M_3 (Hanging pipes with Cocopeat: Perlite: FYM); S_2M_4 (Hanging pipes with Cocopeat: Perlite: Vermicompost); S_3M_1 (Hanging bottles with Soil: Cocopeat: FYM); S_3M_2 (Hanging bottles with Soil: Cocopeat: Vermicompost); S_3M_3 (Hanging bottles with Cocopeat: Perlite: FYM); S_3M_4 (Hanging bottles with Cocopeat: Perlite: Vermicompost); S_4M_1 (Vertical garden with Soil: Cocopeat: FYM); S_4M_2 (Vertical garden with Soil: Cocopeat: Vermicompost); S_4M_3 (Vertical garden with Cocopeat: Perlite: FYM); S_4M_4 (Vertical garden with Cocopeat: Perlite: Vermicompost); S_5M_1 (Grow bags with Soil: Cocopeat: FYM); S_5M_2 (Grow bags with Soil: Cocopeat: Vermicompost); S_5M_3 (Grow bags with Cocopeat: Perlite: FYM); S_5M_4 (Grow bags with Cocopeat: Perlite: Vermicompost); S_6M_1 (Raised bed with Soil: Cocopeat: FYM); S_6M_2 (Raised bed with Soil: Cocopeat: Vermicompost); S_6M_3 (Raised bed with Cocopeat: Perlite: FYM) and S_6M_4 (Raised bed with Cocopeat: Perlite: Vermicompost) were studied and presented below.

4.4.1 Vegetative characters

Various observations on growth of strawberry under open condition in six growing systems *viz.*, Hanging pots (S_1), Hanging pipes (S_2), Hanging bottles (S_3), Vertical garden (S_4), Grow bags (S_5), Raised beds (S_6) with four growing media in ratio 1:1:1 *viz.*, Soil: Cocopeat: FYM (M_1), Soil: Cocopeat: Vermicompost (M_2), Cocopeat: Perlite: FYM (M_3), Cocopeat: Perlite: Vermicompost (M_4) during one season (September 2017-March 2018) at Central mid-lands of Kerala were recorded, analyzed and the results are presented in Tables 86-89.

4.4.1.1 Plant height

Analysis of the data corresponding to the plant height of strawberry at Central midlands of Kerala during September 2017-March 2018 are presented in Table 85.

At 1 MAP, the plant height under each growing system was observed to be highest in S_6 (9.45 cm) which was on par with S_5 (9.09 cm) and S_2 (8.87 cm). The lowest plant height was recorded in S_3 (6.92 cm). At 2 MAP, the highest plant height of 13.81 cm was recorded in S_2. It was followed by S_5 (12.45 cm), S_6 (12.40 cm), S_4 (10.96 cm), S_1 (10.75 cm) and S_3 (10.13 cm). At 3 MAP, the highest plant height of 16.92 cm was observed in S_2 which was on par with S_5 (15.76 cm). The lowest plant height of 12.66 cm was recorded in S_3. At 4 MAP, the plant height was observed to be highest in S_2 (18.03 cm) which was followed by S_5 (16.65 cm), S_6 (15.90 cm), S_1 (15.33 cm), S_4 (14.78 cm) and S_3 (13.72 cm). At 5 MAP, the plant height was observed to be highest in S_2 (19.25 cm) which was followed by S_6 (17.84 cm), S_5 (17.36 cm), S_1 (16.85 cm), S_4 (16.55 cm) and S_3 (15.55 cm).

At 1 MAP, the plant height under each media of application was observed to be highest in M_2 (9.16 cm) which was followed by M_4 (8.13 cm), M_1 (8.10 cm) and M_3 (8.08 cm). At 2 MAP, the highest plant height of 12.68 cm was observed in M_2. It was followed by M_1 (11.56 cm), M_3 (11.39 cm) and M_4 (11.37 cm). At 3 MAP, the highest plant height of 15.66 cm was observed in M_2 which was on par with M_1 (15.06 cm). It was followed by M_4 (13.95 cm) and M_3 (13.58 cm). At 4 MAP, M_2 recorded the highest plant height of 16.86 cm which was on par with M_1 (16.31 cm). It was followed by M_4 (15.00 cm) and M_3 (14.77 cm). At 5 MAP, M_2 recorded the highest plant height of 18.62 cm which was on par with M_1 (18.16 cm). It was followed by M_4 (16.31 cm) and M_3 (15.84 cm).

S x M interactions were found to be significant. At 1 MAP, the effect of S x M interactions on plant height was significant and maximum plant height was recorded under the combinations S_6M_3 (10.37 cm) which was on par with S_5M_2 (10.17 cm), S_6M_1 (9.58 cm), S_5M_1 (9.40 cm) and S_6M_2 (9.19 cm). The interaction effect were non significant during 2 MAP, 3 MAP and 4 MAP. At 5 MAP, significantly higher plant height was recorded under the combinations S_2M_2 (21.13 cm) which was on par with S_2M_1 (19.67 cm).

Table 85. Effect of different growing system and growing medium on plant height (cm) in strawberry

	1MAP				
Systems (S)	M_1	M_2	M_3	M_4	Mean
S_1	8.20	8.87	7.32	7.97	8.09
S_2	8.38	10.18	8.15	8.77	8.87
S_3	5.65	8.38	6.97	6.67	6.92
S_4	7.40	8.19	7.20	8.42	7.80
S_5	9.40	10.17	8.48	8.30	9.09
S_6	9.58	9.19	10.37	8.66	9.45
Mean	8.10	9.16	8.08	8.13	
CD	M =0.52 S=0.63 M x S=1. 27				
Systems (S)	2 MAP				
S_1	11.26	11.45	9.89	10.40	10.75
S_2	13.11	15.16	13.83	13.15	13.81
S_3	9.18	10.88	9.19	11.29	10.13
S_4	11.10	11.11	10.83	10.82	10.96
S_5	12.50	13.81	12.04	11.45	12.45
S_6	12.21	13.66	12.58	11.14	12.40
Mean	11.56	12.68	11.39	11.37	
CD	M=0.8 9 S=1. 10 M x S=NS				
Systems (S)	3MAP				
S_1	15.20	14.67	12.13	13.33	13.83
S_2	17.60	18.67	15.53	15.87	16.92
S_3	12.53	14.20	11.93	11.97	12.66
S_4	15.80	13.73	12.33	13.93	13.95
S_5	15.73	16.78	15.00	15.53	15.76
S_6	13.51	15.93	14.53	13.07	14.26
Mean	15.06	15.66	13.58	13.95	
CD	M=0.9 6 S=1. 18 M x S=NS				
Systems (S)	4MAP				
S_1	17.07	16.87	12.80	14.60	15.33
S_2	19.00	19.80	16.37	16.93	18.03
S_3	13.40	15.27	12.93	13.28	13.72
S_4	16.00	14.53	13.80	14.80	14.78
S_5	16.73	17.36	16.33	16.17	16.65
S_6	15.67	17.33	16.40	14.20	15.90
Mean	16.31	16.86	14.77	15.00	
CD	M=0.8 3 S=1. 02 M x S=NS				
Systems (S)	5MAP				
S_1	19.13	18.47	13.87	15.93	16.85
S_2	19.67	21.13	17.20	18.98	19.25
S_3	15.80	18.20	13.73	14.47	15.55
S_4	17.87	16.53	15.13	16.67	16.55
S_5	17.69	18.33	17.00	16.40	17.36
S_6	18.79	19.04	18.13	15.40	17.84
Mean	18.16	18.62	15.84	16.31	
CD	M=0.65 S=0.80 M x S=1.60				

Table 86. Effect of different growing systems and growing media on number of leaves of strawberry

	1MAP				
Systems (S)	M_1	M_2	M_3	M_4	Mean
S_1	4.03	3.87	4.31	4.66	4.22
S_2	3.61	4.58	3.90	4.30	4.10
S_3	3.84	4.07	3.97	4.76	4.16
S_4	5.53	4.76	3.68	4.34	4.58
S_5	4.78	5.47	4.46	4.32	4.76
S_6	4.32	5.03	4.49	4.11	4.49
Mean	4.35	4.63	4.13	4.42	
CD	M=NS S =0.44 M x S=0. 88				
Systems (S)	2 MAP				
S_1	7.20	5.80	5.87	5.87	6.18
S_2	5.53	6.13	5.20	5.80	5.67
S_3	5.87	5.73	6.00	7.73	6.33
S_4	9.67	9.13	6.20	6.53	7.88
S_5	6.80	9.13	6.33	6.73	7.25
S_6	7.33	9.30	6.73	5.73	7.28
Mean	7.07	7.54	6.06	6.40	
CD	M=0.7 6 S=0. 93 M x S =1.86				
Systems (S)	3MAP				
S_1	11.40	9.40	7.13	7.87	8.95
S_2	8.40	9.73	8.87	8.67	8.92
S_3	7.33	7.07	8.07	7.33	7.45
S_4	12.40	9.60	6.27	7.87	9.03
S_5	10.47	14.27	9.20	9.53	10.87
S_6	9.60	12.47	9.60	8.40	10.02
Mean	9.93	10.42	8.19	8.28	
CD	M=1.3 3 S=1. 63 M x S =NS				
Systems (S)	4MAP				
S_1	13.57	12.96	8.65	9.00	11.05
S_2	11.83	13.58	10.14	10.83	11.60
S_3	9.24	10.28	9.30	8.64	9.37
S_4	18.36	13.39	9.02	8.45	12.31
S_5	13.33	18.13	11.20	11.13	13.45
S_6	12.88	17.56	12.77	10.82	13.51
Mean	13.20	14.32	10.18	9.81	
CD	M=1.5 4 S=1.8 9 M x S =3.78				
Systems (S)	5MAP				
S_1	14.47	14.20	9.33	9.60	11.90
S_2	13.40	14.87	11.43	11.67	12.84
S_3	9.40	11.07	9.93	9.27	9.92
S_4	20.47	14.93	10.47	8.87	13.68
S_5	11.55	15.82	10.93	9.40	11.93
S_6	11.40	17.67	11.00	8.53	12.15
Mean	13.45	14.76	10.52	9.56	
CD	M=1.91 S=NS M x S=NS				

4.4.1.2 Number of leaves

Analysis of the data corresponding to the number of leaves of strawberry at Central midlands of Kerala during September 2017-March 2018 are presented in Table 86.

At 1 MAP, the number of leaves under each growing system was observed to be highest in S_5 (4.76) which was on par with S_4 (4.58) and S_6 (4.49). It was followed by S_1 (4.22), S_3 (4.16) and S_2 (4.10). At 2 MAP, S_4 recorded the highest number of leaves (7.88) which was on par with S_6 (7.28) and S_5 (7.25).It was followed by S_3 (6.33), S_1 (6.18) and S_2 (5.67). At 3 MAP, S_5 (10.87) recorded highest number of leaves which was on par with S_6 (10.02). It was followed by S_4 (9.03), S_1 (8.95), S_2 (8.92) and S_3 (7.45). At 4 MAP, highest number of leaves was recorded in S_6 (13.51) which was on par with S_5 (13.45) and S_4 (12.31). It was followed by S_2 (11.60), S_1 (11.05) and S_3 (9.37). Number of leaves per plant was non significant at 5 MAP.

At 1 MAP, the number of leaves under each media of application was observed to be non significant. At 2 MAP, M_2 (7.54) recorded maximum number of leaves which was on par with M_1 (7.07). It was followed by M_4 (6.4) and M_3 (6.06). At 3 MAP, M_2 recorded maximum number of leaves (10.42) which was on par with M_1 (9.93). It was followed by M_4 (8.28) and M_3 (8.19). At 4 MAP, highest number of leaves was observed in M_2 (14.32) which was on par with M_1 (13.20). It was followed by M_3 (10.18) and M_4 (9.81). At 5 MAP, highest number of leaves per plant was recorded in M_2 (14.76) which was on par with M_1 (13.45). It was followed by M_3 (10.52) and M_4 (9.56).

S x M interactions were found to be significant. At 1 MAP, the effect of S x M interactions on number of leaves was significant as maximum number of leaves were recorded under the combinations S_4M_1 (5.53) which was on par with S_5M_2 (5.47), S_5M_1 (4.78), S_4M_2 (4.76), S_3M_4 (4.76) and S_1M_4 (4.66). At 2 MAP, the maximum number of leaves was recorded under the combinations S_4M_1 (9.67) which was on par with S_6M_2 (9.30), S_5M_2 (9.13) and S_4M_2 (9.13). The interaction effect were non significant during 3 MAP. At 4 MAP the maximum number of leaves were recorded under the combinations S_4M_1 (18.36) which was on par with S_5M_2 (18.13) and S_6M_2 (17.56). At 5 MAP, the interaction effect were found to be non significant.

Plant spread

Analysis of the data corresponding to the plant spread of strawberry at Central midlands of Kerala during September 2017 - March 2018 are presented in Table 87.

At 1 MAP, the plant spread under each growing system was non significant. At 2 MAP, highest plant spread was observed in S_1 (17.73 cm) which was on par with S_2 (16.73 cm). It was followed by S_4 (15.44 cm), S_6 (15.31cm), S_5 (15.30 cm) and S_3 (13.75 cm). At 3 MAP, S_6 recorded maximum plant spread (19.64 cm) which was on par with S_1 (19.58 cm), S_5 (18.87 cm), S_2 (18.80 cm). It was followed by S_4 (17.78 cm) and S_3 (15.54 cm). At 4 MAP, S_6 (22.54 cm) recorded maximum plant spread which was on par with S_4 (21.50cm). It was followed by S_5 (20.37 cm), S_1 (20.35 cm), S_2 (20.24 cm) and S_3 (16.54 cm). At 5 MAP, highest plant spread was observed in S_6 (25.20 cm) which was followed by S_4 (23.10 cm), S_5 (22.51 cm), S_2 (21.48 cm), S_1 (21.12 cm) and S_3 (17.37 cm).

At 1 MAP, the plant spread under each media of application was observed to be to be highest in M_2 (10.54 cm) which was followed by M_1 (9.64 cm), M_4 (9.05 cm) and M_3 (8.87 cm). At 2 MAP the highest plant spread of 17.56cm was recorded in M_2 which was followed by M_1 (16.09 cm), M_4 (14.71 cm) and M_3 (14.47cm).M_2 (20.31 cm) recorded maximum plant spread which was on par with M_1 (19.00 cm) at 3 MAP. It was followed by M_3 (16.93 cm) and M_4 (17.23 cm). At 4 MAP, highest plant spread of 22.70 cm was recorded in M_2 which was followed by M_1 (20.88 cm), M_4 (18.76 cm)

Table 87. Effect of growing systems and growing media on plant spread (cm) of strawberry

	1MAP				
Systems (S)	M_1	M_2	M_3	M_4	Mean
S_1	10.10	8.37	8.64	9.28	9.10
S_2	8.20	11.19	8.34	8.62	9.09
S_3	8.57	9.44	8.41	9.82	9.06
S_4	11.82	10.99	8.20	7.50	9.63
S_5	8.64	11.55	9.57	9.85	9.90
S_6	10.50	11.68	10.07	9.26	10.38
Mean	9.64	10.54	8.87	9.05	
CD	M=0.86 S=NS M x S=2. 11				
Systems (S)	2 MAP				
S_1	20.13	19.37	14.73	16.67	17.73
S_2	15.97	20.10	14.40	16.43	16.73
S_3	13.86	17.40	11.50	12.22	13.75
S_4	19.43	16.53	13.87	11.91	15.44
S_5	12.48	13.93	17.13	17.63	15.30
S_6	14.64	18.01	15.20	13.38	15.31
Mean	16.09	17.56	14.47	14.71	
CD	M=1.1 8 S=1. 45 M x S =2.89				
Systems (S)	3MAP				
S_1	21.93	21.27	17.40	17.70	19.58
S_2	18.95	22.27	15.80	18.20	18.80
S_3	16.13	18.57	13.43	14.03	15.54
S_4	20.80	18.47	14.40	17.47	17.78
S_5	15.87	18.29	21.30	20.03	18.87
S_6	20.33	23.03	19.22	15.97	19.64
Mean	19.00	20.31	16.93	17.23	
CD	M=1.3 6 S=1. 67 M x S =3.34				
Systems (S)	4MAP				
S_1	22.80	21.63	18.20	18.77	20.35
S_2	20.47	23.70	17.27	19.53	20.24
S_3	16.63	19.27	15.37	14.90	16.54
S_4	23.12	24.59	19.09	19.20	21.50
S_5	18.97	21.47	19.57	21.47	20.37
S_6	23.27	25.57	22.63	18.70	22.54
Mean	20.88	22.70	18.69	18.76	
CD	M=1.4 6 S=1. 79 M x S =NS				
Systems (S)	5MAP				
S_1	23.90	22.20	18.77	19.60	21.12
S_2	21.63	25.23	18.87	20.20	21.48
S_3	17.13	20.00	16.23	16.10	17.37
S_4	25.20	26.07	21.20	19.93	23.10
S_5	20.37	23.27	23.37	23.05	22.51
S_6	24.97	31.40	24.63	19.80	25.20
Mean	22.20	24.69	20.51	19.78	

and M_3 (18.69 cm). At 5 MAP, highest plant spread was observed in M_2 (24.69 cm) which was followed by M_1 (22.20 cm), M_3 (20.51 cm) and M_4 (19.78 cm).

S x M interactions were found to be significant. At 1 MAP, the effect of S x M interactions on plant spread was significant as maximum plant spread was recorded under the combinations S_4M_1 (11.82 cm) which was on par with S_6M_2 (11.68 cm), S_5M_2 (11.55 cm), S_2M_2 (11.19 cm), S_6M_1 (10.50 cm), S_1M_1 (10.10 cm), S_6M_3 (10.07 cm), S_5M_4 (9.85 cm) and S_3M_4 (9.82 cm). At 2 MAP, the maximum plant spread was recorded under the combinations S_1M_1 (20.13 cm) which was on par with S_2M_2 (20.10 cm), S_4M_1 (19.43 cm), S_1M_2 (19.37 cm), S_6M_2 (18.01 cm), S_5M_4 (17.63 cm) and S_3M_2 (17.40 cm). At 3 MAP, the maximum plant spread was recorded in S_6M_2 (23.03 cm) which was on par with S_2M_2 (22.27 cm), S_1M_1 (21.93 cm), S_5M_3 (21.30 cm), S_1M_2 (21.27 cm), S_4M_1 (20.80 cm), S_6M_1 (20.33 cm) and S_5M_4 (20.03 cm). The interaction effect were non significant during 4 MAP. At 5 MAP, the interaction effect on plant spread was recorded maximum in S_6M_2 (31.40 cm).

4.4.1.4 Number of crowns

Analysis of the data corresponding to the number of crowns of strawberry at Central midlands of Kerala are presented in Table 88.

At 1 MAP, the effect of different growing systems on number of crowns of strawberry was non significant. At 2 MAP, highest number of crowns was observed in S_4 (1.43) which was on par with S_5 (1.40), S_6 (1.35) and S_1 (1.23). It was followed by S_2 (1.18) and S_3 (1.18). At 3MAP, highest number of crowns was observed in S_5 (1.87) which was on par with S_6 (1.63) and S_4 (1.60). It was followed by S_1 (1.48), S_2 (1.37) and S_3 (1.30). At 4 MAP, S_4 and S_5 recorded highest number of crowns (1.95) which was on par with S_6 (1.82) and S_1 (1.77). It was followed by S_2 (1.55) and S_3 (1.43). At

Table 88. Effect of growing systems and growing media on number of crowns of strawberry

	1MAP				
Systems (S)	M_1	M_2	M_3	M_4	Mean
S_1	1.00	1.00	1.00	1.00	1.00
S_2	1.00	1.00	1.00	1.00	1.00
S_3	1.00	1.00	1.00	1.00	1.00
S_4	1.00	1.00	1.00	1.00	1.00
S_5	1.00	1.00	1.00	1.00	1.00
S_6	1.00	1.00	1.00	1.00	1.00
Mean	1.00	1.00	1.00	1.00	1.00
CD	M=NS S=NS M x S= NS				
Systems (S)	2 MA P				
S_1	1.33	1.27	1.13	1.20	1.23
S_2	1.20	1.13	1.27	1.13	1.18
S_3	1.20	1.00	1.27	1.27	1.18
S_4	1.80	1.60	1.20	1.13	1.43
S_5	1.47	1.87	1.13	1.13	1.40
S_6	1.27	1.53	1.20	1.40	1.35
Mean	1.38	1.40	1.20	1.21	
CD	M=0. 17 S= 0.20 M x S=0. 40				
Systems (S)	3MAP				
S_1	1.93	1.53	1.20	1.27	1.48
S_2	1.20	1.53	1.47	1.27	1.37
S_3	1.33	1.27	1.33	1.27	1.30
S_4	1.93	1.80	1.40	1.27	1.60
S_5	1.87	2.60	1.47	1.53	1.87
S_6	1.80	1.87	1.47	1.40	1.63
Mean	1.68	1.77	1.39	1.33	
CD	M=0. 29 S= 0.36 M x S=NS				
Systems (S)	4MAP				
S_1	2.40	2.07	1.33	1.27	1.77
S_2	1.60	1.60	1.53	1.47	1.55
S_3	1.47	1.40	1.47	1.40	1.43
S_4	2.80	2.00	1.67	1.33	1.95
S_5	2.07	2.67	1.47	1.60	1.95
S_6	1.80	2.40	1.67	1.40	1.82
Mean	2.02	2.02	1.52	1.41	
CD	M=0. 25 S= 0.31 M x S=0. 61				
Systems (S)	5MAP				
S_1	2.47	2.27	1.47	1.33	1.88
S_2	1.93	1.93	1.73	1.53	1.78
S_3	1.60	1.53	1.60	1.53	1.57
S_4	3.07	2.13	1.80	1.33	2.08
S_5	2.13	2.67	1.47	1.67	1.98
S_6	1.80	2.67	1.80	1.47	1.93
Mean	2.17	2.20	1.64	1.48	

5 MAP, S_4 (2.08) recorded the maximum number of crowns which was on par with S_5 (1.98), S_6 (1.93) and S_1 (1.88) and S_2 (1.78). It was followed by S_3 (1.57).

At 1 MAP, the effect of different growing media on number of crowns of strawberry was non significant. The number of leaves averaged over the six growing systems under each media of application was observed to be highest in M_2 (1.40) which was on par with M_1 (1.38). It was followed by M_4 (1.21) and M_3 (1.20). At 3 MAP, M_2 recorded maximum number of crowns (1.77) which was on par with M_1 (1.68). It was followed by M_3 (1.39) and M_4 (1.33). At 4 MAP, highest number of crowns was observed in M_1 and M_2 (2.02). It was followed by M_3 (1.52) and M_4 (1.41). At 5 MAP, M_2 recorded maximum number of crowns (2.20) which was on par with M_1 (2.17). It was followed by M_3 (1.64) and M_4 (1.48).

At 1 MAP, S x M interactions were found to be non significant. At 2 MAP, the effect of S x M interactions on number of crowns was significant as maximum number of crowns was recorded under the combinations S_5M_1 (1.87) which was on par with S_4M_1 (1.80), S_4M_2 (1.60), S_6M_2 (1.53) and S_5M_1 (1.47). At 3 MAP, S x M interactions were found to be non significant. At 4 MAP, the maximum number of crowns were recorded under the combinations S_4M_1 (2.80) which was on par with S_5M_2 (2.67), S_1M_1 (2.40) S_6M_2 (2.40). At 5 MAP, the interaction effect on number of crowns was found to be maximum under the combination S_4M_1 (3.07) which was on par with S_6M_2 (2.67), S_5M_2 (2.67) and S_1M_1 (2.47).

4.4.2 Flowering attributes

Various observations on the flowering attributes of strawberry under open condition in six growing systems *viz.*, Hanging pots (S_1), Hanging pipes (S_2), Hanging bottles (S_3), Vertical garden (S_4), Grow bags (S_5), Raised beds (S_6) with four growing media in ratio 1:1:1 *viz.*, Soil: Cocopeat: FYM (M_1), Soil: Cocopeat: Vermicompost (M_2), Cocopeat: Perlite: FYM (M_3), Cocopeat: Perlite: Vermicompost (M_4) during one season (September 2017 - March 2018) at Central mid-lands of Kerala were recorded, analyzed and the results are presented in Table 89.

4.4.2.1 Days to first flowering

Analysis of the data corresponding to days to first flowering of strawberry at Central mid lands of Kerala are presented in Table 89.

The number of days to first flowering averaged over different growing media under each growing system was non significant.

Minimum number of days to first flowering was observed in M_2 and M_1 (66.61 days) which was followed by M_3 (69.78 days) and M_4 (72.22 days).

S x M interactions were found to be significant. S_1M_1 recorded minimum number of days to first flowering (57.33 days) which was on par with S_2M_3 (62.00 days), S_3M_1 (62.33 days), S_5M_2 (64.00 days) and S_6M_2 (65.33 days).

4.4.2.2 Number of clusters per plant

Analysis of the data corresponding to number of clusters per plant of strawberry at Central midlands of Kerala are presented in Table 89.

The number of clusters per plant under each growing system was observed to be maximum in S_6 (1.33) which was followed by S_5 (0.75), S_4 (0.48), S_2 (0.47), S_1 (0.35) and S_3 (0.15).

The number of clusters per plant under each growing media was observed to be maximum in M_2 (0.92) which was followed by M_1 (0.53), M_3 (0.51) and M_4 (0.39).

S x M interactions were found to be non significant.

Table 89. Effect of different growing systems and media on days to first flowering, number of clusters per plant and number of flowers per plant of strawberry

Systems (S)	Days to first flowering					Number of clusters per plant					Number of flowers per plant				
	Media (M)					Media (M)					Media (M)				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	57.33	66.00	74	71.67	67.25	0.13	0.47	0.33	0.47	0.35	4.83	5.13	3.90	3.63	4.37
S_2	66.33	66	62	73.67	67.00	0.20	0.87	0.47	0.33	0.47	4.78	5.44	3.03	3.97	4.30
S_3	62.33	71	72.67	70.33	69.08	0.00	0.47	0.13	0.00	0.15	3.20	3.90	1.78	2.04	2.73
S_4	66	67.33	69	69.33	67.92	0.93	0.53	0.13	0.33	0.48	5.53	6.07	4.35	4.88	5.21
S_5	68.67	64	67.33	81	70.25	0.67	0.93	0.67	0.73	0.75	8.53	8.83	5.80	5.97	7.28
S_6	79	65.33	73.67	67.33	71.33	1.27	2.27	1.33	0.47	1.33	9.43	10.10	6.36	6.73	8.16
Mean	66.61	66.61	69.78	72.22		0.53	0.92	0.51	0.39		6.05	6.58	4.20	4.54	
CD	M= 3.44 S=NS S x M = 8.43					M= 0.33 S=0.41 S x M =NS					M= 0.19 S=0.24 S x M =0.47				

Table 90. Effect of different growing systems and media on number of fruits per plant, fruit length and fruit breadth of strawberry

Systems (S)	Number of fruits per plant					Fruit length (cm)					Fruit breadth (cm)				
	Media (M)					Media (M)					Media (M)				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	3.02	3.48	2.03	1.83	2.59	2.63	2.50	2.87	2.17	2.54	2.33	2.07	2.33	1.97	2.18
S_2	2.96	3.51	1.46	2.23	2.54	2.73	2.97	2.67	2.73	2.78	2.43	2.80	2.47	2.43	2.53
S_3	1.49	2.12	0.87	0.93	1.35	2.53	2.53	2.77	2.40	2.56	3.03	2.47	2.07	2.27	2.46
S_4	3.93	4.18	2.60	2.83	3.39	3.33	3.47	2.70	3.23	3.18	2.77	2.87	2.17	2.63	2.61
S_5	6.61	6.92	3.84	4.15	5.38	3.17	3.20	2.93	3.23	3.13	2.67	2.63	2.70	2.80	2.70
S_6	7.91	8.88	4.36	4.93	6.52	3.50	3.50	3.43	3.47	3.48	2.87	2.87	2.93	2.80	2.87
Mean	4.32	4.85	2.53	2.82		2.98	3.03	2.89	2.87		2.68	2.62	2.44	2.48	
CD	M= 0.24 S=0.29 S x M =0.58					M= NS S=0.22 S x M =NS					M= 0.19 S=0.23 S x M =0.45				

4.4.2.3 Number of flowers

Analysis of the data corresponding to number of flowers per plant of strawberry at Central midlands of Kerala are presented in Table 89.

The number of flowers per plant under each growing system was significant. Maximum number of flowers per plant was recorded in S_6 (8.16) which was followed by S_5 (7.28), S_4 (5.21), S_1 (4.37), S_2 (4.30) and S_3 (2.73).

The number of flowers per plant under each growing media was significant. M_2 (6.58) recorded maximum number of flowers per plant which was followed by M_1 (6.05), M_4 (4.54) and M_3 (4.20).

S x M interactions were found to be significant. S_6M_2 recorded maximum number of flowers per plant (10.10).

4.4.3 Yield attributes

Various observations on yield attributes of strawberry under open condition in six growing systems *viz.,* Hanging pots (S_1), Hanging pipes (S_2), Hanging bottles (S_3), Vertical garden (S_4), Grow bags (S_5), Raised beds (S_6) with four growing media in ratio 1:1:1 *viz.,* Soil : Cocopeat : FYM (M_1), Soil : Cocopeat : Vermicompost (M_2), Cocopeat : Perlite : FYM (M_3), Cocopeat : Perlite : Vermicompost (M_4) during one season (September 2017 - March 2018) at Central mid-lands of Kerala were recorded, analyzed and the results are presented in Tables 90-92.

4.4.3.1 Number of fruits

Analysis of the data corresponding to number of fruits per plant of strawberry at Central midlands of Kerala are presented in Table 90.

The number of fruits per plant under each growing system was significant. S_6 (6.52) recorded maximum number of fruits per plant which was followed by S_5 (5.38), S_4 (3.39), S_1 (2.59), S_2 (2.54) and S_3 (1.35).

The number of fruits per plant under each growing media was significant. M_2 (4.85) recorded maximum number of fruits per plant which was followed by M_1 (4.32), M_4 (2.82) and M_3 (2.53).

S x M interactions were found to be significant. S_6M_2 recorded maximum number of fruits per plant (8.88).

4.4.3.2 Fruit length

Analysis of the data corresponding to fruit length of strawberry at Central midlands of Kerala are presented in Table 90.

The fruit length under each growing system was observed to be maximum in S_6 (3.48 cm) which was followed by S_4 (3.18 cm), S_5 (3.13 cm), S_2 (2.78 cm), S_3 (2.56 cm) and S_1 (2.54 cm).

The fruit length under each growing media of application was non- significant.

S x M interactions were found to be non significant on fruit length.

4.4.3.3 Fruit breadth

Analysis of the data corresponding to fruit breadth of strawberry at Central midlands of Kerala are presented in Table 90.

The fruit breadth under each growing system was observed to be maximum in S_6 (2.87 cm) which was on par with S_5 (2.70 cm) and was followed by S_4 (2.61 cm), S_2 (2.53 cm), S_3 (2.46 cm) and S_1 (2.18 cm).

The fruit breadth under each media of application was observed to be maximum in M_1 (2.68 cm) which was on par with M_2 (2.62 cm) and was followed by M_4 (2.48 cm) and M_3 (2.44 cm).

S x M interactions were found to be significant. S_3M_1 recorded maximum fruit breadth (3.03 cm) which was on par with S_6M_3 (2.93 cm), S_6M_1 (2.87 cm), S_6M_2 (2.87 cm), S_4M_2 (2.87 cm), S_2M_2 (2.80 cm), S_6M_4 (2.80 cm), S_5M_4 (2.80 cm), S_4M_1 (2.77 cm), S_5M_3 (2.70 cm), S_5M_1 (2.67 cm), S_5M_2 (2.63 cm) and S_4M_4 (2.63 cm).

4.4.3.4 Average fruit weight per plant

Analysis of the data corresponding to average fruit weight of strawberry at Central midlands of Kerala are presented in Table 92.

The average fruit weight per plant under each growing system was observed to be maximum in S_6 (8.80 g) which was followed by S_4 (7.65 g), S_1 (7.26 g), S_5 (6.98 g), S_2 (6.67 g) and S_3 (5.38 g).

The average fruit weight per plant under each growing media was observed to be maximum in M_2 (8.18 g) which was on par with M_1 (7.81 g) and was followed by M_4 (6.32 g) and M_3 (6.19 g).

S x M interactions were found to be non-significant.

4.4.3.5 Days to first harvest

Analysis of the data corresponding to days to first harvest of strawberry at Central midlands of Kerala are presented in Table 91.

The number of days to first harvest under each growing system was observed to be non significant.

Table 91. Effect of growing systems and growing media on number of days to first harvest and final harvest of strawberry

Systems (S)	Days to first harvest					Days to final harvest				
	Media (M)					Media (M)				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	81.33	90.00	98.00	95.67	91.25	168.00	171.60	172.80	174.00	171.60
S_2	90.33	90.00	86.00	97.67	91.00	162.00	171.60	169.20	168.00	167.70
S_3	86.33	95.00	96.67	94.33	93.08	170.40	169.20	165.60	170.40	168.90
S_4	90.00	91.33	93.00	93.33	91.92	164.17	164.17	170.00	162.00	165.08
S_5	92.67	88.00	91.33	105.00	94.25	166.00	168.00	162.00	164.00	165.00
S_6	103.00	89.33	97.67	91.33	95.33	168.00	170.00	162.00	166.80	166.70
Mean	90.61	90.61	93.78	96.22		166.43	169.09	166.93	167.53	
CD	M= 3.44 S=NS S x M = 8.43					M= NS S=3.15 S x M =6.30				

Table 92. Effect of growing systems and media on average fruit weight and yield per plant of strawberry

Systems (S)	Average fruit weight per plant (g)					Yield per plant (g)				
	Media (M)					Media (M)				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	7.68	8.93	7.41	5.04	7.26	23.72	33.15	14.90	9.21	20.24
S_2	7.24	7.50	5.59	6.33	6.67	21.48	26.58	7.97	14.15	17.54
S_3	7.42	5.90	4.59	3.62	5.38	11.05	12.51	12.61	3.40	9.89
S_4	8.50	9.35	5.84	6.90	7.65	33.51	39.03	15.30	19.40	26.81
S_5	7.33	7.67	4.97	7.96	6.98	48.56	53.66	19.58	33.00	38.70
S_6	8.67	9.75	8.73	8.07	8.80	68.43	86.26	38.12	39.80	58.15
Mean	7.81	8.18	6.19	6.32		34.46	41.87	18.08	19.83	
CD	M= 0.89 S=1.09 S x M = NS					M= 5.12 S=6.26 S x M =12.53				

The number of days to first harvest averaged under each growing media was observed to be minimum in M_1 and M_2 (90.61 days) which was on par with M_3 (93.78 days). It was followed by M_4 (96.22 days).

S x M interactions were found to be significant.S_1M_1 (81.33 days) recorded minimum number of days to first harvest which was on par with S_2M_3 (86.00 days), S_3M_1 (86.33 days), S_5M_2 (88.00 days) and S_6M_2 (89.33 days).

4.4.3.6 Days to final harvest

Analysis of the data corresponding to days to final harvest of strawberry at Central midlands of Kerala are presented in Table 91.

The number of days to final harvest under each growing system was observed to be maximum in S_1 (171.60 days) which was on par with S_3 (168.90 days) and was followed by S_2 (167.70 days), S_6 (166.70 days), S_4 (165.08 days) and S_5 (165.00 days).

The number of days to final harvest under each growing media was found to be non significant.

S x M interactions were found to be significant. S_1M_4 (174.00 days) recorded maximum number of days to final harvest which was on par with S_1M_3 (172.80 days), S_1M_2 (171.60 days), S_2M_2 (171.60 days), S_3M_1 (170.40 days) and S_3M_1 (170.40 days).

4.4.3.7 Yield

Analysis of the data corresponding to yield of strawberry at Central midlands of Kerala are presented in Table 92.

The yield per plant under each growing system was observed to be maximum in S_6 (58.15 g) which was followed by S_5 (38.70 g), S_4 (26.81 g), S_1 (20.24 g), S_2 (17.54 g) and S_3 (9.89 g).

The yield per plant under each growing media was observed to be maximum in M_2 (41.87 g) which was followed by M_1 (34.46 g), M_4 (19.83 g) and M_3 (18.08 g).

S x M interactions were found to be significant. S_6M_2 (86.26 g) recorded maximum yield per plant which was followed by S_6M_1 (68.43 g), S_5M_2 (53.66 g), S_5M_1 (48.56 g), S_6M_4 (39.80 g) andS_4M_2 (39.03 g), S_6M_3 (38.12 g), S_4M_1 (33.51 g), S_1M_2 (33.15 g), S_5M_4 (33.00 g), S_2M_2 (26.58 g), S_1M_1 (23.72 g), S_2M_1 (21.48 g), S_5M_3 (19.58 g) and S_4M_4 (19.40 g).

4.4.4 Quality attributes

Various observations on quality of strawberry under open condition in six growing systems *viz.*, Hanging pots (S_1), Hanging pipes (S_2), Hanging bottles (S_3), Vertical garden (S_4), Grow bags (S_5), Raised beds (S_6) with four growing media in ratio 1:1:1 *viz.*, Soil: Cocopeat: FYM (M_1), Soil: Cocopeat: Vermicompost (M_2), Cocopeat: Perlite: FYM (M_3), Cocopeat: Perlite: Vermicompost (M_4) during one season (September 2017 - March 2018) at Central mid-lands of Kerala were recorded, analyzed and the results are presented in Tables 93 - 95.

4.4.4.1 Total Soluble Solids

Analysis of the data corresponding to TSS of strawberry at Central midlands of Kerala are presented in Table 93.

The TSS content of fruits under each growing system was observed to be maximum in S_6 (5.83 ^{0}Brix) which was on par with S_3 (5.49 ^{0}Brix) and S_2 (5.45 ^{0}Brix). It was followed by S_1 (5.04 ^{0}Brix), S_4 (4.64 ^{0}Brix) and S_5 (4.57 ^{0}Brix).

The TSS content of fruits under each growing media was observed to be maximum in M_4 (5.81 ^{0}Brix) which was on par with M_2 (5.67 ^{0}Brix). It was followed by M_1 (4.83 ^{0}Brix) and M_3 (4.37 ^{0}Brix).

The TSS content of fruits due to the interactive effect of growing system and media was observed to be maximum in S_2M_4 (7.13 ^{0}Brix) which was on par with S_1M_4 (6.80 ^{0}Brix), S_2M_2 (6.77 ^{0}Brix), S_6M_1 (6.50 ^{0}Brix), S_3M_4 (6.27 ^{0}Brix), S_6M_2 (6.07 ^{0}Brix), S_5M_2 (5.77 ^{0}Brix), S_1M_2 (5.73 ^{0}Brix) and S_6M_4 (5.70 ^{0}Brix)

4.4.4.2 Acidity

Analysis of the data corresponding to acidity of strawberry at Central midlands of Kerala are presented in Table 93.

The acidity of strawberry fruits under each growing system was observed to be minimum in S_1 (0.49 per cent) which was on par with S_6 (0.53 per cent). It was followed by S_3 (0.63 per cent), S_4 (0.66 per cent), S_2 (0.67 per cent) and S_5 (0.78 per cent).

The acidity of strawberry fruits under each growing media was observed to be maximum in M_4 (0.54 per cent) which was on par with M_2 (0.63 per cent). It was followed by M_1 (0.65 per cent) and M_3 (0.68 per cent).

S x M interactions were found to be non significant.

4.4.4.3 TSS/acidity

Analysis of the data corresponding to TSS/acidity of strawberry at Central midlands of Kerala are presented in Table 93.

The TSS/acidity ratio of strawberry fruits under each growing system was observed to be maximum in S_6 (11.56) which was on par with S_1 (10.94) and S_3 (9.78). It was followed by S_2 (8.26), S_4 (7.52) and S_5 (5.91).

The TSS/acidity ratio of strawberry fruits under each growing media was observed to be maximum in M_4 (11.51) which was followed by M_2 (9.61), M_1 (7.83) and M_3 (7.03).

Table 93. Effect of growing systems and growing media on TSS, acidity and TSS/acidity of strawberry

Systems (S)	TSS (^{0}Brix)					Acidity (%)					TSS/Acidity				
	Media (M)					Media (M)					Media (M)				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	3.33	5.73	4.30	6.80	5.04	0.51	0.55	0.47	0.42	0.49	7.44	10.57	9.39	16.37	10.94
S_2	4.73	6.77	3.17	7.13	5.45	0.64	0.64	0.73	0.68	0.67	7.56	10.57	4.39	10.52	8.26
S_3	5.63	5.17	4.90	6.27	5.49	0.73	0.59	0.68	0.51	0.63	7.85	11.06	7.30	12.89	9.78
S_4	5.13	4.53	4.10	4.80	4.64	0.64	0.73	0.77	0.51	0.66	8.52	6.28	5.43	9.84	7.52
S_5	3.67	5.77	4.70	4.13	4.57	0.81	0.77	0.86	0.68	0.78	4.54	7.49	5.52	6.10	5.91
S_6	6.50	6.07	5.07	5.70	5.83	0.60	0.52	0.55	0.43	0.53	11.09	11.69	10.13	13.31	11.56
Mean	4.83	5.67	4.37	5.81		0.65	0.63	0.68	0.54		7.83	9.61	7.03	11.51	
CD	M= 0.61 S=0.74 S x M = 1.48					M= 0.09 S=0.11 S x M =NS					M=1.77 S=2.17 S x M=NS				

Table 94. Effect of growing systems and growing media on total sugars, ascorbic acid and anthocyanin content of strawberry

Systems (S)	Total sugars (%)					Ascorbic acid (mg $100g^{-1}$)					Anthocyanin (mg $100g^{-1}$)				
	Media (M)					Media (M)					Media (M)				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	5.20	5.93	6.50	4.80	5.61	18.94	26.52	27.78	31.99	26.31	38.80	13.67	31.37	20.60	26.11
S_2	4.83	5.07	5.60	6.23	5.43	55.56	11.36	59.26	15.15	35.33	15.17	34.90	29.73	22.27	25.52
S_3	5.60	5.47	3.30	6.23	5.15	27.78	34.09	92.59	83.33	59.45	42.55	37.03	25.93	22.33	31.96
S_4	5.60	5.37	5.40	3.90	5.07	27.78	22.72	41.67	15.15	26.83	11.00	18.10	12.73	26.33	17.04
S_5	4.03	4.93	4.90	6.30	5.04	7.57	22.72	30.30	69.44	32.51	32.17	31.43	5.87	21.57	22.76
S_6	5.00	5.47	6.70	5.23	5.60	21.47	29.04	55.55	34.09	35.04	45.67	35.80	33.73	25.73	35.23
Mean	5.04	5.37	5.40	5.45		26.52	24.41	51.19	41.52		30.89	28.49	23.23	23.14	
CD	M= 0.24 S=0.29 S x M = 0.58					M= 2.91 S=3.56 S x M =7.12					M = 1.20 S=1.46 S x M =2.93				

S x M interactions were found to be non significant.

4.4.4.4 Total sugars

Analysis of the data corresponding to total sugars of strawberry at Central midlands of Kerala are presented in Table 94.

The total sugars of strawberry fruits under each growing system was observed to be maximum in S_1 (5.61 %) which was on par with S_6 (5.60 %) and S_2 (5.43 %). It was followed by S_3 (5.15 %), S_4 (5.07 %) and S_5 (5.04 %).

The total sugars of strawberry fruits under each growing media was observed to be maximum in M_4 (5.45 %) which was on par with M_3 (5.40 %) and M_2 (5.37 %). It was followed by M_1 (5.04 %).

S x M interactions were found to be significant. S_6M_3 (6.70 %) recorded maximum total sugars which was on par with S_1M_3 (6.50 %), S_5M_4 (6.30 %), S_3M_4 (6.23 %) and S_2M_4 (6.23 %) and S_3M_4 (6.23 %).

4.4.4.5 Ascorbic acid

Analysis of the data corresponding to ascorbic acid of strawberry at Central midlands of Kerala are presented in Table 94.

The ascorbic acid content of strawberry fruits averaged over each growing system was observed to be maximum in S_3 (59.45 mg $100g^{-1}$) which was on par with S_2 (35.33 mg $100g^{-1}$), S_6 (35.04 mg $100g^{-1}$), S_5 (32.51 mg $100g^{-1}$), S_4 (26.83 mg $100g^{-1}$) and S_1 (26.31 mg $100g^{-1}$).

The ascorbic acid content of strawberry fruits under each growing media was observed to be maximum in M_3 (51.19 mg $100g^{-1}$) which was followed by M_4 (41.52 mg $100g^{-1}$), M_1 (26.52 mg $100g^{-1}$) and M_2 (24.41 mg $100g^{-1}$).

Table 95. Effect of growing systems and growing media on β-Carotene content, shelf life and colour of strawberry

Systems (S)	β-Carotene content (µg $100g^{-1}$)					Shelf life (Days)					Colour				
	Media (M)					Media (M)					Media (M)				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	3.56	4.36	2.17	2.78	3.22	3	3	3	3	3	61D	61D	61D	61D	61D
S_2	4.70	3.87	2.38	2.98	3.48	3	3	3	3	3	61D	61D	61D	61D	61D
S_3	3.76	4.49	3.52	4.42	4.05	3	3	3	3	3	61D	61D	61D	61D	61D
S_4	4.64	3.98	1.82	2.64	3.27	3	3	3	3	3	61D	61D	61D	61D	61D
S_5	4.80	2.16	3.30	2.57	3.21	3	3	3	3	3	61D	61D	61D	61D	61D
S_6	3.90	3.36	3.79	2.59	3.41	3	3	3	3	3	61D	61D	61D	61D	61D
Mean	4.23	3.70	2.83	3.00		3	3	3	3		61D	61D	61D	61D	61D
CD	M= 0.07 S=0.09 S x M = 0.18														

S x M interactions were found to be significant. S_3M_3 (92.59mg 100g^{-1}) recorded maximum ascorbic acid content which was followed by S_3M_4 (83.33 mg 100g^{-1}), S_5M_4 (69.44 mg 100g^{-1}), S_2M_3 (59.26 mg 100g^{-1}) and S_2M_1 (55.56 mg 100g^{-1}), S_6M_3 (55.55 mg 100g^{-1}), S_4M_3 (41.67 mg 100g^{-1}), S_3M_2 (34.09 mg 100g^{-1}) and S_6M_4 (34.09 mg 100g^{-1}), S_1M_4 (31.99 mg 100g^{-1}), S_5M_3 (30.30 mg 100g^{-1}), S_6M_2 (29.04 mg 100g^{-1}), S_1M_3 (27.78 mg 100g^{-1}), S_3M_1 (27.78 mg 100g^{-1}), S_1M_2(26.52 mg 100g^{-1}), S_4M_2 (22.72 mg 100g^{-1}), S_5M_2 (22.72 mg 100g^{-1}), S_6M_1 (21.47 mg 100g^{-1}), S_1M_1 (18.94 mg 100g^{-1}), S_2M_4 (15.15 mg 100g^{-1}), S_4M_4 (15.15 mg 100g^{-1}), S_2M_4 (11.36 mg 100g^{-1}).

4.4.4.6 Anthocyanin

Analysis of the data corresponding to anthocyanin content of strawberry (mg 100g^{-1}) at Central midlands of Kerala are presented in Table 94.

The anthocyanin content of strawberry fruits under each growing system was observed to be maximum in S_6 (35.23 mg 100g^{-1}) which was followed by S_3 (31.96 mg 100g^{-1}), S_1 (26.11 mg 100g^{-1}), S_2 (25.52 mg 100g^{-1}), S5 (22.76 mg 100g^{-1}) and S_4 (17.04 mg 100g^{-1}).

The anthocyanin content of strawberry fruits under each growing media was observed to be maximum in M_1 (30.89 mg 100g^{-1}) which was followed by M_2 (28.49 mg 100g^{-1}), M_3 (23.23 mg 100g^{-1}) and M_4 (23.14 mg 100g^{-1}).

S x M interactions were found to be significant. S_6M_1 (45.67 mg 100g^{-1}) recorded maximum anthocyanin content which was followed by S_3M_1 (42.55 mg 100g^{-1}), S_1M_1 (38.80 mg 100g^{-1}), S_3M_2 (37.03 mg 100g^{-1}), S_6M_2 (35.80 mg 100g^{-1}),S_2M_2 (34.90 mg 100g^{-1}), S_6M_3 (33.73 mg 100g^{-1}), S_5M_1 (32.17 mg 100g^{-1}), S_5M_2 (31.43 mg 100g^{-1}), S_1M_3 (31.37 mg 100g^{-1}), S_2M_3 (29.73 mg 100g^{-1}), S_4M_4 (26.33 mg 100g^{-1}), S_3M_3 (25.93 mg 100g^{-1}), S_6M_4 (25.73 mg 100g^{-1}).

4.4.4.7 β- Carotene

Analysis of the data corresponding to β- Carotene content of strawberry (µg $100g^{-1}$) at Central midlands of Kerala are presented in Table 95.

The β- Carotene content of strawberry under each growing system was observed to be maximum in S_3 (4.05 µg $100g^{-1}$) which was followed by S_2 (3.48 µg $100g^{-1}$), S_6 (3.41 µg $100g^{-1}$), S_4 (3.27 µg $100g^{-1}$), S_1 (3.22 µg $100g^{-1}$) and S_5 (3.21 µg $100g^{-1}$).

The β- Carotene content of strawberry fruits under each growing media was observed to be maximum in M_1 (4.23 µg $100g^{-1}$) which was followed by M_2 (3.70 µg $100g^{-1}$), M_4 (3.00 µg $100g^{-1}$) and M_3 (2.83 µg $100g^{-1}$).

S x M interactions were found to be significant. S_5M_1 (4.80 µg $100g^{-1}$)recorded maximum β- Carotene content which was followed by S_2M_1 (4.70 µg $100g^{-1}$), S_4M_1 (4.64 µg $100g^{-1}$), S_3M_2 (4.49 µg $100g^{-1}$), S_3M_4 (4.42 µg $100g^{-1}$),S_1M_2 (4.36 µg $100g^{-1}$), S_4M_2 (3.98 µg $100g^{-1}$), S_6M_1 (3.90 µg $100g^{-1}$), S_2M_2 (3.87 µg $100g^{-1}$), S_6M_3 (3.79 µg $100g^{-1}$), S_3M_1 (3.76 µg $100g^{-1}$), S_1M_1 (3.56 µg $100g^{-1}$), S_3M_3 (3.52 µg $100g^{-1}$) and S_6M_2 (3.36 µg $100g^{-1}$).

4.4.4.8 Shelf life

The treatments have no significant effect on shelf life of strawberry (Table 95). Fruits harvested from all the treatments have a shelf life of 3 days during both seasons of growth. It is evident that the strawberry variety has a maximum shelf life of 3 days irrespective of the different growing systems and growing media.

4.4.4.9 Colour

The data on colour of fruit skin is presented in Table 95. The skin colour was described using Universal Colour Language (UCL) and it was deep purplish pink (61 D) for all treatments. The treatments had no significant effect on the colour of strawberry.

4.4.4.10 Sensory evaluation

Data corresponding to the sensory evaluation of strawberry fruits grown at Central mid-lands of Kerala are presented in Table 96.

In strawberry, the sensory evaluation was carried out on a nine point hedonic scale using score card for eight attributes namely appearance, colour, texture, flavour, 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 carried out on the same day of harvest by panel of judges.

The highest score for appearance was recorded by S_4M_3 (7.89) and the lowest score by S_2M_3 (6.01). The highest score for colour was recorded by S_4M_4 (8.0) and the lowest score was by S_3M_3 (6.62). The highest score for taste was recorded by S_6M_1 (7.33) and the lowest score was by S_3M_4 (4.89). Highest score for flavour was recorded by S_3M_1 (7.43) and the lowest score was by S_2M_1 (5.82). Highest score for aroma was recorded by S_3M_1 (7.06) and the lowest score was by S_6M_4 (5.43). Highest score for texture was recorded by S_6M_1 (7.13) and the lowest score was by S_2M_1 (5.70). S_6M_1 (7.13) recorded highest score for after taste and the lowest score was by S_3M_4 (4.46). Highest score for overall acceptability was recorded by S_6M_1 (7.6) and the lowest score was by S_3M_4 (4.8).

The highest total sensory score was recorded by S_6M_1 (57.84) and the lowest score was recorded by S_3M_4 (46.0).

Table 96. Sensory evaluation of fruits

Treatments	Appearance	Colour	Taste	Flavour	Aroma	Texture	After taste	Overall acceptability	Total score
S_1M_1	7.22	7.17	5.71	5.94	5.72	6.79	5.1	5.8	49.45
S_1M_2	7.57	7.44	6.62	6.37	6.48	6.37	6.61	6.8	54.26
S_1M_3	7.42	7.42	6.69	6.69	6.8	6.89	6.55	6.8	55.26
S_1M_4	7.17	7.27	5.55	6.24	6.24	6.21	5.81	6.1	50.59
S_2M_1	6.74	6.93	5.46	5.82	5.55	5.70	5.3	6.0	47.50
S_2M_2	7.76	7.47	6.31	6.49	6.04	6.2	6.27	6.5	53.04
S_2M_3	6.01	6.66	5.95	6.22	6.28	5.85	5.97	6.0	48.94
S_2M_4	7.23	7.4	6.57	6.66	6.36	6.41	6.53	6.8	53.96
S_3M_1	7.69	7.62	6.96	7.43	7.06	6.8	6.53	6.9	56.99
S_3M_2	6.78	7.03	6.53	6.37	5.82	6.21	6.13	6.7	51.57
S_3M_3	6.82	6.62	6.16	6.42	5.45	5.72	5.99	6.5	49.68
S_3M_4	6.52	6.92	4.89	5.87	6.18	6.36	4.46	4.8	46.00
S_4M_1	7.62	7.66	6.11	6.95	6.33	6.67	6.23	6.6	54.17
S_4M_2	7.85	7.69	6.94	6.9	6.56	6.77	6.6	7.2	56.51
S_4M_3	7.89	7.87	6.29	6.57	6.32	6.57	6.01	6.3	53.82
S_4M_4	7.5	8.00	7.11	7.15	7.02	6.91	6.34	7.1	57.13
S_5M_1	6.94	6.85	6.7	6.35	6.37	6.41	6.74	6.6	52.96
S_5M_2	7.2	6.94	6.87	6.73	6.58	6.53	6.8	7.1	54.75
S_5M_3	6.66	7.2	6.64	5.98	6.50	6.38	6.09	6.7	52.15
S_5M_4	7.24	7.14	6.24	6.39	6.12	6.41	5.94	6.7	52.18
S_6M_1	7.53	7.06	7.33	7.16	6.9	7.13	7.13	7.6	57.84
S_6M_2	7.17	7.04	6.32	6.58	6.05	6.33	6.04	6.5	52.03
S_6M_3	7.69	7.4	6.34	6.66	6.2	6.67	6.22	6.6	53.78
S_6M_4	6.97	6.84	5.85	5.84	5.43	6.0	5.46	6.1	48.49

Table 97. Economics of strawberry cultivation in different growing systems and growing media

Treatments	Total cost incurred (Rs)	Total benefit (Rs)	B/C Ratio
S_1M_1	1413.7	533.7	0.38
S_1M_2	1479.07	745.88	0.50
S_1M_3	1580.32	335.25	0.21
S_1M_4	1799.39	207.23	0.12
S_2M_1	1673.02	483.30	0.29
S_2M_2	1698.85	598.05	0.35
S_2M_3	1691.55	179.33	0.11
S_2M_4	1717.03	318.38	0.19
S_3M_1	1155.97	248.63	0.22
S_3M_2	1188.87	281.48	0.24
S_3M_3	1189.68	283.73	0.24
S_3M_4	1222.28	76.50	0.06
S_4M_1	4080.32	753.98	0.18
S_4M_2	4161.97	878.18	0.21
S_4M_3	4164.6	344.25	0.08
S_4M_4	4246.07	436.50	0.10
S_5M_1	1831.42	1092.60	0.60
S_5M_2	2018.17	1207.35	0.60
S_5M_3	2170.72	440.55	0.20
S_5M_4	2357.47	742.50	0.31
S_6M_1	1348.07	1539.68	1.14
S_6M_2	1428.07	1940.85	**1.36**
S_6M_3	1493.07	857.70	0.57
S_6M_4	1573.07	895.50	0.57

4.4.5 Pests and diseases

No severe attack of pests and diseases.

4.4.6 Economics of cultivation

Data corresponding to the economics of cultivation of strawberry fruits grown Central mid-lands of Kerala are presented in Table 97 and Appendix V.

The B/C (Benefit: Cost ratio) was highest in S_6M_2 (1.36) which was followed by S_6M_1 (1.14). The lowest B/C ratio was recorded in S_3M_4 (0.06).

Discussion

5. DISCUSSION

Kerala is blessed with different agro-ecological conditions and altitudinal variations which provides humid tropical climate in low altitudes (plains) to subtropical-temperate climate in high altitude regions (high ranges). Availability of day neutral varieties opens the possibility of strawberry cultivation in Kerala. State Horticulture Mission – Kerala started cultivating strawberry in 750 acres of land mainly in Idukki and Wayanad districts of Kerala. Horticorp also started a state-wide cold chain to market strawberry under the 'Safe to Eat' brand. But the farmers are not aware of the suitable variety for their location and the unavailability of Package of Practices recommendation makes the strawberry cultivation in jeopardy. In Kerala, land value is increasing and the per capita land holding is decreasing day by day. The different systems of cultivation like vertical garden, grow bags, hanging pots *etc.* for growing strawberry will aid in the inclusion of strawberry in the urban and peri-urban horticultural programme which is the need of the hour. Earlier research results have proved that strawberry can be grown in the plains of Kerala during September to March even in the open condition with high B/C ratio of 1.5 in Central mid-lands and 3.0 in High ranges (Kurian, 2015). Performance of different strawberry varieties at Wayanad condition revealed that *cv.* Winter Dawn outperformed other varieties (Aslam, 2017). In this context, the present study was undertaken to identify suitable varieties of strawberry in respect of quality and yield of strawberry in the tropical and sub-tropical climatic conditions of Kerala and also to standardize the nutrient requirement and spacing of strawberry for commercial cultivation in Kerala and also for developing growing systems for homestead cultivation.

The study pertaining to the production dynamics of strawberry (*Fragaria* x *ananassa* Duch.) in Kerala was conducted during the period of September 2016- March 2017 and September 2017- March 2018 at two locations of Kerala *viz.*, Central mid-lands (College of Agriculture) and High ranges (RARS, Ambalavayal). The results of the experiments are discussed in this chapter.

5.1 Evaluation of strawberry varieties

5.2 Nutrient management in strawberry

5.3 Effect of spacing on growth and yield

5.4 Evaluating different growing systems for home-gardening

5.1 Evaluation of strawberry varieties

The results are discussed under six heads namely vegetative growth attributes, flower attributes, yield attributes, quality attributes, postharvest study and pest and disease incidence.

5.1.1 Vegetative growth attributes

5.1.1.1 Plant height

In Central midlands, among the varieties there were significant differences observed for plant height. Sabrina-1 recorded maximum plant height (23.77 cm) irrespective of the age of the plant. Gili recorded minimum plant height (12.35 cm) during all stages of growth (Fig. 1a). Similar trend was observed in strawberry *cv*. Winter Dawn which recorded 17.13 cm in Central midlands (Kurian, 2015). The increase in height might be due to low temperature (21.9 ^{0} C) and high relative humidity (68 %) in the current cropping season (Appendix III) compared to the earlier research which recorded temperature of 24.24 ^{0} C and relative humidity of 64.71% (Kurian, 2015).

However in High ranges, plant height ranges from 13.66 cm to 21.75 cm. Winter Dawn recorded maximum plant height in later stages of growth and Gili recorded minimum plant height during all stages of growth (Fig 1b). Similar trend was recorded in *cv*. Winter Dawn in High ranges which recorded maximum plant height of 18.50 cm (Arjun, 2017).

The increase in plant height might be due to increased length and erect growth of leaf. Lower plant height may be due to the genetic makeup and higher chilling requirements which had hampered the proper growth and development of plants (Grewal and Dhaliwal, 1984).

5.1.1.2 Number of leaves per plant

In Central midlands, among the varieties there were significant differences observed for number of leaves per plant. Among the varieties, Winter Dawn recorded maximum number of leaves per plant (56.39) (Fig 2a). Earlier similar trend was recorded in strawberry *cv*. Winter Dawn which recorded maximum number of leaves in Central midlands of Kerala (63.04) (Kurian, 2015).

However in High ranges, Sabrina-1 recorded maximum number of leaves per plant during the early stages of growth. While during the later stages of growth, Winter Dawn recorded maximum number of leaves per plant (37.82). Optimum temperature range for flower induction and growth of strawberry ranges from 15 ^{0}C to 18 ^{0}C. In High ranges, the temperature range of 16 ^{0}C – 17 ^{0}C during the growing period might have influenced the production of higher number of leaves per plant (Fig. 2b, Appendix IV).

More number of leaves per plant in Central midlands compared to High ranges was earlier reported by Kurian (2015). Variation with respect to number of leaves per plant could be attributed to the fact that different cultivars may react differently to photoperiod, light and temperature. So there is a corresponding increase in the length of epidermal and parenchyma cells, higher rate of cell division and cell elongation in sub apical meristem of strawberry shoots which might led to the production of higher

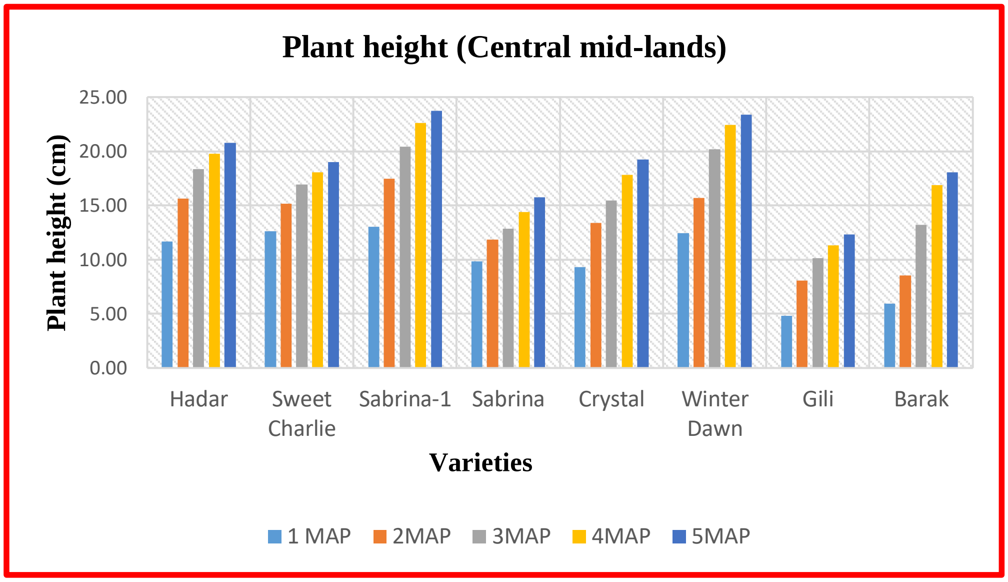


Fig 1a. Performance of strawberry varieties for plant height at Central midlands of Kerala

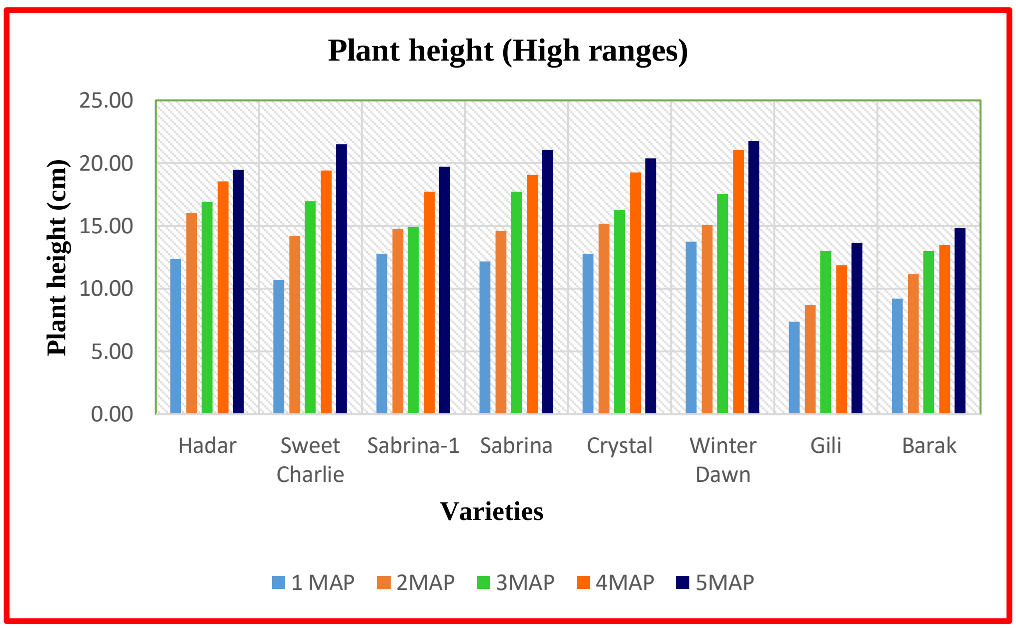


Fig 1b. Performance of strawberry varieties for plant height at High ranges of Kerala

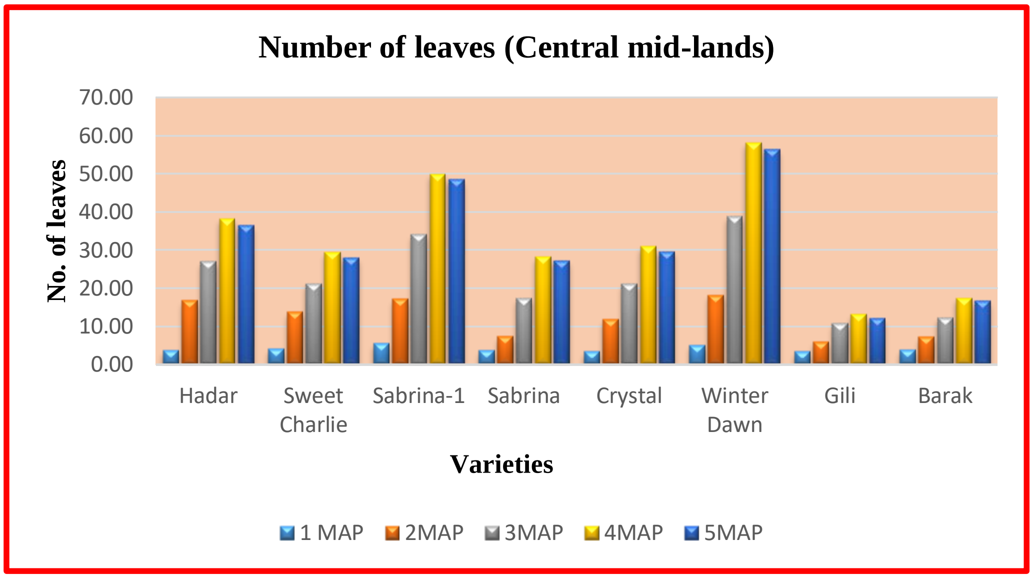


Fig 2a. Performance of strawberry varieties for number of leaves at Central midlands of Kerala

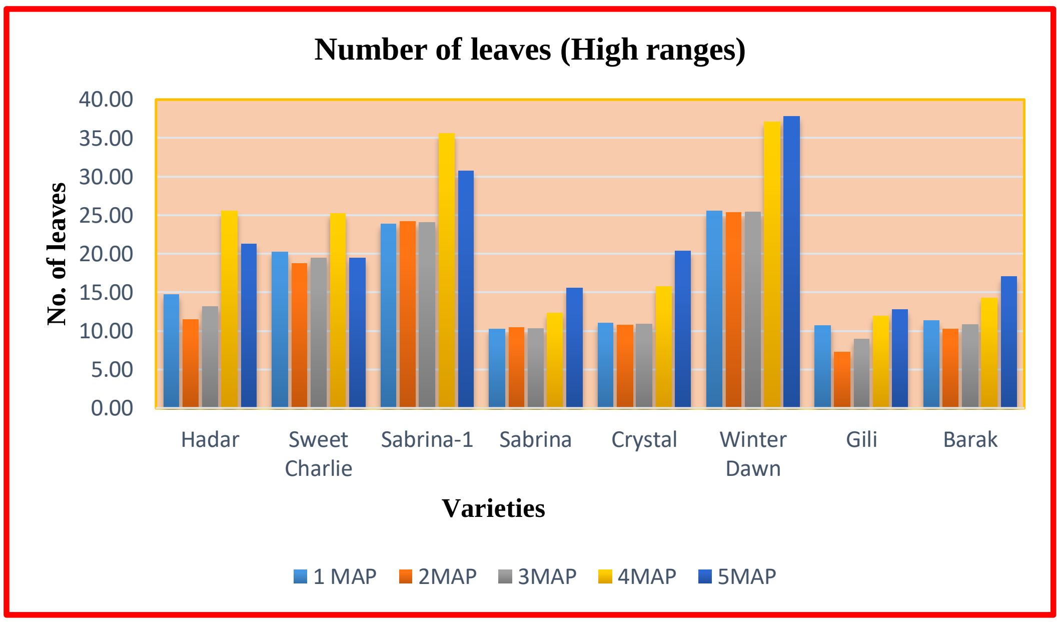


Fig 2b. Performance of strawberry varieties for number of leaves at High ranges of Kerala

number of leaves per plant of strawberry. This is in accordance with the findings of Strik (1988) in strawberry.

5.1.1.3 Plant spread

In Central midlands, among the varieties there were significant differences observed for plant spread. During the early stages of growth, *cv*. Hadar recorded maximum plant spread. While in the later stages of growth, Sabrina-1 recorded maximum plant spread (37.52 cm). Gili recorded minimum spread during all the stages of growth (15.89 cm). The favourable environmental conditions would influence the production of more plant height in *cv*. Sabrina-1 might have ultimately resulted in more plant spread also (Fig 3a).

However in High ranges, during the initial stages of the growth, *cv*. Winter Dawn recorded maximum plant spread. While in the later stages of growth, Hadar recorded maximum plant spread (40.25 cm), (Fig 3b). Varietal differences in plant spread were also noted by Singh *et al*. (2008) in Meghalaya and Aslam, (2017) in Wayanad which supports the present observation.

This is in accordance to the findings of Sharma *et al*. (2014) who proposed that the genes responsible for the plant spread did not express them fully with the same degree as it does at other places because of different agro-climatic conditions.

5.1.1.4 Number of crowns

In Central midlands, among the varieties there were significant differences observed for number of crowns per plant. During the initial stages of growth, Sabrina-1 recorded maximum number of crowns per plant (3.03). While during the later stages of growth, Winter Dawn recorded maximum number of crowns per plant (3.88). Barak and Sweet Charlie recorded least number of crowns per plant (Fig 4a). The favourable environmental conditions which would influence the production of more number of

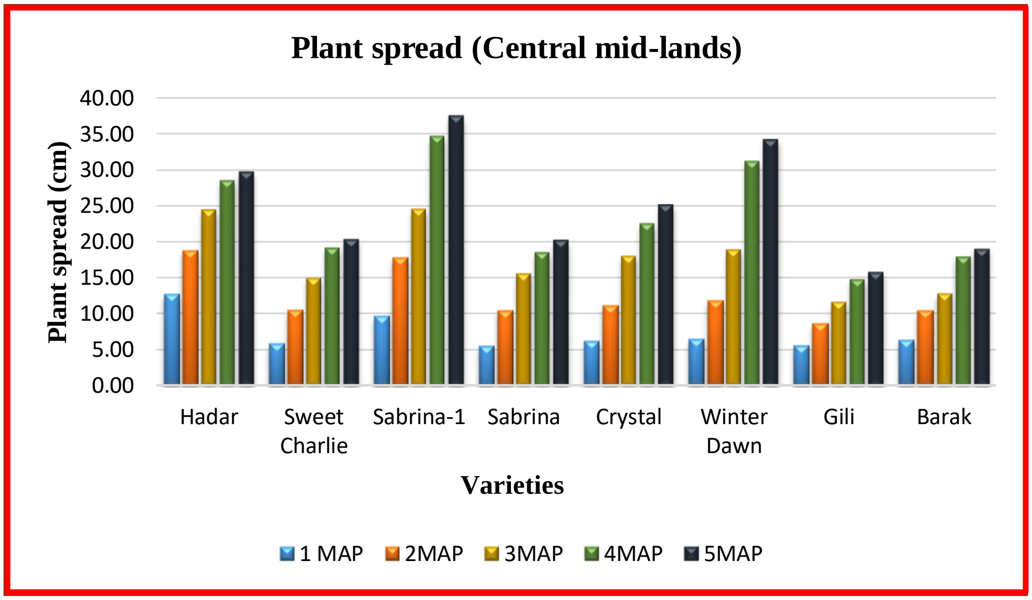


Fig 3a. Performance of strawberry varieties for plant spread at Central midlands of Kerala

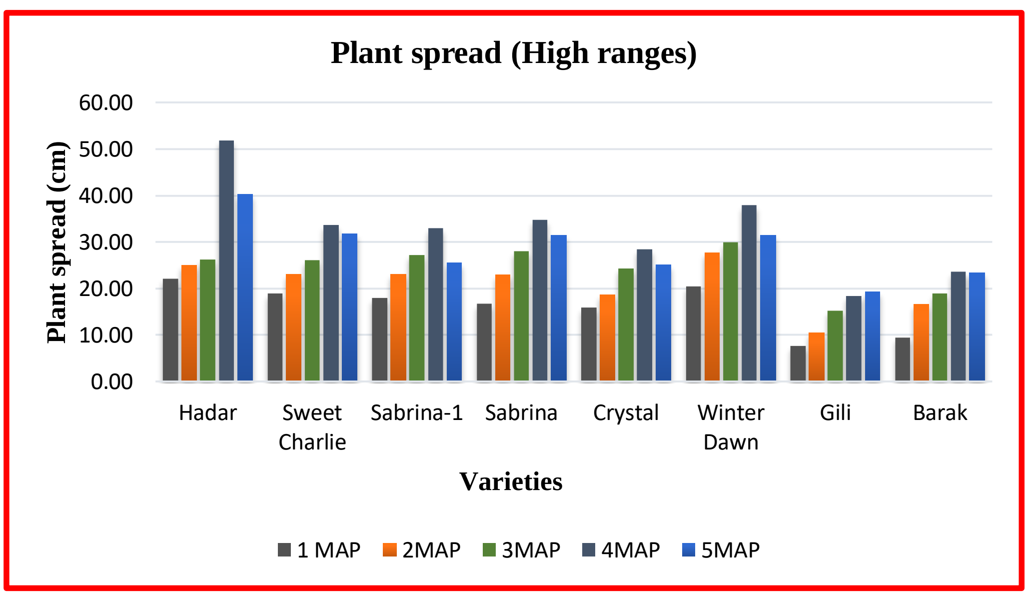


Fig 3b. Performance of strawberry varieties for plant spread at High ranges of Kerala

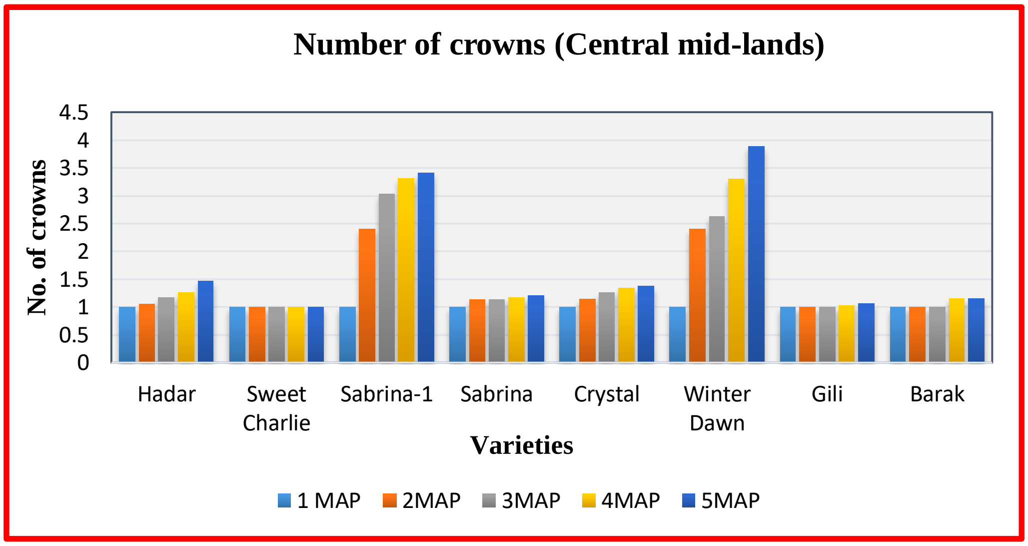


Fig 4a. Performance of strawberry varieties for number of crowns at Central midlands of Kerala

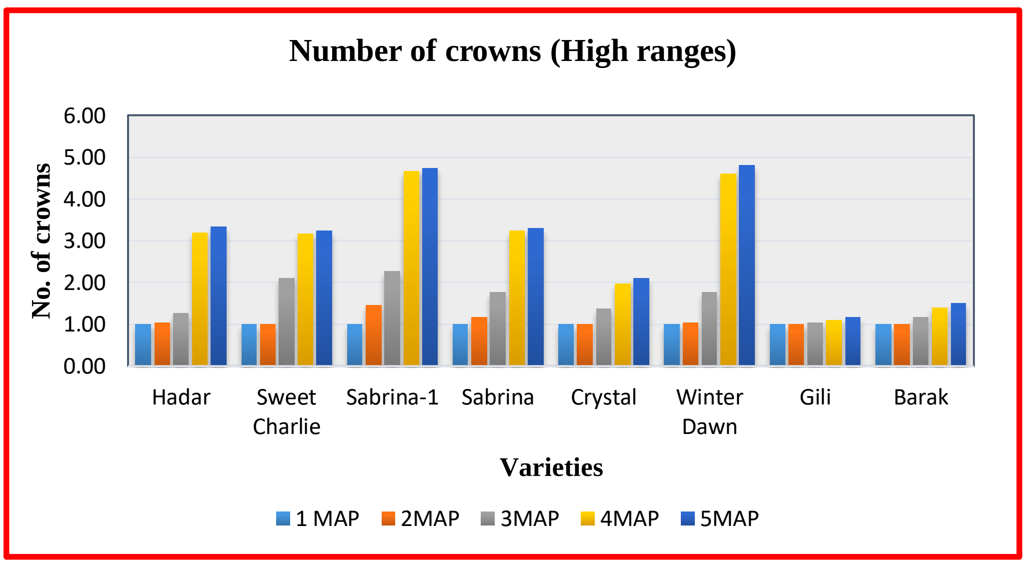


Fig 4b. Performance of strawberry varieties for number of crowns at High ranges of Kerala

leaves per plant in *cv.* Winter Dawn might have ultimately resulted in more number of crowns per plant.

However in High ranges, Sabrina-1 recorded the maximum number of crowns (2.27) during the initial stages of growth, while during the later stages of growth, Winter Dawn recorded maximum number of crowns per plant (4.80). Gili recorded least number of crowns per plant (1.17) (Fig. 4b). The favourable environmental conditions available in the High ranges would have influenced the vegetative growth which ultimately resulted in more number of crowns per plant in *cv.* Winter Dawn.

5.1.2 Flowering attributes

5.1.2.1 Days to first flowering

In Central midlands, among the varieties there was significant difference observed for number of days to first flowering. Winter Dawn recorded the minimum number of days to first flowering (49.00 days). The maximum number of days to first flowering was recorded by Barak (101.50 days). Days to first flowering is a varietal character and might be the difference of different varieties for their adaptability to a particular climatic condition (Joolka and Badiyala, 1983).

However in High ranges, Gili recorded the minimum number of days to first flowering (42.33 days), while Crystal recorded maximum number of days for first flowering (71.83 days) (Fig. 5). Earlier research work conducted in the high ranges recorded earliness in flowering from 47.33 days to 55 days in *cv*. Winter Dawn (Arjun, 2017). The optimum temperature for short day flower induction is 15 – 18 ^{0}C, while below 10 ^{0}C and above 25 ^{0}C, short day flower induction is rather ineffective. Early flowering in High ranges may be due to the fact that varieties (Manakasem and Goodwin, 2001; Sonsteby and Heide, 2006; Verheul *et al.*, 2006).

The variation in the time of flowering among different strawberry cultivars may be probably due to the fact that different cultivars differ widely in their chilling

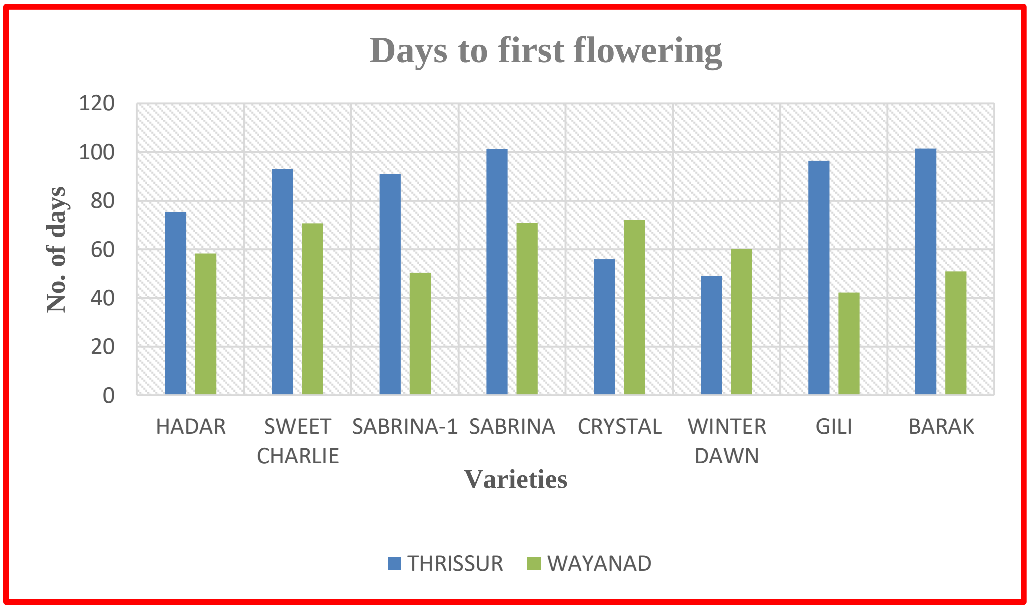


Fig 5. Performance of strawberry varieties for days to first flowering

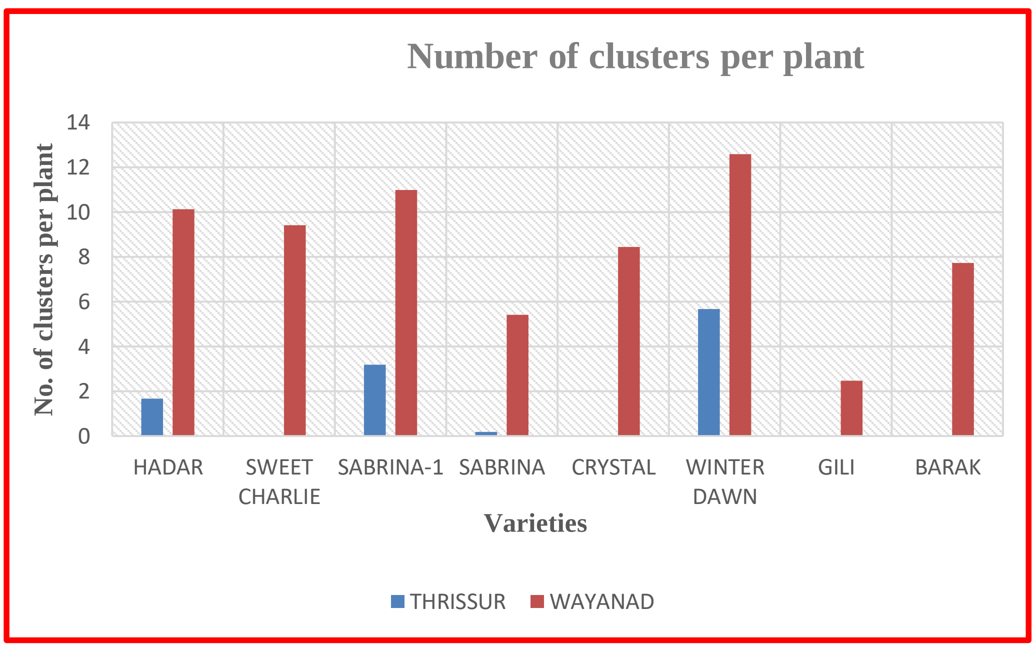


Fig 6. Performance of strawberry varieties for number of clusters per plant

requirement and plants of varieties which showed early flowering were capable of growing and producing early flowers without a prolonged chilling period (Craig and Brown, 1977; Nicoll and Galletta, 1987).

5.1.2.2 Number of flowers per plant

In Central midlands (Thrissur), among the varieties there were significant differences observed for number of flowers per plant. Winter Dawn recorded maximum number of flowers per plant (8.13) while Gili recorded least number of flowers per plant (1.1). Maximum number of leaves (56.39) and number of crowns per plant (Table No. 11a) were observed with variety Winter Dawn in Central midlands, which might have influenced the production of maximum number of flowers per plant.

In High ranges (Wayanad), Winter Dawn recorded maximum number of flowers per plant (24.62) while Gili produced least number of flowers per plant (6.63) (Fig. 7). Maximum plant height, maximum number of leaves and maximum number of crowns per plant were observed with variety Winter Dawn in High ranges, which might have influenced the production of maximum number of flowers per plant. A similar result was reported in *cv*. Winter Dawn in High ranges by Aslam (2017).

Congenial environmental conditions prevailing during the production period in both locations favoured the production of maximum number of flowers per plant (Appendix III and IV).

5.1.2.3 Number of clusters per plant

In Central midlands, among the varieties studied, there were significant differences observed for number of clusters per plant. The *cv.* Winter Dawn recorded maximum number of clusters per plant (5.67), while varieties Sweet Charlie, Crystal, Gili and Barak produced no clusters. Winter Dawn recorded maximum number of flowers per plant. This may be the reason for having higher number of clusters per plant.

However in High ranges, Winter Dawn produced the maximum number of clusters per plant (12.57), while variety Gili produced least number of clusters per plant and the value ranges from 2.48 to 12.57 (Fig 6). Similar trend was observed in strawberry *cv*. Winter Dawn by Aslam (2017).

5.1.3 Yield attributes

5.1.3.1 Number of fruits per plant

In Central midlands, among the varieties there were significant differences observed for number of fruits per plant. Winter Dawn recorded maximum number of fruits per plant (4.85), while Gili recorded least number of fruits per plant (0.73). The result was in conformity with the observations of Kurian (2015).

In High ranges also, the maximum number of fruits per plant was recorded by Winter Dawn (13.68)**,** while Gili recorded least number of fruits per plant (3.22)~~,~~ (Fig. 8). The result was in conformity with the findings of Aslam (2017) in strawberry *cv*. Winter Dawn.

The number of flowers per plant recorded maximum in case of variety Winter Dawn which may lead to the production of more number of fruits per plant in both locations. These findings are in agreement with the earlier reports of Beniwal *et al*. (1989), Baumann *et al*. (1993) and Belakhud *et al*. (2015).

5.1.3.2 Fruit length

In Central midlands, variety Winter Dawn recorded maximum fruit length (4.55 cm) while variety Gili recorded minimum fruit length (1.93 cm). Pandey *et al*. (2015) reported fruit length of 4.8 cm in strawberry *cv*. Winter Dawn in open field. Hence, our results get support from the findings of above authors for fruit length.

In High ranges also, Winter Dawn recorded maximum fruit length (4.02 cm) while Gili recorded minimum fruit length (2.59 cm) (Fig. 9). The findings was in conformity with the observations of Pandey *et al*. (2015) in strawberry.

5.1.3.3 Fruit breadth

In Central midlands, Sabrina-1 recorded maximum fruit breadth (4.57 cm) compared to all other varieties. Variety Gili recorded least fruit breadth (1.90 cm).

In High ranges, Sabrina recorded maximum fruit breadth (2.95 cm), while Gili recorded minimum fruit breadth (1.76 cm), (Fig 10). This is in accordance with the findings of Kumar (2018) where fruit breadth ranges from 2.47 cm to 1.58 cm.

5.1.3.4 Average fruit weight

In Central midlands, Sabrina-1 recorded maximum average fruit weight (10.26 g) compared to all other varieties. While Gili recorded lowest average fruit weight (2.24 g). As discussed earlier, Sabrina-1 recorded maximum plant height, plant spread and fruit breadth which might have a positive influence on average fruit weight in Central midlands.

However in High ranges, Winter Dawn recorded maximum average fruit weight (13.79 g) and Gili recorded the lowest average fruit weight (4.45 g) (Fig. 11). The maximum plant height, maximum number of leaves and fruit length recorded by Winter Dawn might have a positive influence on average fruit weight in High ranges.

5.1.3.5 Days to first harvest

In Central midlands, Winter Dawn recorded the minimum number of days to first harvest (70.17 days). Maximum number of days to first harvest was recorded by Barak (124.33 days). Plants of Winter Dawn recorded earliness in flowering in Central midlands which may lead to early harvesting of strawberry fruits.

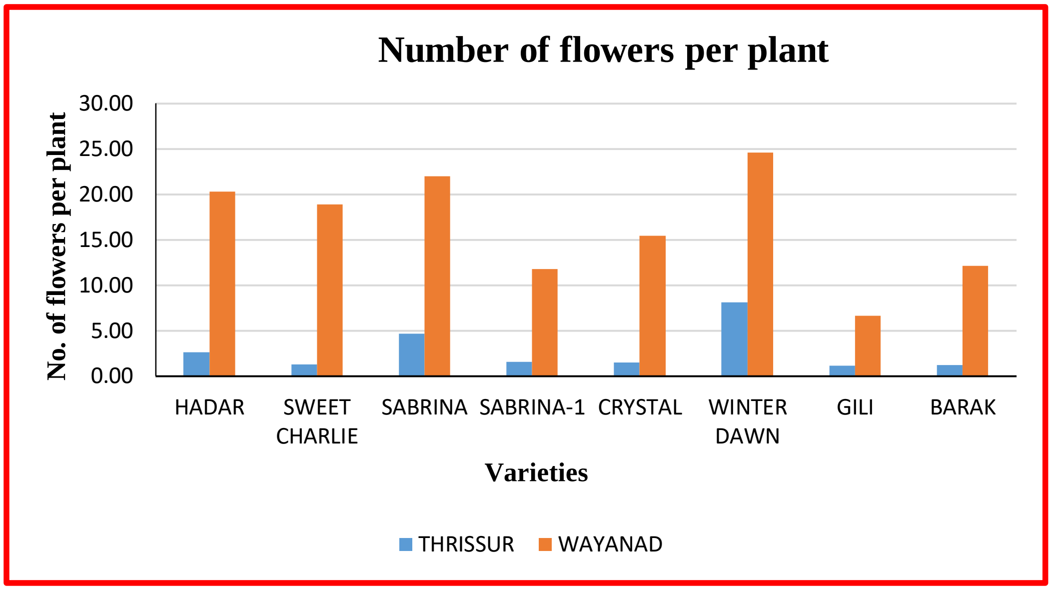


Fig 7. Performance of strawberry varieties for number of flowers per plant

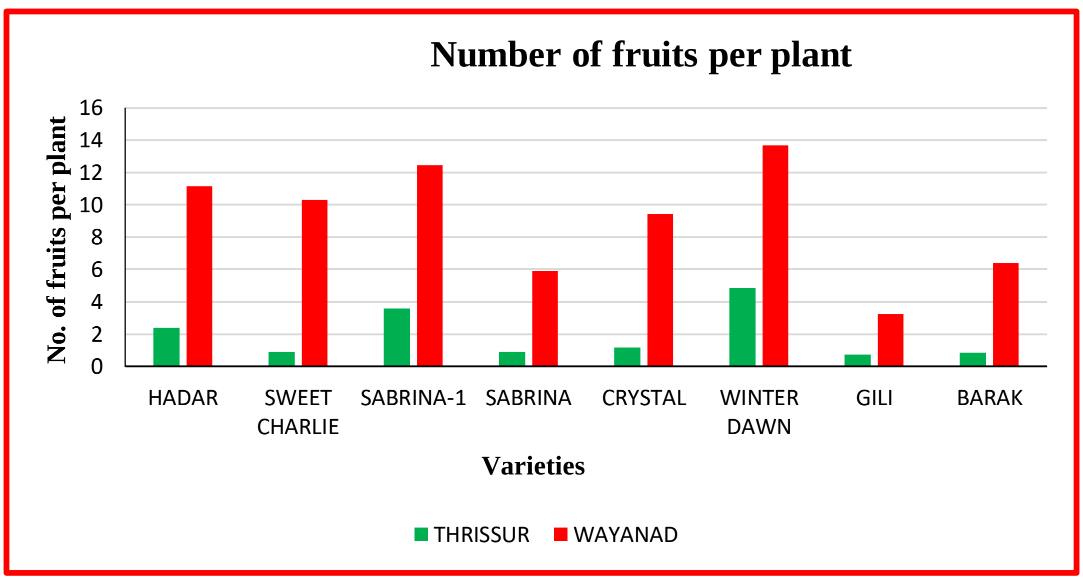


Fig 8. Performance of strawberry varieties for number of fruits per plant

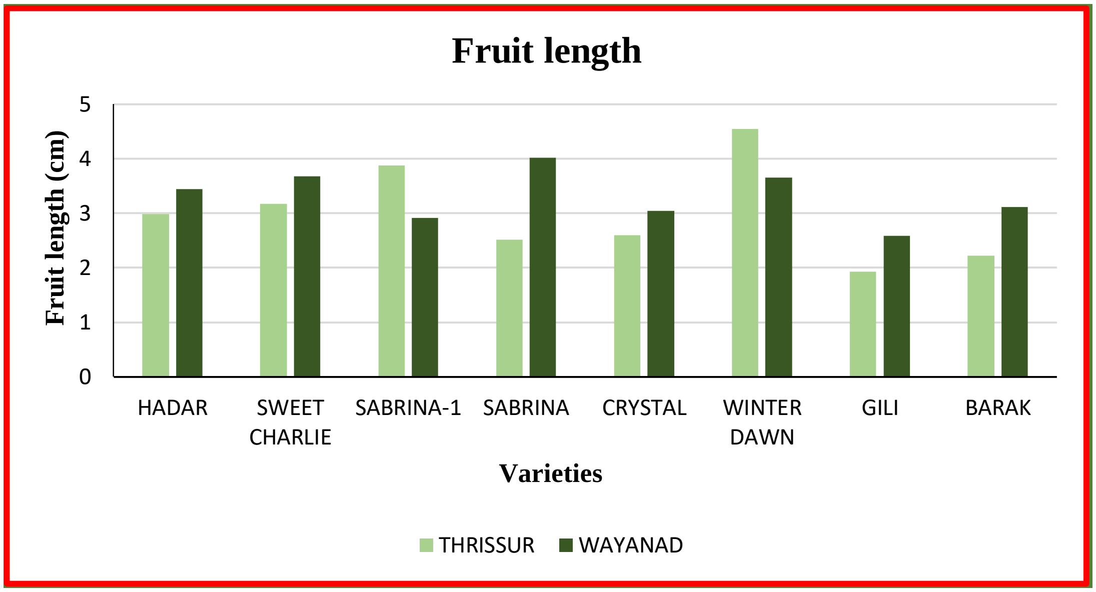


Fig 9. Performance of strawberry varieties for fruit length

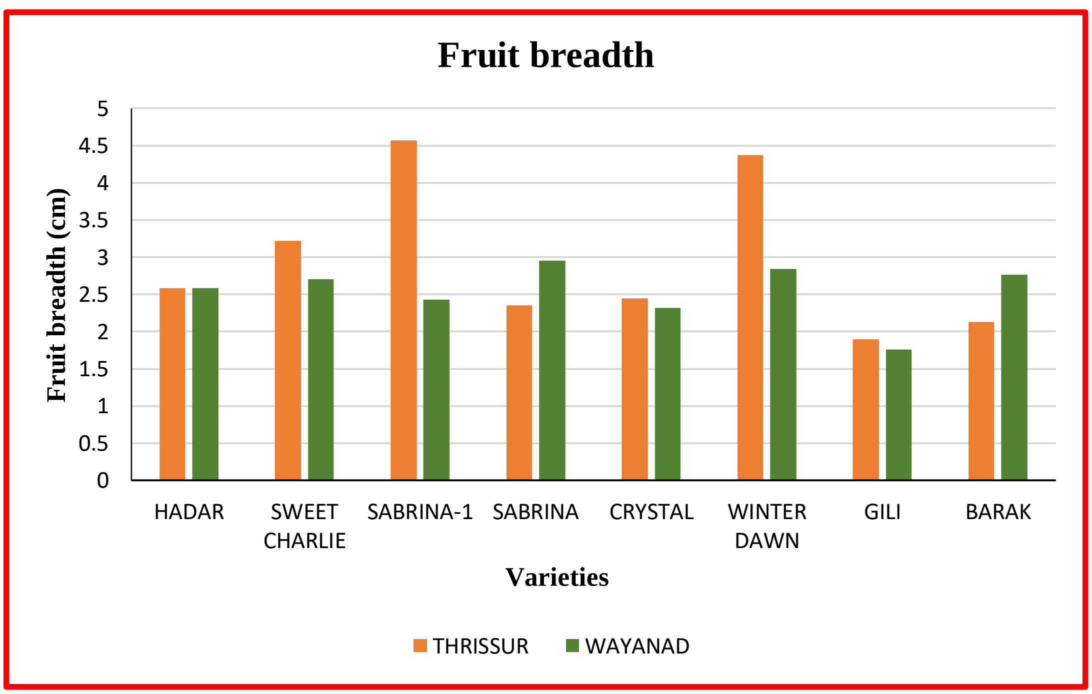


Fig 10. Performance of strawberry varieties for fruit breadth

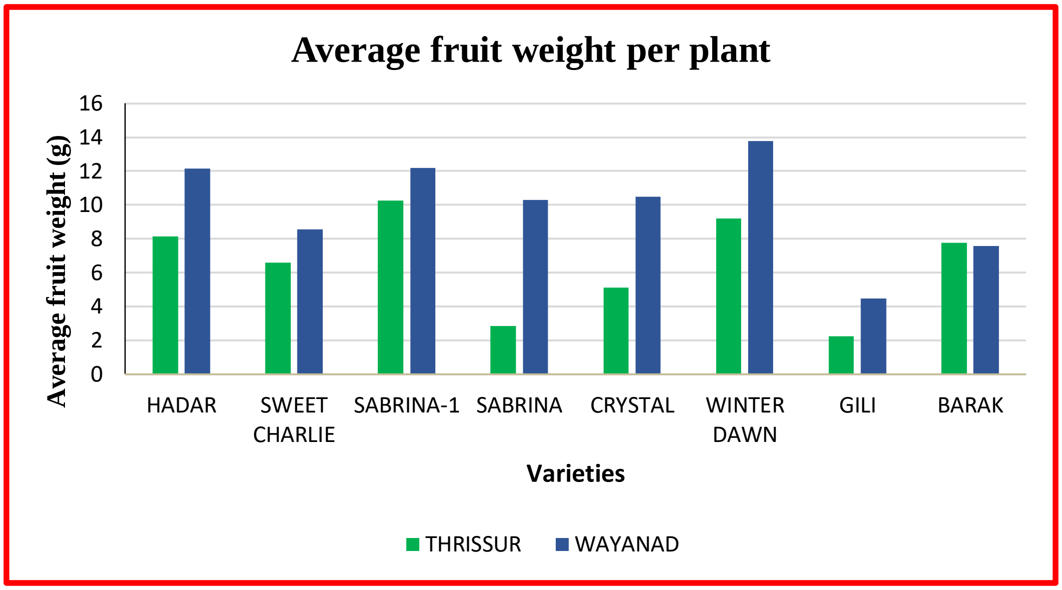


Fig 11. Performance of strawberry varieties for average fruit weight

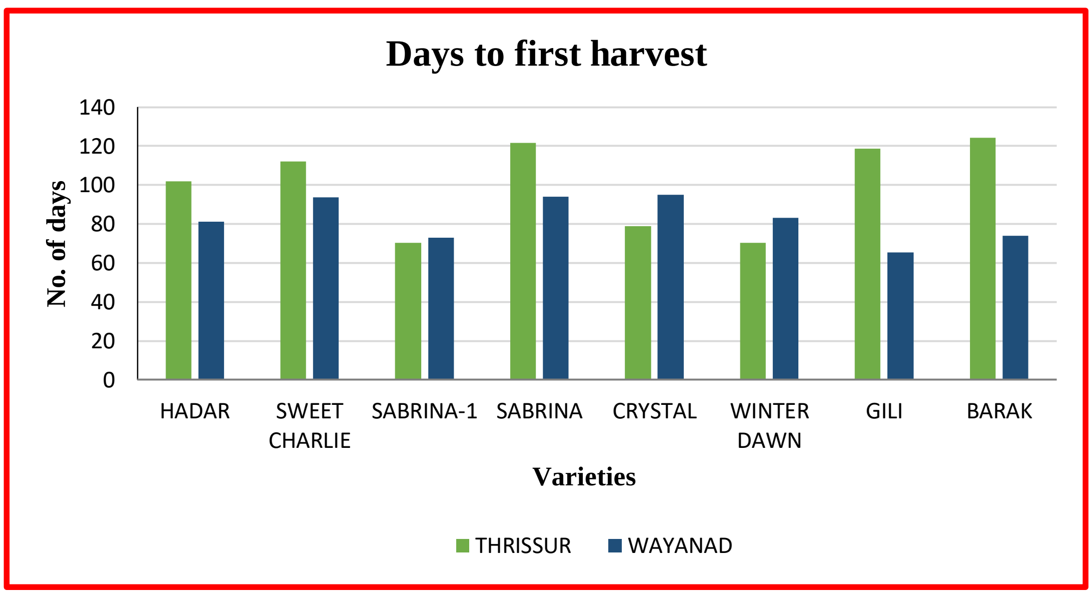


Fig 12. Performance of strawberry varieties for days to first harvest

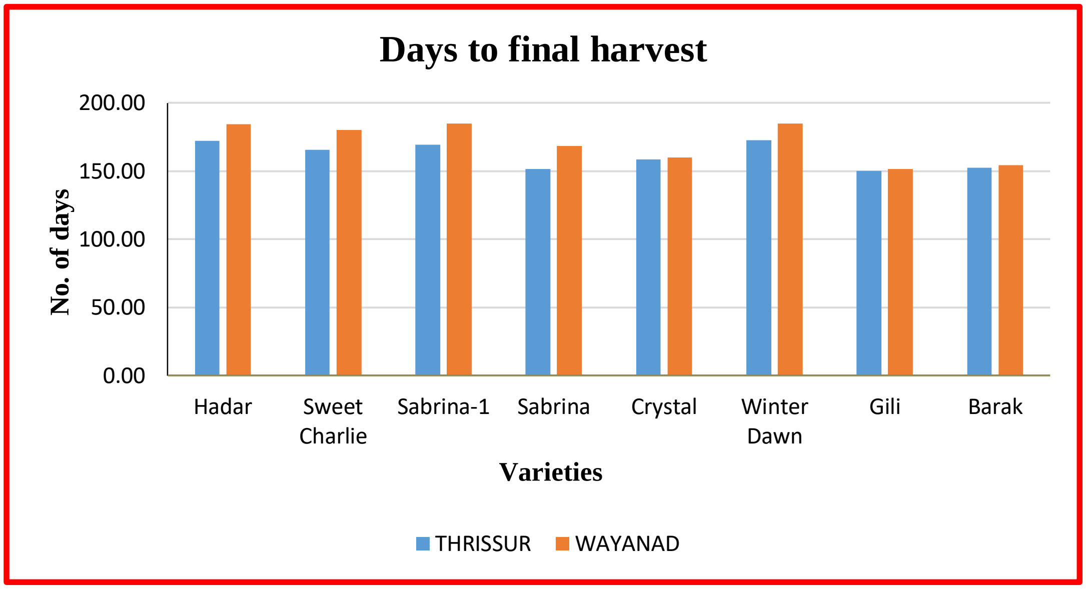


Fig 13. Performance of strawberry varieties for days to final harvest

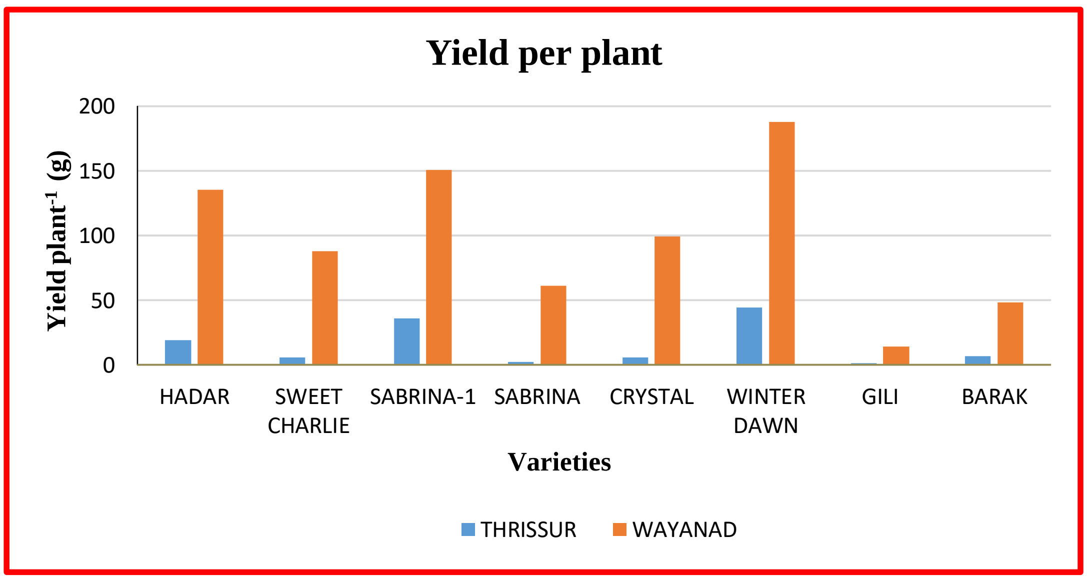


Fig 14. Performance of strawberry varieties for yield per plant

However in High ranges, variety Gili recorded minimum number of days to first harvest (65.33 days) and maximum number of days to first harvest was recorded by Crystal (94.83 days) (Fig 12). Plants of Gili recorded earliness in flowering in High ranges which may lead to early harvesting of strawberry in High ranges also.

5.1.3.6 Days to final harvest

In Central midlands, Winter Dawn significantly recorded maximum number of days to final harvest (172.67 days). Gili recorded the minimum number of days to final harvest (150.00 days).

In High ranges also, Winter Dawn recorded maximum number of days to final harvest (185 days) while Gili recorded minimum days to final harvest (151.67 days) (Fig 13). Similar findings were also recorded with Aslam (2017), where Winter Dawn recorded the maximum number of days to final harvest in High ranges.

Joolka and Badiyala (1983) suggested that harvest duration might be difference in different varieties for their adaptability of cool temperature condition. Also similar variation was found by Macit *et al*. (2007) in strawberry.

5.1.3.7 Yield per plant

In Central midlands, Winter Dawn recorded the maximum yield per plant of 44.53 g per plant while minimum yield per plant of 1.65 g per plant was recorded by Gili. These results are in conformity with the findings of Kurian (2015) in strawberry *cv*. Winter Dawn which recorded yield of 32.67 g. Strawberry *cv*. Winter Dawn recorded maximum number of leaves, maximum number of crowns, maximum number of flowers, maximum number of clusters and fruits per plant which would have ultimately resulted in maximum yield per plant.

In High ranges also, Winter Dawn recorded the maximum yield per plant (187.89 g) and the lowest yield per plant was recorded by Gili (14.42 g) (Fig 14). Earlier results showed that strawberry *cv*. Winter Dawn recorded maximum plant height, number of leaves, number of crowns, number of clusters, number of flowers and number of fruits per plant. This would have ultimately resulted in maximum yield per plant. These findings are in agreement with the observations of Aslam (2017) in strawberry *cv.* Winter Dawn.

These results are also in accordance with the findings of several research workers (Bedarad *et al*., 1971; Lal and Seth, 1980; Sharma and Badiyala, 1980; Singh 1982; Hancock and Bringhurst, 1983). They found a strong correlation with fruit number per plant and weight with total fruit yield but in contrast**,** Dhaliwal and Singh (1983) reported that higher yield of strawberry cultivars was due to number of fruits per plant which may be smaller and lighter in size.

5.1.4 Quality attributes

5.1.4.1 TSS

In Central midlands, Gili recorded the highest TSS content (7.07 ^{0}Brix) which was comparable with Sweet Charlie (6.97 ^{0}Brix) while lowest TSS content of 4.43 ^{0}Brix was recorded by Sabrina.

In High ranges, Hadar recorded maximum TSS content of 9.37 ^{0}Brix. Lowest TSS content was recorded by Crystal of 6.63 ^{0}Brix (Fig 15).

The difference in TSS content of strawberry varieties in two locations may be due to the variation in climatic conditions prevailing in two locations and the genetic makeup of genotypes. Higher temperature (36 ^{0}C) in Central midlands during the production season resulted in the lower TSS content compared to High ranges. The concentration of soluble solids have been reported to be affected by environmental factors, was supported by Sacks and Shaw (1994) and Das *et al*. (2007).

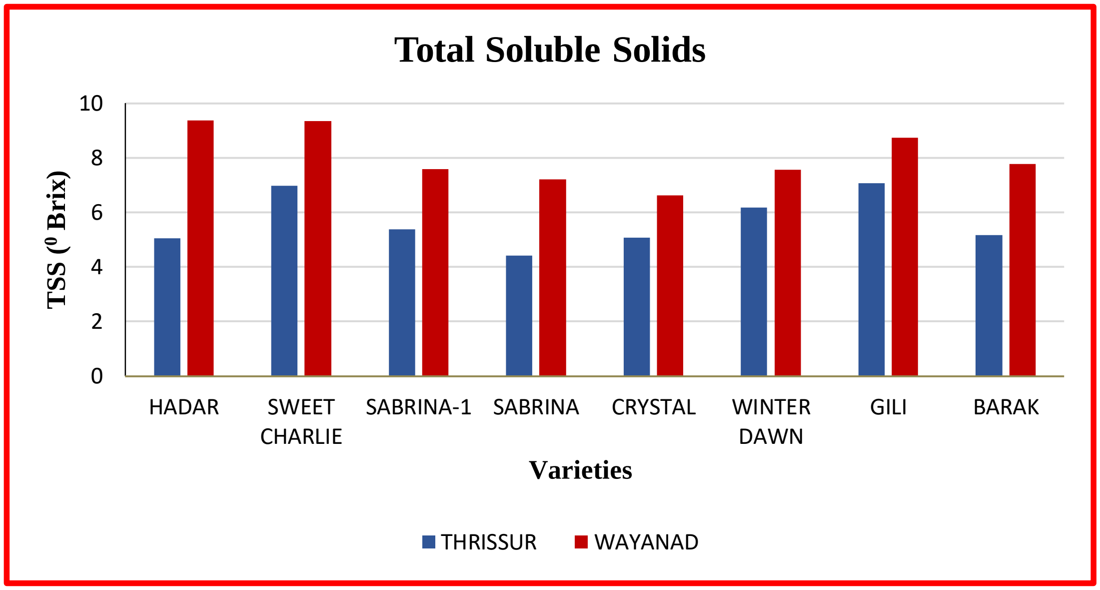


Fig 15. Performance of strawberry varieties for TSS

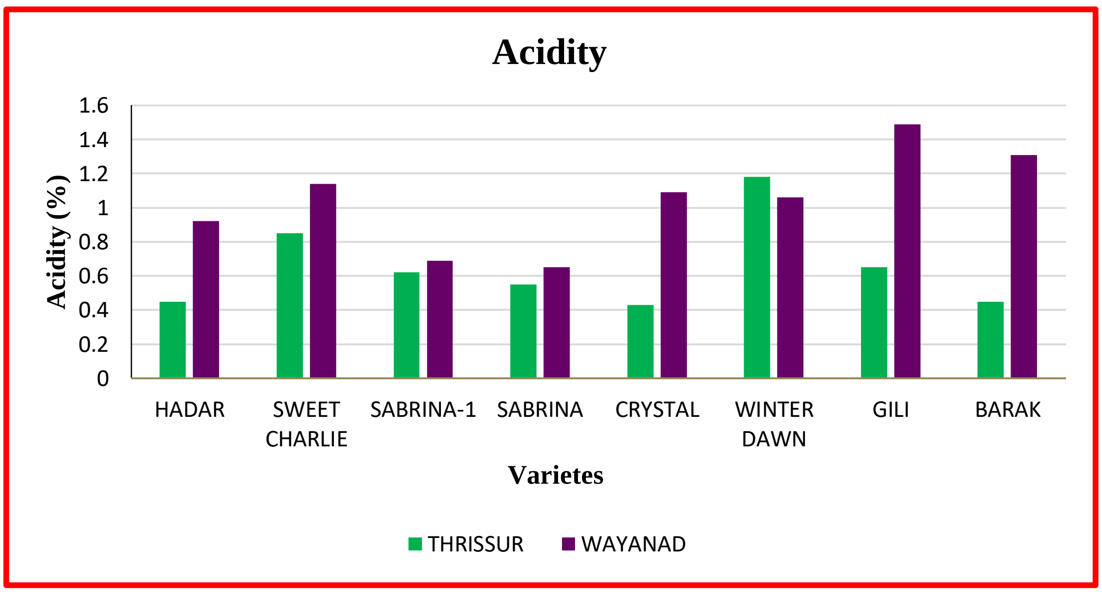


Fig 16. Performance of strawberry varieties for acidity

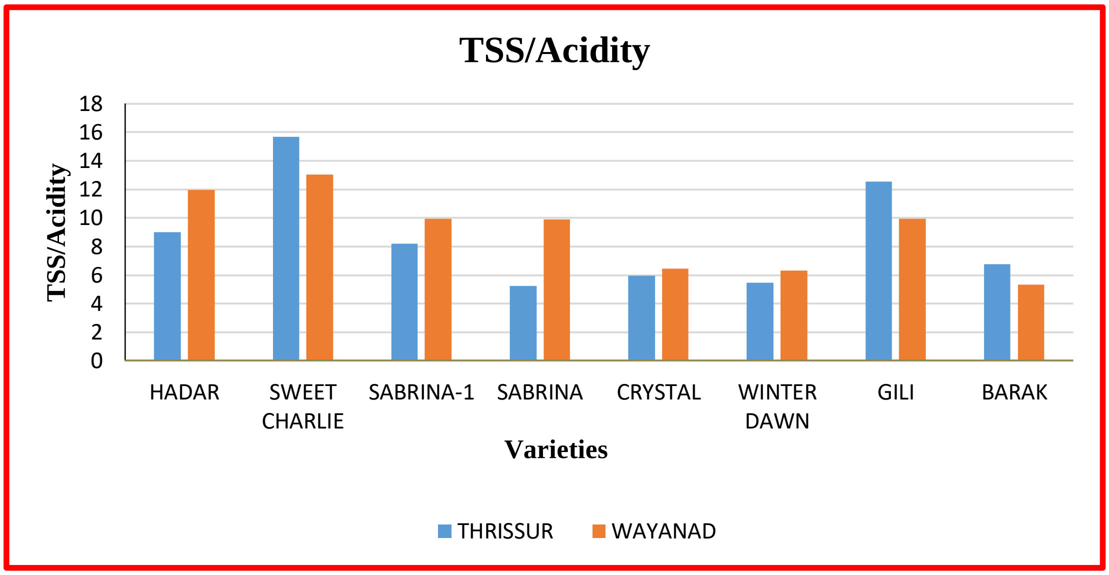


Fig 17. Performance of strawberry varieties for TSS/Acidity

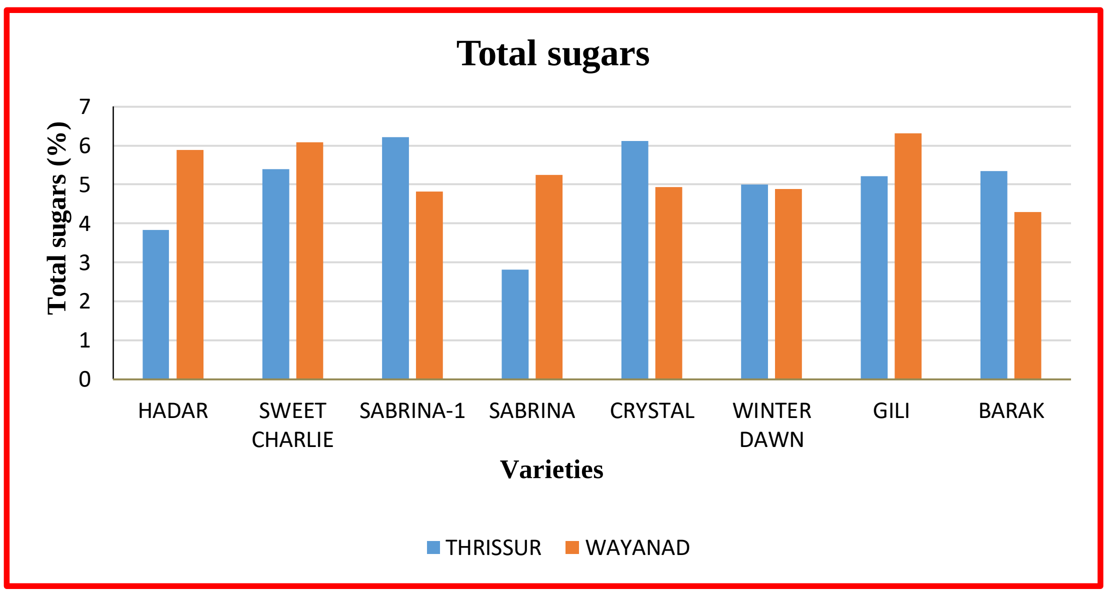


Fig 18. Performance of strawberry varieties for total sugars

5.1.4.2 Acidity

In Central midlands, the lowest titrable acidity was recorded by Sweet Charlie while the highest acidity was recorded by Winter Dawn and it ranges from 0.45 % to 1.14 %.

In High ranges, lowest titrable acidity was recorded in Sweet Charlie and Sabrina and the highest value for titrable acidity was recorded by Barak and it ranges from 0.75 % to 1.46 % (Fig 16).

Titrable acidity of the fruits ranged from 0.31 % to 0.36 % (Spayed and Morris, 1981). Titratable acidity gradually declined during ripening. So content of titrable acidity vary in different reports and in recent experiment ranged from 0.45 to 1.46 % which can be due to incomplete ripening of fruits. Results also shown that titrable acidity of Central midlands was lower than that of High ranges. Results also support the findings that with increase in day/night temperature, citric acid content decreases (Wang and Camp, 2000). Contrary to that there is a positive correlation between TA and air temperature (Yommi *et al*., 2003). Hence in the same corollary, plants grown at Central midlands produced less acidic fruits.

5.1.4.3 TSS/Acidity

In Central midlands, maximum TSS/Acidity was recorded by Sweet Charlie (15.68) and the minimum TSS/Acidity was recorded by Sabrina (5.22). Earlier results showed that cv. Sweet Charlie recorded higher TSS content and lower acidity. This might be the reason for maximum TSS/Acidity.

In High ranges, maximum TSS/Acidity was recorded by Sweet Charlie (13.02) while minimum TSS/Acidity was recorded by Barak (5.35). Winter Dawn recorded TSS/Acidity ratio of 6.30 (Fig 17). These findings were supported by the earlier research studies by Maheshgowda *et al*. (2016) they observed that *cv*. Sweet Charlie recorded sugar: acid ratio of 12 and *cv*. Winter Dawn recorded sugar: acid ratio of 7.63 in hilly zones of Karnataka.

These findings were also supported by Sims *et al*. (1997); Hakala *et al*. (2003); Crespo *et al*. (2010); Larrouy *et al*. (2011) and Aslam (2017) for the main fact that in the same location, the genotype was a major factor in the expression of fruit quality attributes in strawberry. Fruit composition is highly dictated by availability of light and night temperature as different genotypes differ in their requirement. The similar results were obtained by Chandel and Badiyala (1996); Das *et al*. (2007); Kumar *et al*. (2011) and Sharma *et al*. (2014).

5.1.4.4 Total sugars

In Central midlands, maximum total sugars content was observed in *cv*. Sabrina-1 (6.21 %), while the lowest total sugars content was observed with Sabrina (2.82 %).

In High ranges, highest total sugars content of fruits was observed with variety Gili (6.32 %) while the lowest total sugars content was observed with variety Barak (4.30 %) (Fig. 18).

These quality parameters vary depend upon the varietal characters.

5.1.4.5 Ascorbic acid

In Central midlands, maximum ascorbic acid was recorded by Winter Dawn (57.81 mg 100 g^{-1}). The lowest ascorbic acid content was recorded by Sabrina (41.41 mg 100g^{-1}).

In High ranges, maximum ascorbic acid content was recorded by Crystal (74.30 mg 100g^{-1}) and the lowest content was recorded by Sweet Charlie (42.50 mg 100g^{-1}) (Fig. 19).

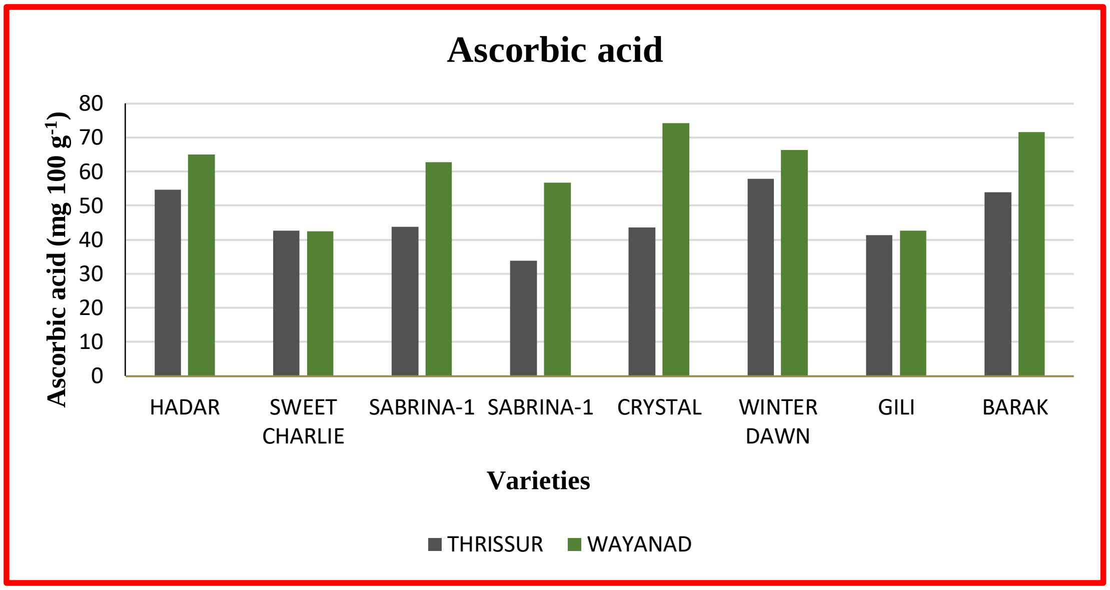


Fig 19. Performance of strawberry varieties for ascorbic acid content

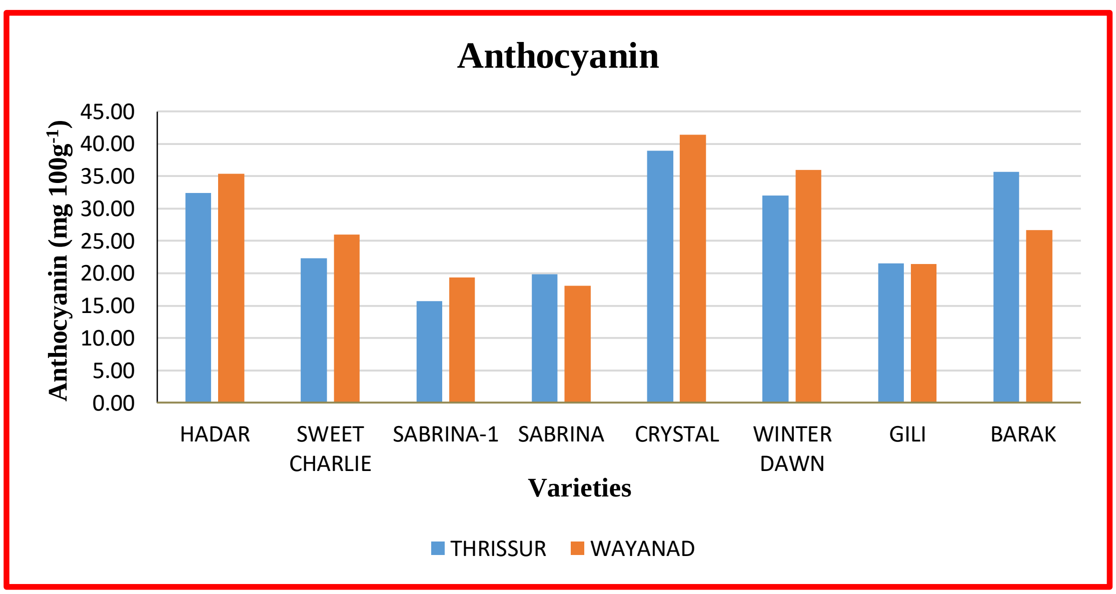


Fig 20. Performance of strawberry varieties for anthocyanin content

These quality parameters vary depend upon the varietal characters. Depend on the cultivars, the effect of different cultivation practices on biosynthesis pathways also vary. The higher ascorbic acid in High ranges compared to Central midlands might be due to higher light intensity prevailing in High ranges. These findings were supported by the observations by Lee and Kader (2000).

5.1.4.6 Anthocyanin

In Central midlands, varieties had significant effect on anthocyanin content of fruits. Maximum anthocyanin content was recorded by Crystal (38.95 mg $100g^{-1}$ and the fruits of Sabrina recorded minimum anthocyanin content (19.80 mg $100g^{-1}$).

In High ranges also, maximum anthocyanin content was recorded by Crystal (41.35 mg $100g^{-1}$) and the lowest anthocyanin content was recorded by Sabrina variety (18.03 mg $100g^{-1}$) (Fig 20).

The high levels of anthocyanin content found in variety Crystal might be due to intense pigmentation of the inner tissues of the fruit than found in other varieties. Notable variability was found among each variety suggesting that edaphic-climatic factors, degree of maturity and the variety itself have a strong influence on the anthocyanin content. The above results can be supported by the earlier research findings of Meyers *et al*. (2003).

5.1.4.7 β-Carotene

In Central midlands, Sabrina-1 recorded the maximum β-Carotene content (3.15 µg $100g^{-1}$) and the lowest β-Carotene content was recorded by variety Hadar (1.85 µg $100g^{-1}$).

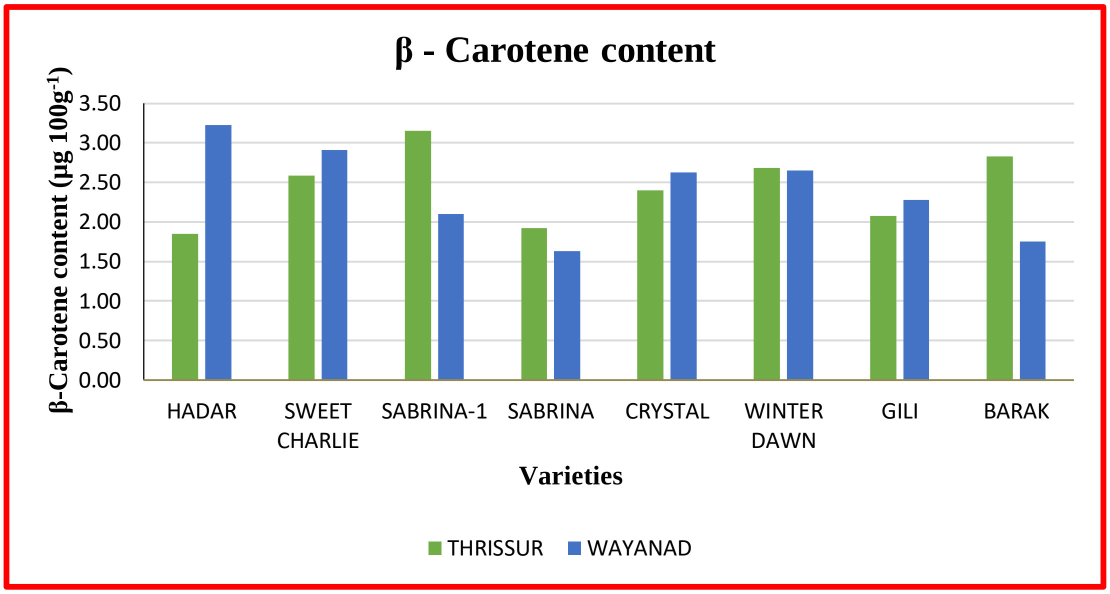


Fig 21. Performance of strawberry varieties for β-Carotene content

In High ranges, Hadar recorded the maximum β-Carotene content of 3.23 µg $100g^{-1}$ and the lowest was recorded by Sabrina (1.63 µg $100g^{-1}$) (Fig 21).

These findings were supported by the main fact that in the same location, the genotype was a major factor in the expression of fruit quality attributes in strawberry (Sims *et al*.**,** 1997; Hakala *et al*., 2003; Crespo *et al*. , 2010; Larrouy *et al*. , 2011).

Plate 4. Strawberry fruits from Central midlands

Plate 5. Strawberry fruits from High ranges

5.1.4.8 Shelf life

In Central midlands, varieties had no significant effect on shelf life of strawberry. In High ranges also, shelf life was not influenced by any of the strawberry varieties. It ranges from 3-4 days. Similar trend was also observed in strawberry by Kurian (2015), Aslam (2017) and Arjun (2017).

5.1.4.9 Colour

In Central midlands, crystal fruits had more deep purplish pink colour of code 67C while all the other varieties were similar in colour of deep purplish pink of 61D. Similar was the case in High lands also. Strawberry fruits of Crystal variety were more deep purplish pink in colour.

Results were supported by earlier findings that Crystal had the maximum anthocyanin content which might lead to the production of more pigmentation in fruits.

5.1.4.10 Sensory evaluation

From consumer’s point of view, sensory qualities are important. It is a result of a complex balance between appearance, colour, flavour, aroma, taste, texture, after taste. Overall acceptability of any fruit is based on all these characters (Table 33a and 33b).

In Central midlands, during first year, overall sensory score was higher for variety Sabrina-1 and Winter Dawn. During second year, overall sensory score was higher for Winter Dawn. Earlier result shown that Sabrina-1 produced fruits with higher total sugars. The fruits of Winter Dawn also showed maximum sensory score for taste, aroma, texture and after taste which might have influenced overall sensory quality of fruits. Evaluating all the characters during both seasons of growth, both Sabrina-1 and Winter Dawn showed stability in their sensory qualities. So in Central midlands, better quality fruits were produced by Sabrina-1 and Winter Dawn.

In High ranges, during first year, overall sensory score was higher for variety Sweet Charlie during both seasons of growth. Earlier results shown that fruits of Sweet Charlie recorded maximum TSS, TSS/acidity and total sugars content. All these may lead to the production of quality fruits.

5.1.5 Pest and Disease incidence and severity

In Central midlands, during the entire period of study, only one severe pest (Termites) was there. Other pests (Black looper – *Hyposidra talaca*, Hairy caterpillar- *Orgyia postica*, Leaf tip roller – *Archis semiferanus* and Fruit borer) were only minor pests. Among the diseases, Fusarium crown rot was a severe one compared to *Alternaria alternata* leaf spot and *Pestalotiopsis longisetula* leaf spot.

In High ranges, there were minor attacks due to looper and fruit borer. Termite attack was not observed there. Alternaria leaf spot was observed in both locations.

The difference in the incidence and severity of pests and diseases may be due to the difference in soil and agro climatic conditions prevailing in Central midlands and High ranges. Pests and diseases were controlled by adopting suitable control measures.

5.1.6 Economics of cultivation

In Central mid-lands, maximum benefit cost ratio was observed in Winter Dawn (0.54) and minimum was recorded in Gili (0.02). In High ranges also, maximum benefit cost ratio was observed in Winter Dawn (2.27) and minimum was recorded in Gili (0.17) (Table 34b, Appendix V).

These findings were supported by Hossain *et al*. (2017) by the research work conducted in north east region of India revealed that cv. Winter dawn recorded maximum benefit cost ratio and the least was recorded by *cv*. Gili.

5.2 Nutrient management in strawberry

5.2.1 Vegetative growth attributes

5.2.1.1 Plant height

In Central midlands, different nutrient combinations had a significant influence on plant height. Among the different nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100 recorded maximum plant height in the later stages of growth. Absolute control recorded minimum plant height during all stages of growth (Fig 22). Earlier results suggested that N rates of 75 kg ha^{-1} or less was sufficient for the vegetative growth of different genotypes. These results are in conformity with the findings of Arjun (2017) where FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100 recorded maximum plant height in *cv*. Winter Dawn. Lower plant height in absolute control may be due to the poor nitrogen content in the soil.

5.2.1.2 Number of leaves per plant

In Central midlands, different nutrient combinations had a significant influence on number of leaves per plant. Among the different nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 recorded maximum number of leaves per plant in later stages of growth. Absolute control recorded minimum number of leaves during all stages of growth (Fig 23). This is in conformity with the findings of Simonne *et al*. (2001); Tworkoskia *et al*. (2001); Abu-Zahra and Tahboub (2008); Santos and Chandler (2009); Arjun (2017). Lower number of leaves in absolute control may be due to the poor nutrient content in the soil.

5.2.1.3 Plant spread

In Central midlands, different nutrient combinations had a significant effect on plant spread. Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 recorded maximum plant spread in the later stages of growth. Absolute control recorded minimum plant spread (Fig 24). Earlier results showed that this

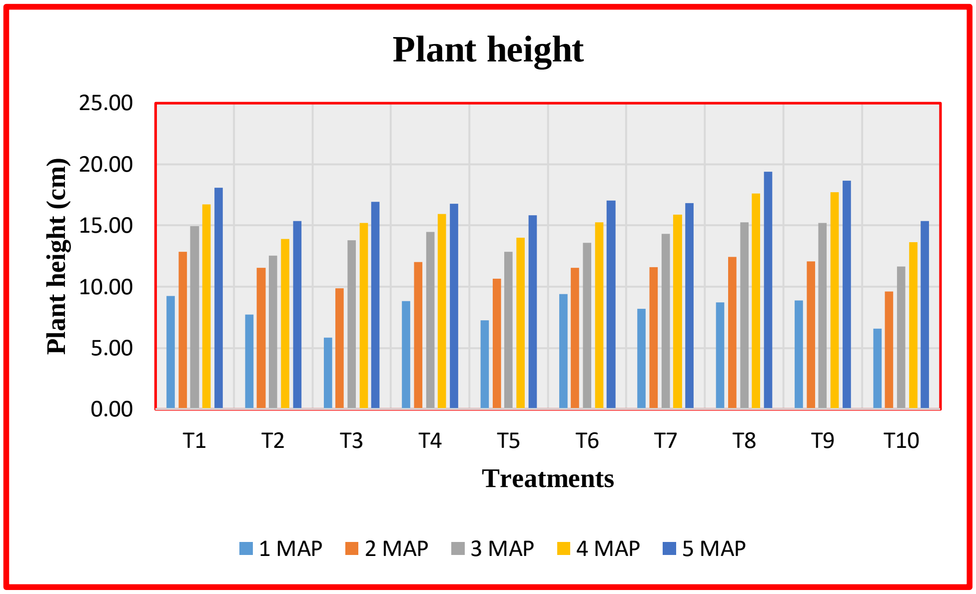


Fig 22. Effect of different treatments on plant height of strawberry

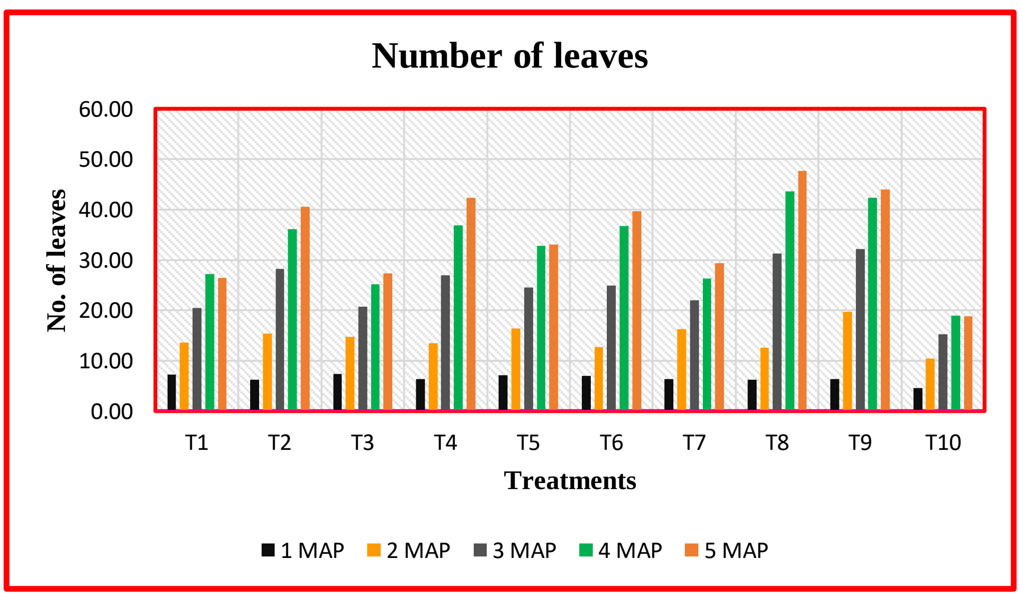


Fig 23. Effect of different treatments on number of leaves of strawberry

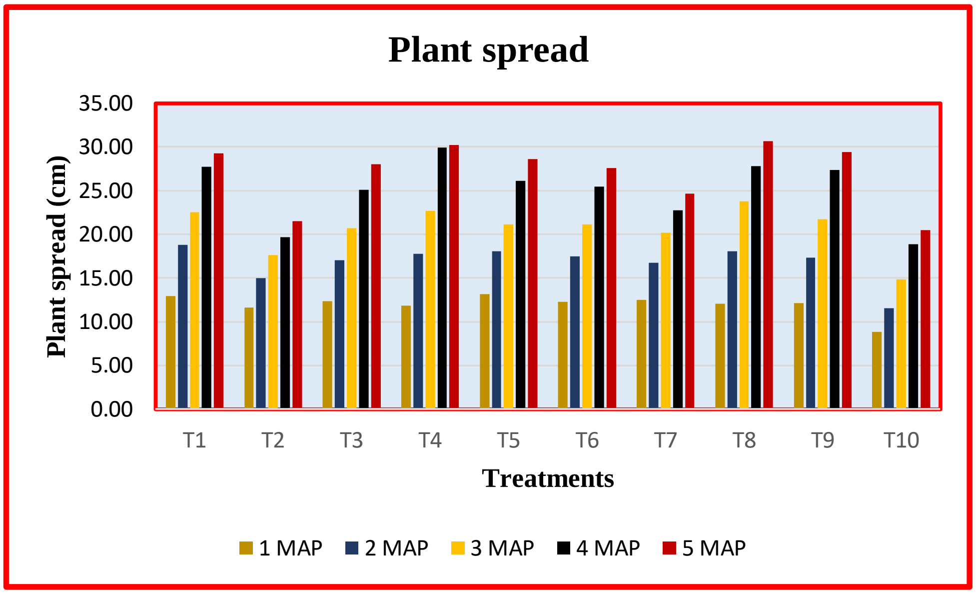


Fig 24. Effect of different treatments on plant spread of strawberry

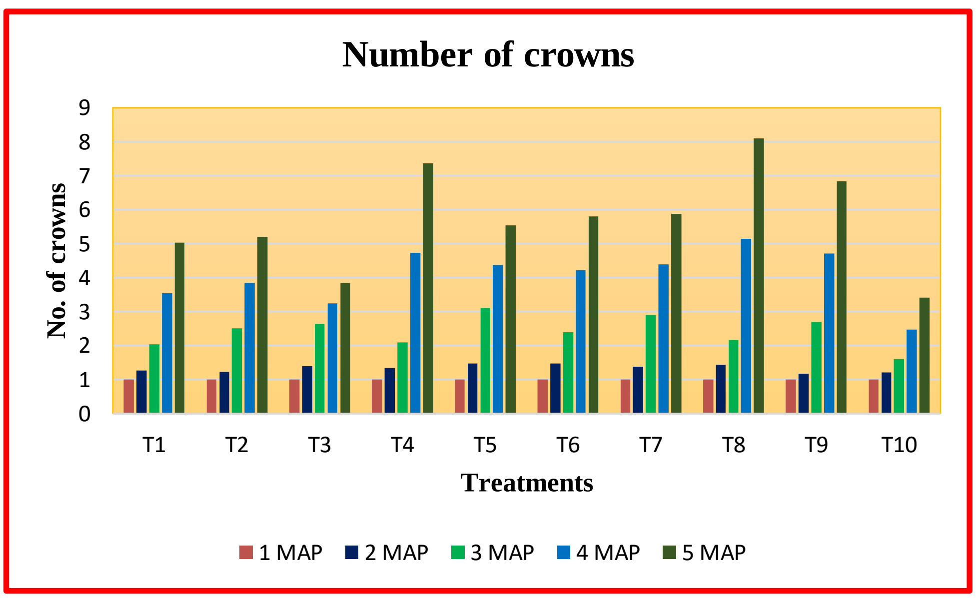


Fig 25. Effect of different treatments on number of crowns of strawberry

nutrient combination had significant influence on plant height and number of leaves of strawberry. This may be the reason for increase in plant spread also. This was supported by the findings of Arjun (2017).

5.2.1.4 Number of crowns

In Central midlands, different nutrient combinations had a significant effect on number of crowns per plant. Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100 recorded maximum number of crowns per plant. Absolute control recorded minimum number of crown per plant (Fig 25). The nutrient combinations favoured for plant height, number of leaves and plant spread in earlier results which might have influenced the production of maximum number of crowns also.

5.2.2 Flowering attributes

5.2.2.1 Days to first flowering

In Central midlands, different nutrient combinations had no significant effect on the number of days to first flowering and number of days to first flowering ranges from 49.70 days to 50.60 days. Since the same variety Winter Dawn was used in all the treatments and it exhibited earliness in flowering (Fig 26).

5.2.2.2 Number of flowers per plant

In Central midlands, different nutrient combinations had a significant effect on the number of flowers per plant. Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 produced more number of flowers per plant (8.71). Absolute control recorded minimum number of flowers per plant (Fig 27). Plants fertilised with the same nutrient combination also exhibited maximum plant height, number of leaves, plant spread and number of crowns per plant. This may be reason for higher number of flowers per plant.

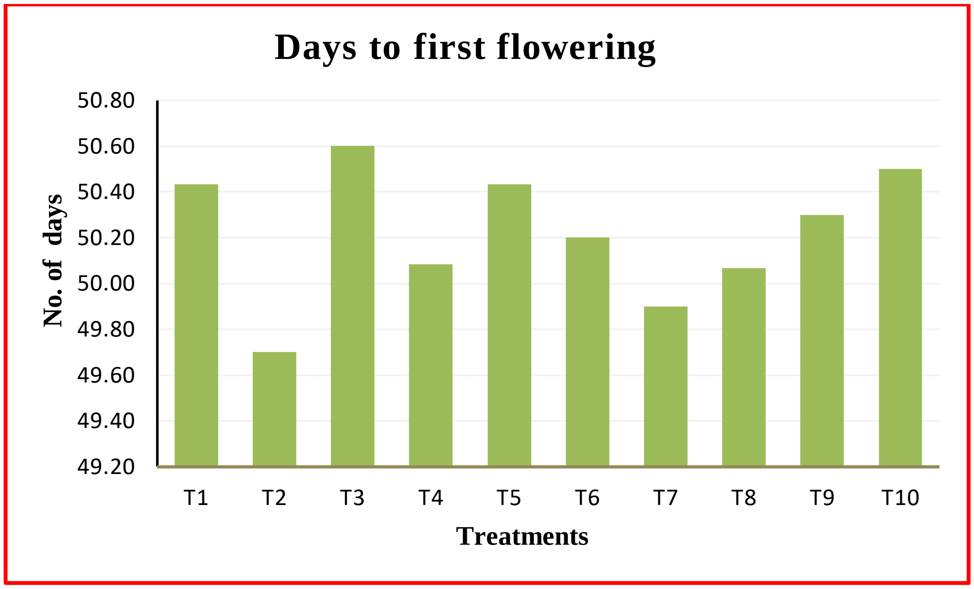


Fig 26. Effect of different treatments on days to first flowering of strawberry

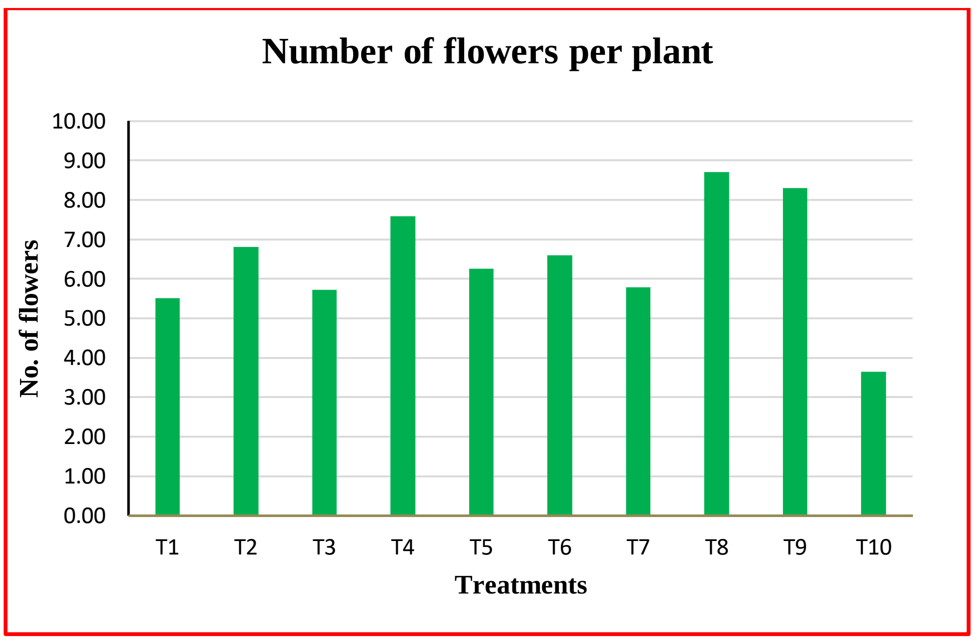


Fig 27. Effect of different treatments on number of flowers per plant of strawberry

5.2.2.3 Number of clusters per plant

In Central midlands, different nutrient combinations had a significant effect on the number of clusters per plant. Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:100:40:50 produced more number of clusters per plant (5.94) which was on par with nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 which produced 5.85 clusters per plant. Absolute control recorded minimum number of clusters per plant (Fig 28). Earlier results reported that plants fertigated with FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 recorded maximum number of flowers and this might be the reason for maximum number of clusters per plant.

5.2.3 Yield attributes

5.2.3.1 Number of fruits per plant

In Central midlands, different nutrient combinations had a significant effect on the number of fruits per plant. Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 produced more number of fruits per plant (6.42). Absolute control recorded minimum number of fruits per plant (Fig 29). The plants applied with nutrient combination FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 exhibited maximum number of flowers per plant. This may be the reason for maximum number of fruits per plant by applying nutrient combination of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100.

5.2.3.2 Fruit length

In Central midlands, different nutrient combinations had a significant effect on fruit length. Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:100:40:50 recorded maximum fruit length (3.33 cm) compared to other nutrient combinations. Absolute control recorded minimum fruit length (Fig 30). Eventhough the number of flowers and fruits recorded are maximum in FYM (t ha^{-1}), N, P_2O_5, K_2O

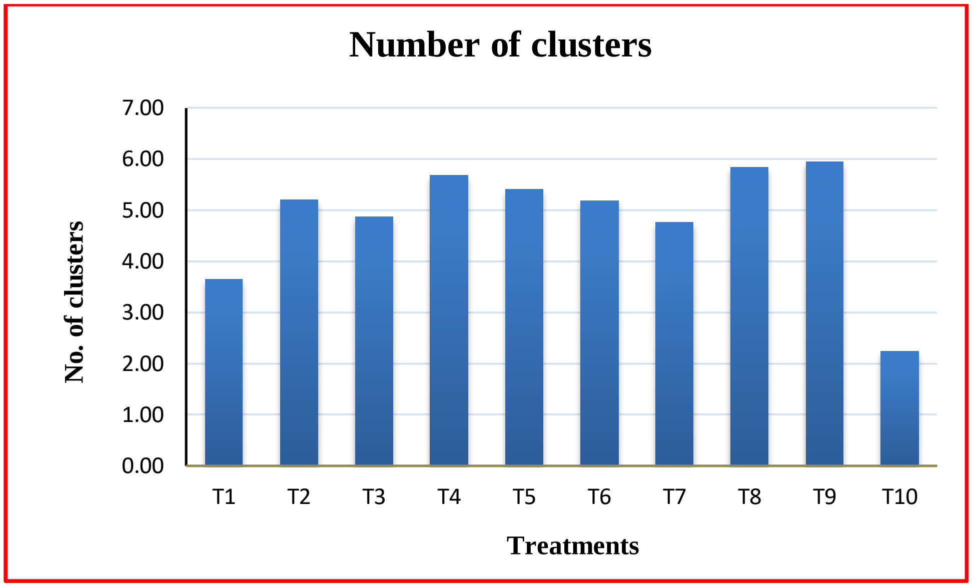


Fig 28. Effect of different treatments on number of clusters per plant of strawberry

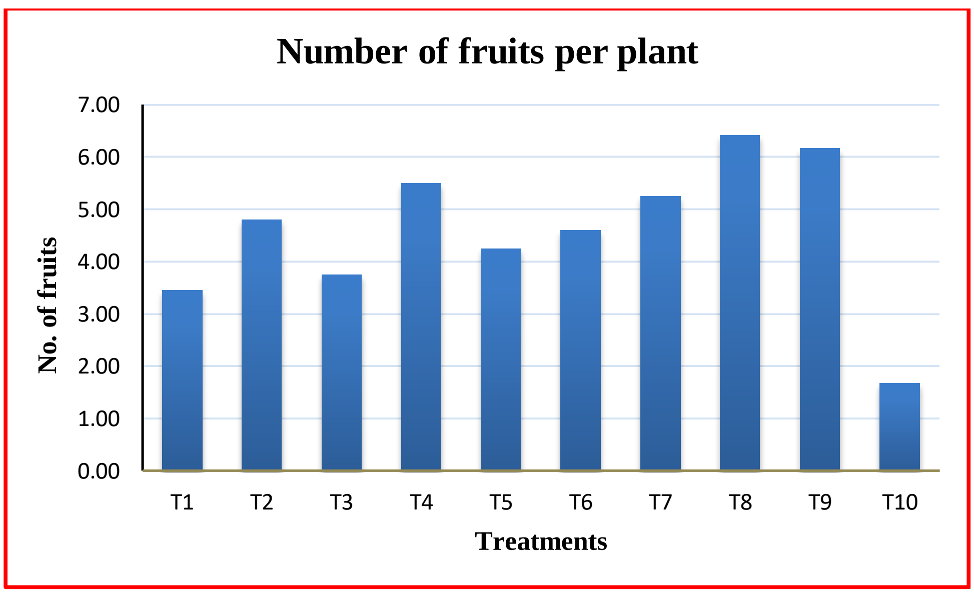


Fig 29. Effect of different treatments on number of fruits per plant of strawberry

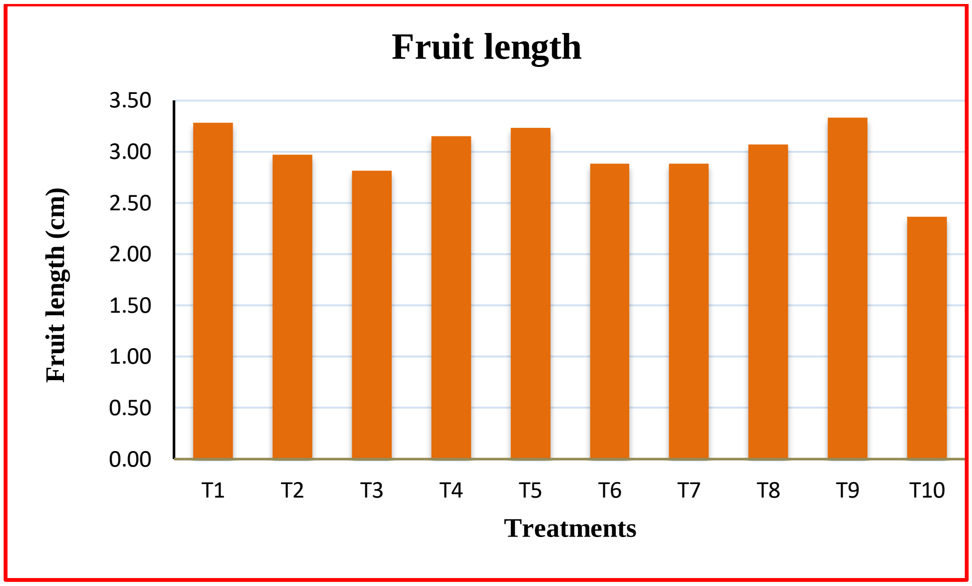


Fig 30. Effect of different treatments on fruit length of strawberry

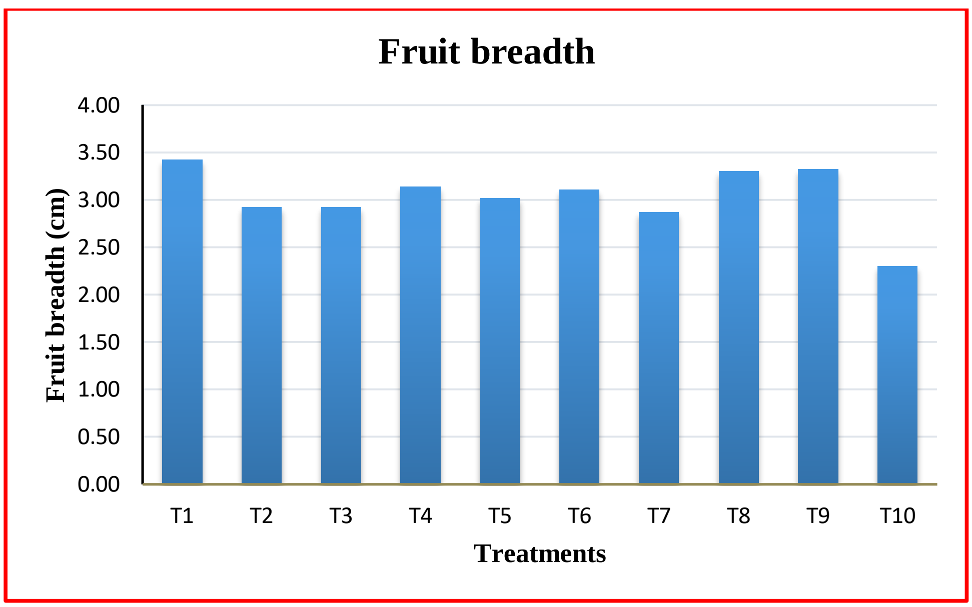


Fig 31. Effect of different treatments on fruit breadth of strawberry

kg ha^{-1}@ 30:75:20:100 nutrient combination, the fruit size is lesser. The increase in number of flowers in plants fertilised with FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 might aggravate internal competition, which in turn impairs flower development resulted in smaller fruits. This is in accordance with the findings of Rindom and Hansen (1995) in strawberry.

5.2.3.3 Fruit breadth

In Central midlands, different nutrient combinations had a significant effect on fruit breadth. Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 10:50:20:50 recorded maximum fruit breadth (3.42 cm) compared to other nutrient combinations. Absolute control recorded minimum fruit breadth (Table 38, Fig 31). In nutrient combination, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 10:50:20:50, the number of flowers and fruits are lesser and the photosynthates get accumulated in lesser number of fruits which ultimately resulted in increased fruit breadth. This is in accordance with the findings of Rindom and Hansen (1995) in strawberry.

5.2.3.4 Average fruit weight per plant

In Central midlands, different nutrient combinations had a significant effect on average fruit weight per plant. Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 10:50:20:50 recorded maximum average fruit weight per plant (12.93 g) compared to other nutrient combinations. Absolute control recorded minimum average fruit weight per plant (Fig 32). In plants fertilised with FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 10:50:20:50 nutrient combinations resulted in maximum fruit breadth which might have resulted in maximum average fruit size and fruit weight per plant.

5.2.3.5 Days to first harvest

In Central midlands, different nutrient combinations had a significant effect on the number of days to first harvest. Among the nutrient combinations, FYM (t ha^{-1}), N,

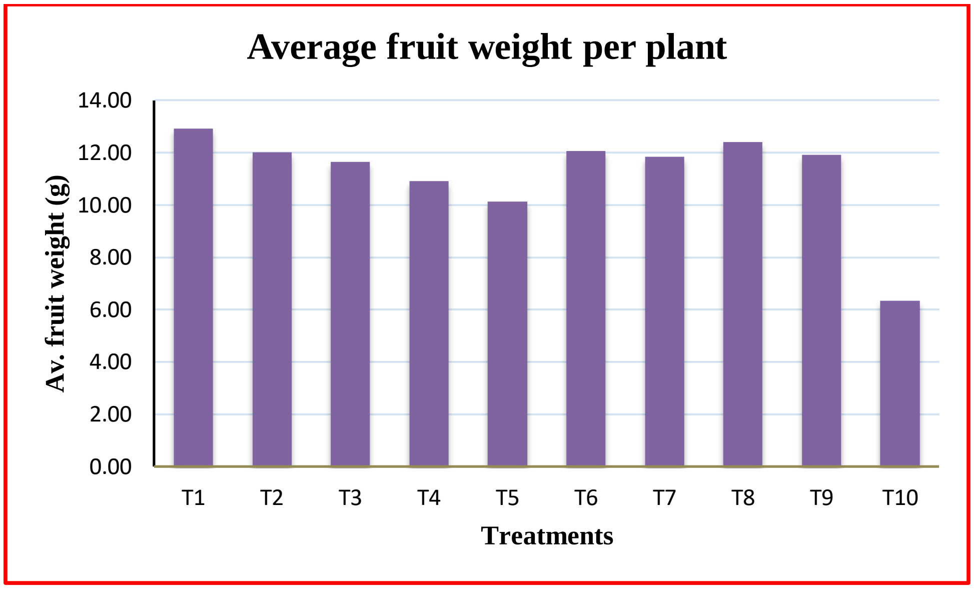


Fig 32. Effect of different treatments on average fruit weight per plant of strawberry

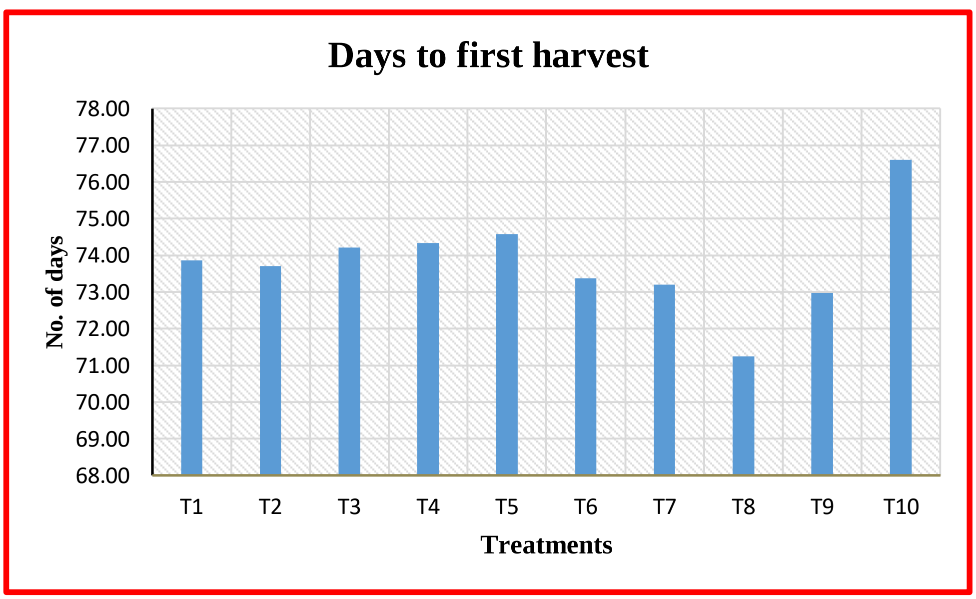


Fig 33. Effect of different treatments on days to first harvest of strawberry

P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 recorded the minimum number of days to first harvest (71.25 days). Absolute control recorded maximum number of days to first harvest (Fig 33). Earlier results showed that nutrient combinations had no significant effect on earliness in flowering. So the nutrient combinations influenced vegetative growth also influenced the fruit growth of strawberry and resulted in early harvesting.

5.2.3.6 Days to final harvest

In Central midlands, different nutrient combinations had a significant effect on the number of days to final harvest. Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 10:100:80:100 recorded the maximum number of days to final harvest (179.33 days), (Table 39, Fig 34). Compared to other nutrient combinations, plants fertilized with FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 10:100:80:100 had high levels of Nitrogen, P_2O_5 and K_2O and this might be the reason for maximum days to final harvest.

5.2.3.7 Yield per plant

In Central midlands, different nutrient combinations had a significant effect on the yield per plant. Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 produced maximum yield per plant (79.92 g). Absolute control recorded lowest yield per plant (Fig 35). Earlier results indicated that plant height, number of leaves, plant spread, number of crowns, number of clusters, number of flowers and number of fruits were maximum in plants fertilised with FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 nutrient combination. This might be the reason for maximum yield per plant in plants fertilized with the above nutrient combination. These findings were in conformity with the observations of Ali *et al*. (2003); Rana and Chandel (2003); Santos and Chandler (2009); Kumar *et al*. (2014); Karlidag and Yildirim (2015).

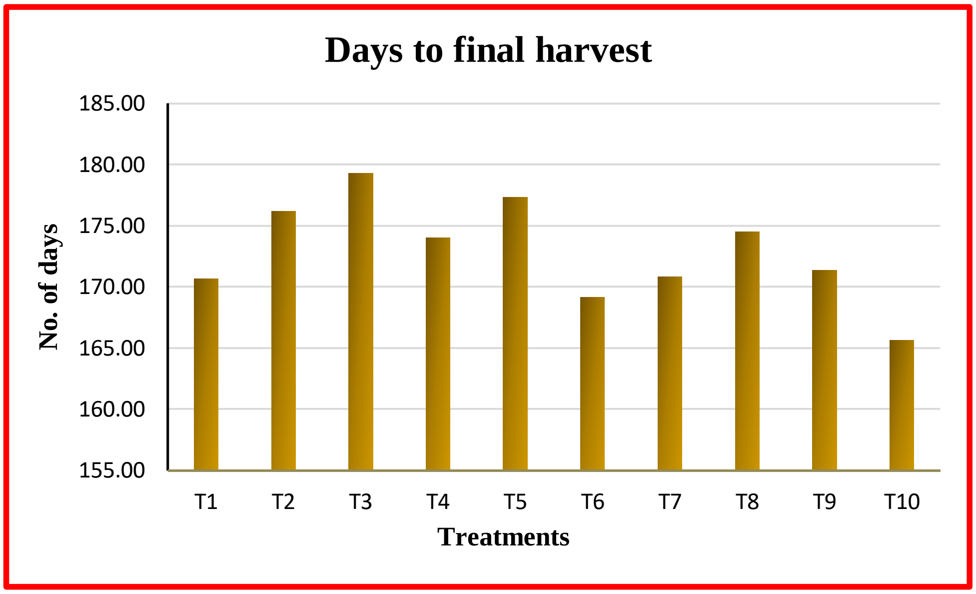


Fig 34. Effect of different treatments on days to final harvest of strawberry

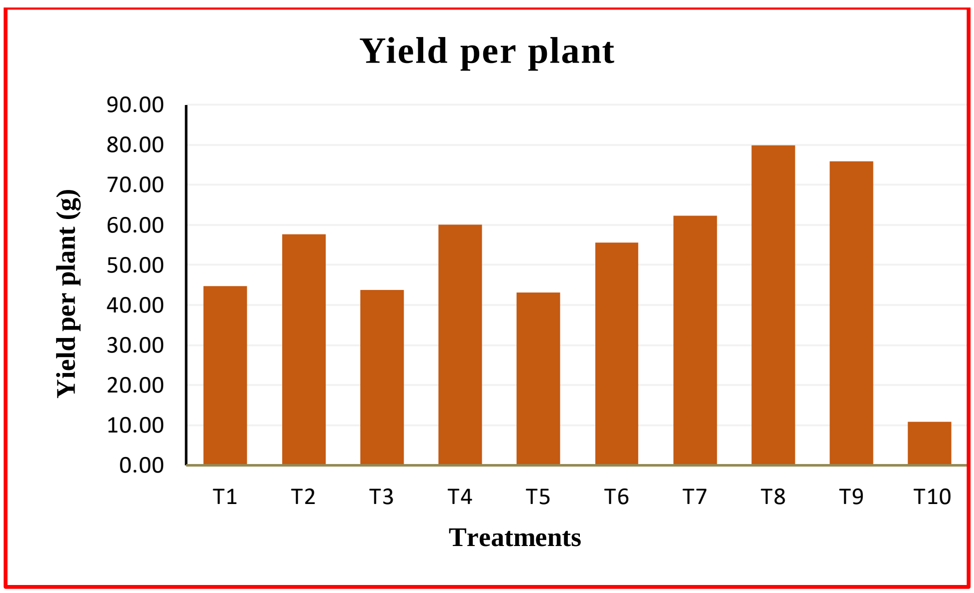


Fig 35. Effect of different treatments on yield per plant of strawberry

5.2.4 Quality attributes

5.2.4.1 TSS

In Central midlands, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 produced maximum TSS of 7.68 ^{0} Brix. Absolute control recorded lowest TSS (Fig. 36). Increase in TSS might be due to the synergistic effect of differential combination of organic and inorganic fertilizers applied in the treatment. This is in close conformity with the findings of Woznaik *et al.* (1997); Ali *et al*. (2003); Aracon *et al*. (2004); El-Hamid *et al*. (2006); Mahadeen (2009); Yadav *et al*. (2010); Shehata *et al*. (2011); Wani *et al*. (2013) and Tripathi *et al*. (2015).

5.2.4.2 Acidity

In Central midlands, different nutrient combinations had no significant effect on the acidity of fruits (Fig. 37).

5.2.4.3 TSS/acidity

In Central midlands, different nutrient combinations had a significant effect on the TSS/acidity ratio of fruits. Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 recorded maximum TSS/acidity ratio of fruits (10.83). FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 20:75:80:50 recorded minimum TSS/acidity ratio of fruits (Fig 38). FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100 recorded maximum TSS content of fruits and this might be the reason for maximum TSS/acidity ratio of fruits.

5.2.4.4 Total sugars

In Central midlands, different nutrient combinations had a significant influence on the total sugars content of fruits. Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:100:40:50 recorded maximum total sugars of fruits (5.23 %). Absolute control recorded lowest total sugars of fruits (Fig 39). The maximum total

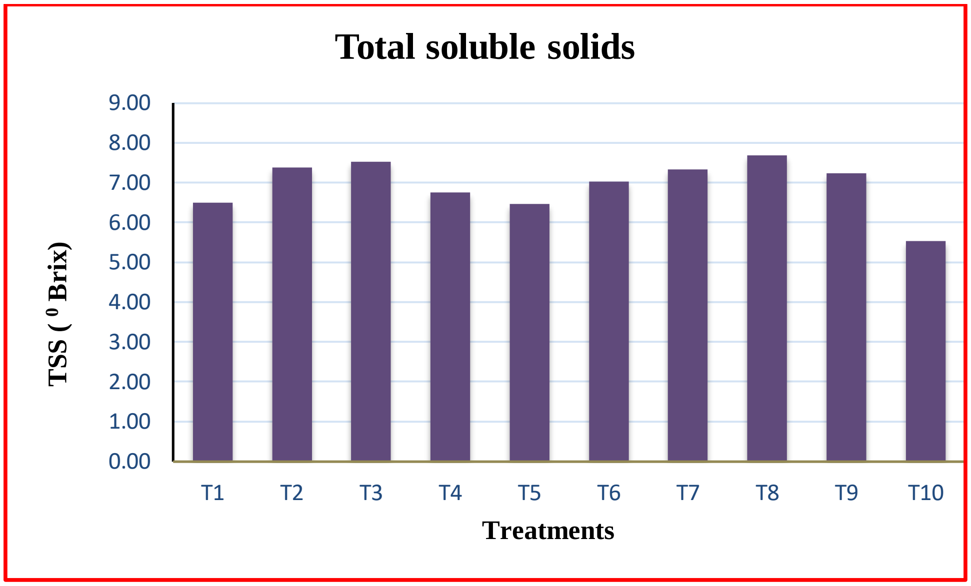


Fig 36. Effect of different treatments on TSS of strawberry

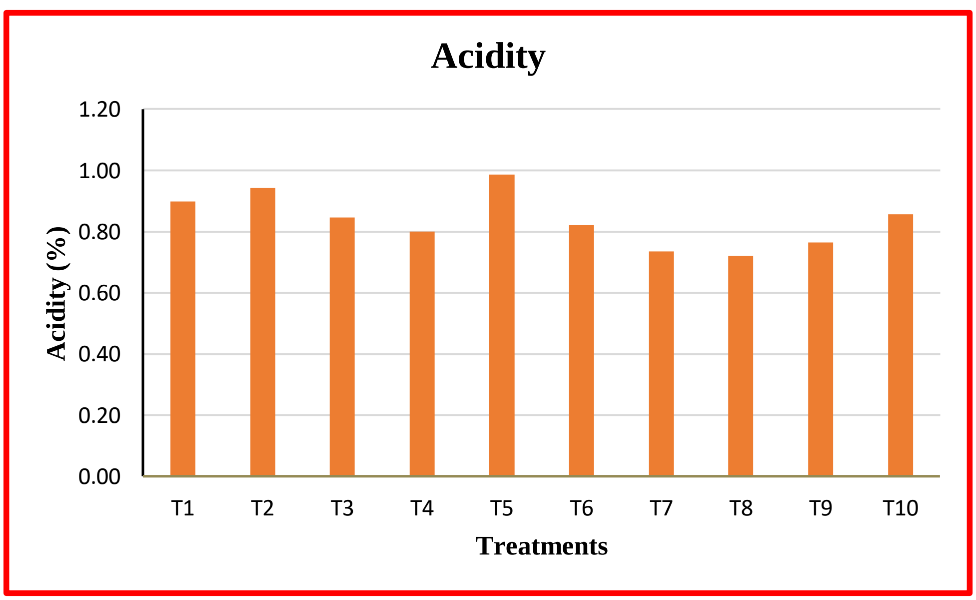


Fig 37. Effect of different treatments on acidity of strawberry

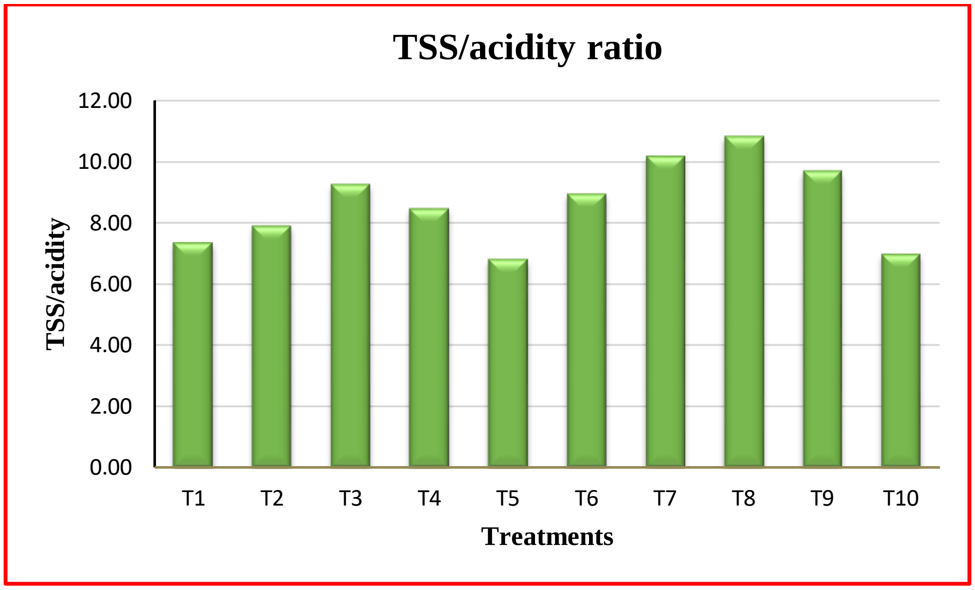


Fig 38. Effect of different treatments on TSS/acidity ratio of strawberry

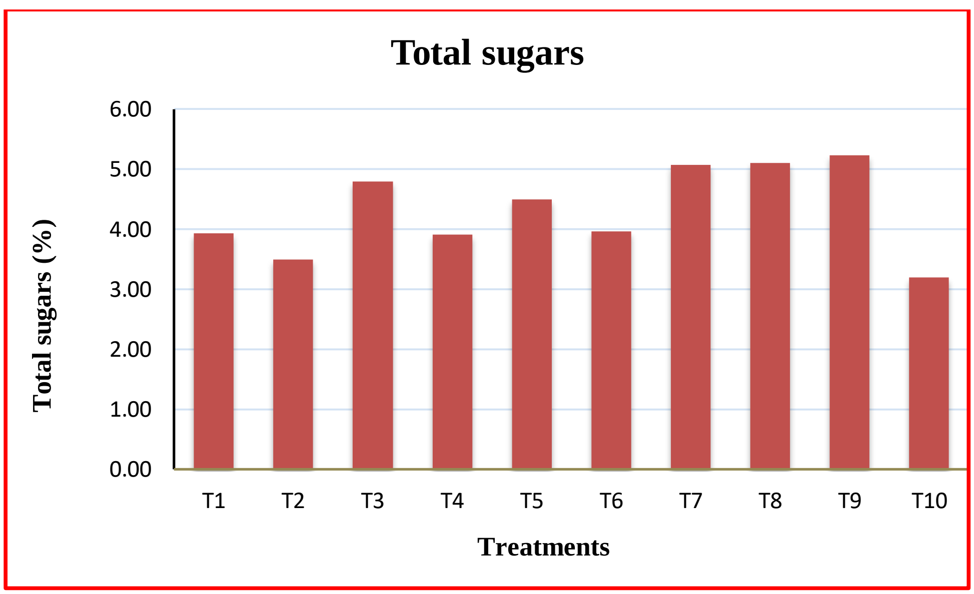


Fig 39. Effect of different treatments on total sugars of strawberry

sugars may be due to the combined effect of higher doses of FYM and nitrogen in the fertilizer application. Hence in same corollary, the organic and inorganic sources are used in combination to exploit their synergistic effect to obtain quality fruits. These findings are in agreement with the observations of Odongo *et al.* (2011); Wani *et al.* (2015); and Arjun (2017).

5.2.4.5 Ascorbic acid

In Central midlands, different nutrient combinations had a significant effect on the ascorbic acid content of fruits. Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50 recorded maximum ascorbic acid content of fruits (52.22 mg 100 g^{-1}). Absolute control recorded lowest ascorbic acid content (Fig. 40). Studies had reported that by increasing the concentration of nitrogen fertilizers, ascorbic acid content increases in strawberry *cv*. Sweet Charlie (Ram and Gaur, 2003). These findings were also supported by Kopanski and Kaweci, 1994; Ali *et al*. (2003). Effect of nutrient combinations varies with variety, soil, season and region (Odongo *et al*.**,** 2011).

5.2.4.6 Anthocyanin content

In Central midlands, different nutrient combinations had a significant effect on the anthocyanin content of fruits. Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:50:80:75 recorded maximum anthocyanin content of fruits (48.15 mg 100 g^{-1}). FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 10:50:20:50 recorded lowest anthocyanin content (Fig. 41). Increasing the concentration of phosphorous content increases quality in strawberry (Cao *et al*., 2015). FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:50:80:75 nutrient combinations have higher phosphorous content. This might had a positive influence on higher ascorbic acid content of fruits. Effect of nutrient combinations varies with variety, soil, season and region (Odongo *et al*. 2011). FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 10:50:20:50 applied plants produced fruits with

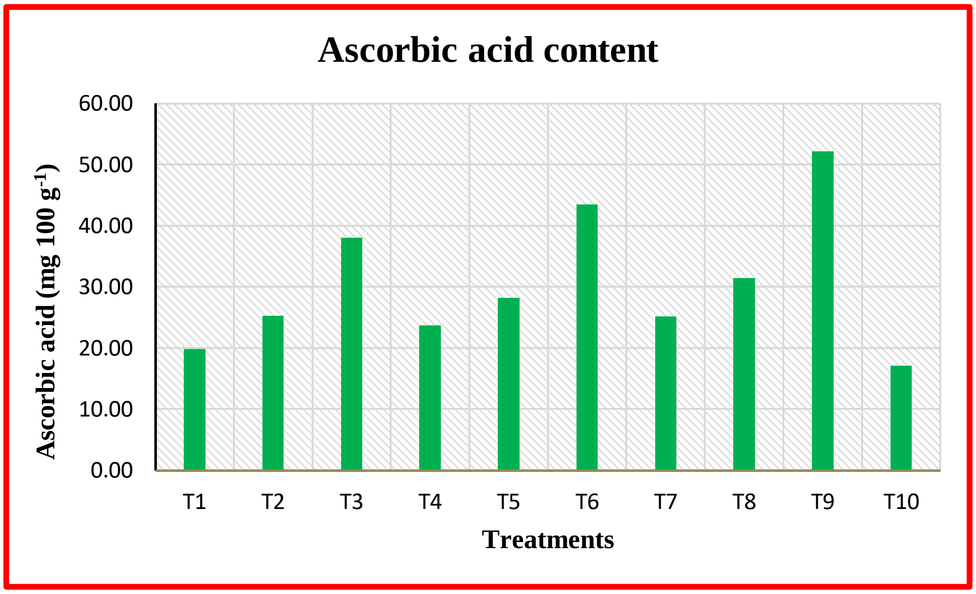


Fig 40. Effect of different treatments on ascorbic acid of strawberry

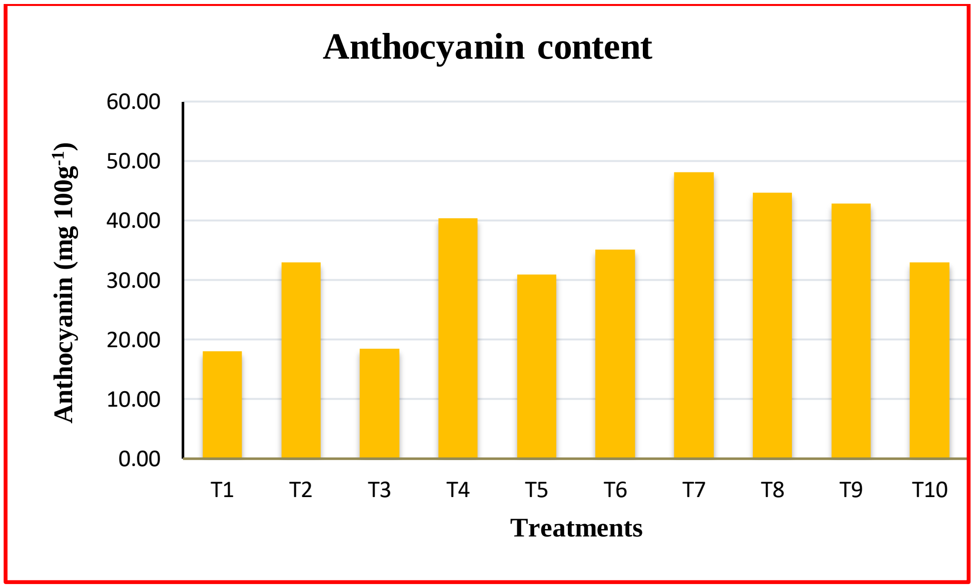


Fig 41. Effect of different treatments on anthocyanin content of strawberry

maximum fruit breadth i.e., maximum fruit size. This may lead to dilution of anthocyanin pigments in the fruits. That may be reason for lower anthocyanin content.

5.2.4.7 β-Carotene content

In Central midlands, different nutrient combinations had a significant effect on the β-Carotene content of fruits. Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 10:100:80:100 recorded maximum β - Carotene content of fruits (2.96 µg 100 g^{-1}). FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 10:50:20:50 recorded lowest β- carotene content (Fig. 42). These findings were supported by the observations of Odongo *et al.* (2011) and Wani *et al*. (2015) indicated that synergistic effect of differential combinations of organic and inorganic fertilizers would influence the production of quality fruits.

5.2.4.8 Shelf life

In Central midlands, fruits from plants applied with all nutrient combinations recorded same shelf life period of 3 days except the nutrient combination FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 10:100:80:100, which recorded shelf life of 4 days when stored at ambient temperature after harvest (Table 44).

5.2.4.9 Colour

In Central midlands, fruits obtained from plants fertilized with different nutrient combinations showed similar fruit colour. All the fruits were similar in colour of deep purplish pink of 61D (Table 45).

5.2.4.10 Sensory evaluation

From consumer's point of view, sensory qualities are important. It is a result of a complex balance between appearance, colour, flavour, aroma, taste, texture, after taste. Overall acceptability of any fruit is based on all these characters~~.~~ (Table 46).

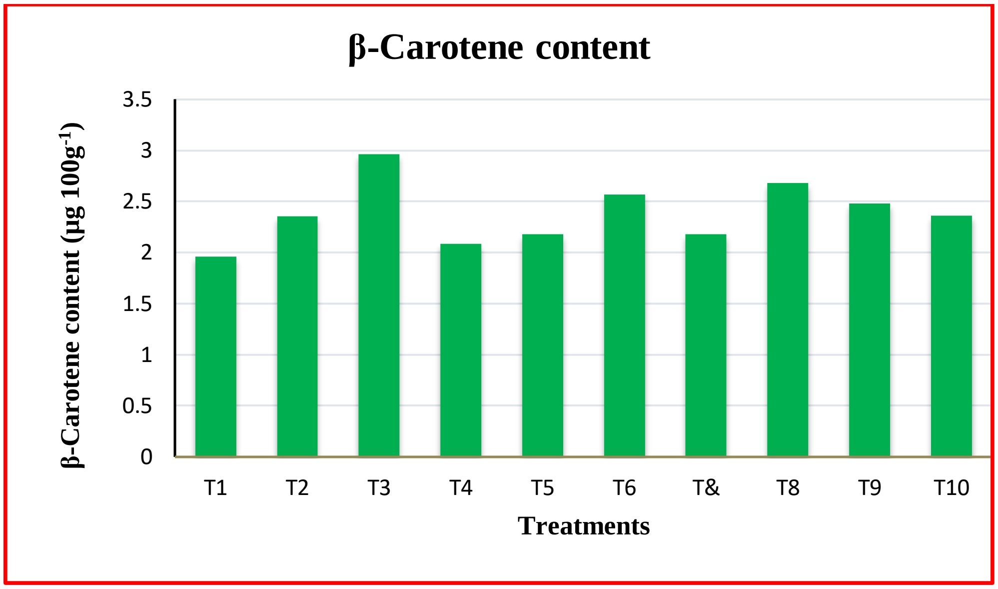


Fig 42. Effect of different treatments on β-Carotene content of strawberry

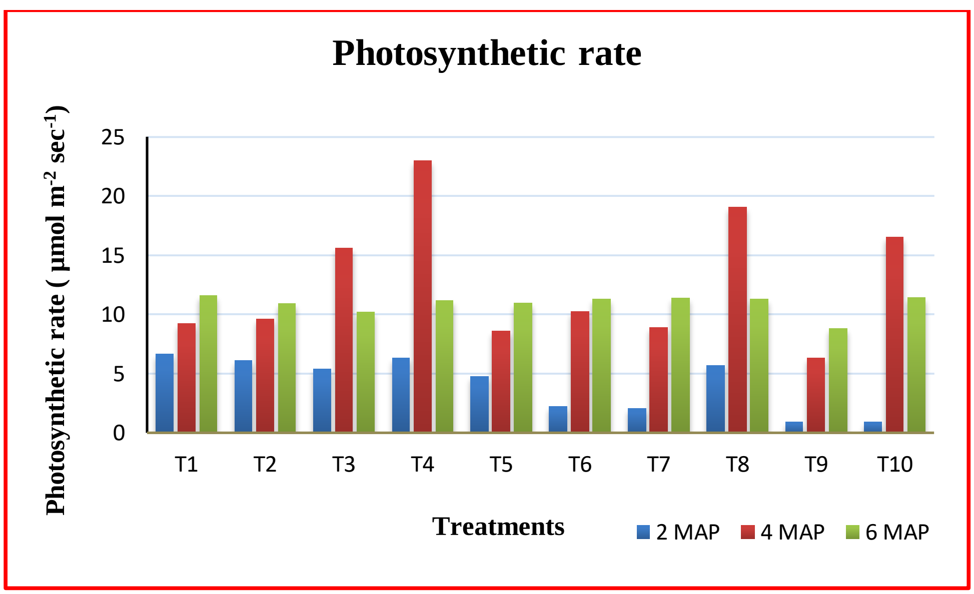


Fig 43. Effect of different treatments on photosynthetic rate of strawberry

In Central midlands, during first year, overall sensory score was higher for nutrient combination of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 20:100:20:75. During second year, overall sensory score was higher for nutrient combination of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50. Earlier result shown that plants applied with nutrient combination of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50 produced fruits with higher total sugars. The fruits produced by plants applied with nutrient combination of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50 also showed maximum sensory score for taste, aroma and overall acceptability which might have influenced overall sensory quality of fruits. Evaluating all the characters during both seasons of growth, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50 only showed stability in their sensory qualities for overall acceptability during both years. So in Central midlands, better quality fruits were produced by plants fertilized with nutrient combination of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50.

5.2.5 Physiological attributes

5.2.5.1 Photosynthetic rate

During the early stages of growth, photosynthetic rate ranges from 0.91 m µmol m^{-2} sec^{-1} to 6.63 m µmol m^{-2} sec^{-1}. Maximum photosynthetic rate was exhibited by plants fertilized with FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 10:50:20:50. Absolute control and FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50 applied plants recorded lowest photosynthetic rate (Fig. 43). During the later part of growth, the photosynthetic rate was more compared to initial stages of the growth and the maximum photosynthetic rate was exhibited by plants fertilized with FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 10:50:20:50 (11.59 m µmol m^{-2} sec^{-1}). FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50 applied plants recorded lowest photosynthetic rate. Between the early and later stages of the growth, the photosynthetic rate was still higher and it ranges from 6.31 m µmol m^{-2} sec^{-1} to 23.02 m µmol m^{-2} sec^{-1}. The maximum photosynthetic

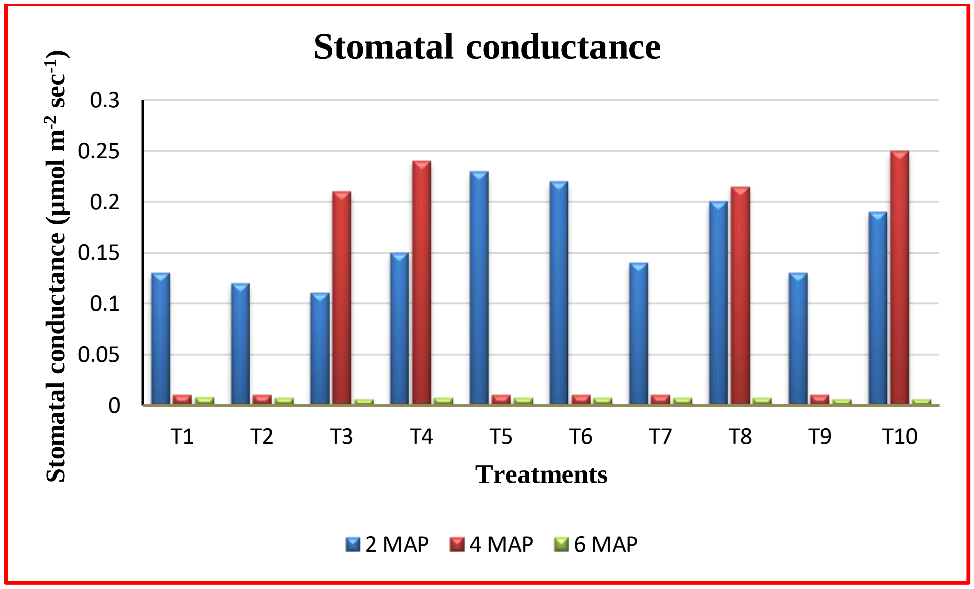


Fig 44. Effect of different treatments on stomatal conductance of strawberry

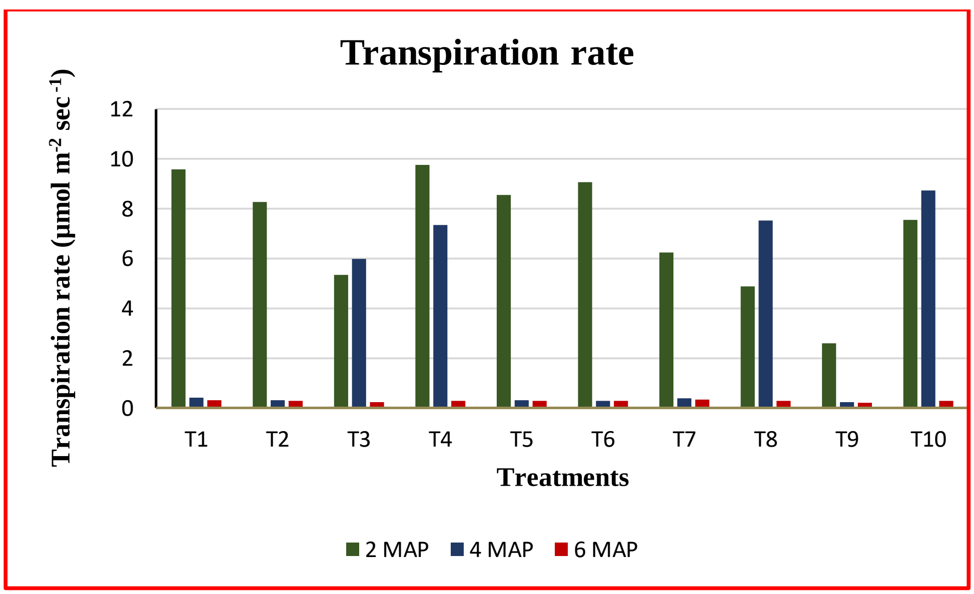


Fig 45. Effect of different treatments on transpiration rate of strawberry

rate was exhibited by plants fertilized with FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 20:50:40:100. FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50 applied plants recorded lowest photosynthetic rate. Considering the entire growth period of strawberry, the crucial growth takes during the middle part *i.e*, 4MAP. So fertilizers applied before the 4MAP had great impact on the growth parameters of strawberry.

5.2.5.2 Stomatal conductance

The stomatal conductance value was observed maximum in plants fertilized with nutrient combinations as FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 10:100:80:100 and FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 20:50:40:100, FYM (t ha^{-1}) and N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100 (Fig 44). This is because all these nutrient combinations are rich in potassium fertilizers. Potassium has a direct role in stomatal opening compared to N and P. This is in line with the results of some previous studies reported by Kim and Lee (2007) and Cakmak (2005). Absolute control also had higher value for stomatal conductance. No fertilizer application may resulted in more stress in plants, decrease in carbohydrate concentration in leaves, less CO_2 concentration near the leaves and resulted in increased stomatal conductance. These findings were also supported by the works by Bunce (2000); Long *et al.* (2004); Yu *et al.* (2004); Leakey *et al.* (2006) and Ainsworth and Rogers (2007) found out that stomatal conductance also increases with decreasing relative humidity and CO_2 concentration on the surface of leaves.

5.2.5.3 Transpiration rate

The transpiration rate varies during the entire growth period of strawberry. During the early growth stages of growth, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 20:50:40:100 recorded maximum transpiration rate. FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50 applied plants recorded lowest transpiration rate. Absolute control recorded maximum transpiration rate during the middle stages of growth (Fig. 45). These findings are supported by the earlier findings that the stomatal conductance and

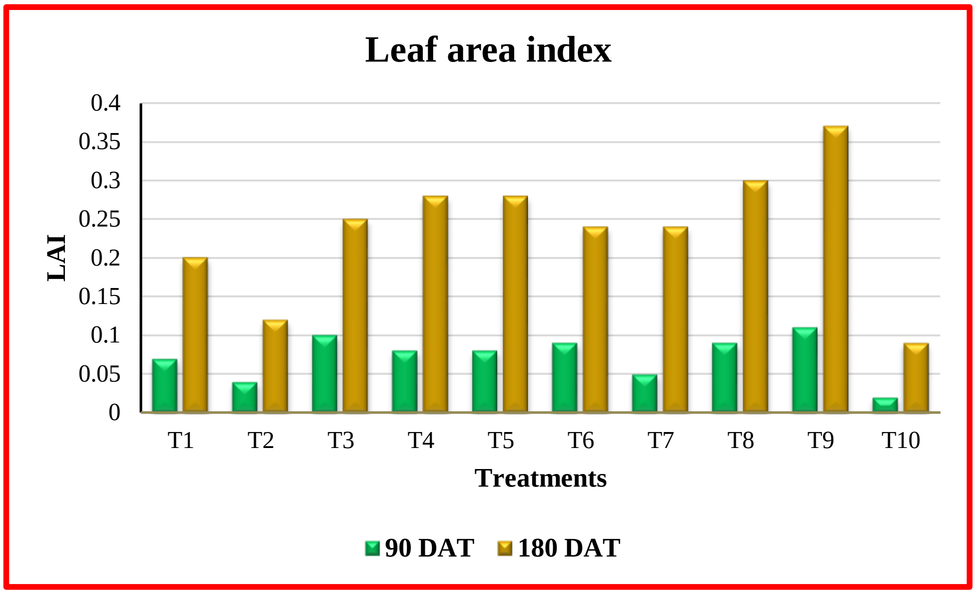


Fig 46. Effect of different treatments on leaf area index of strawberry

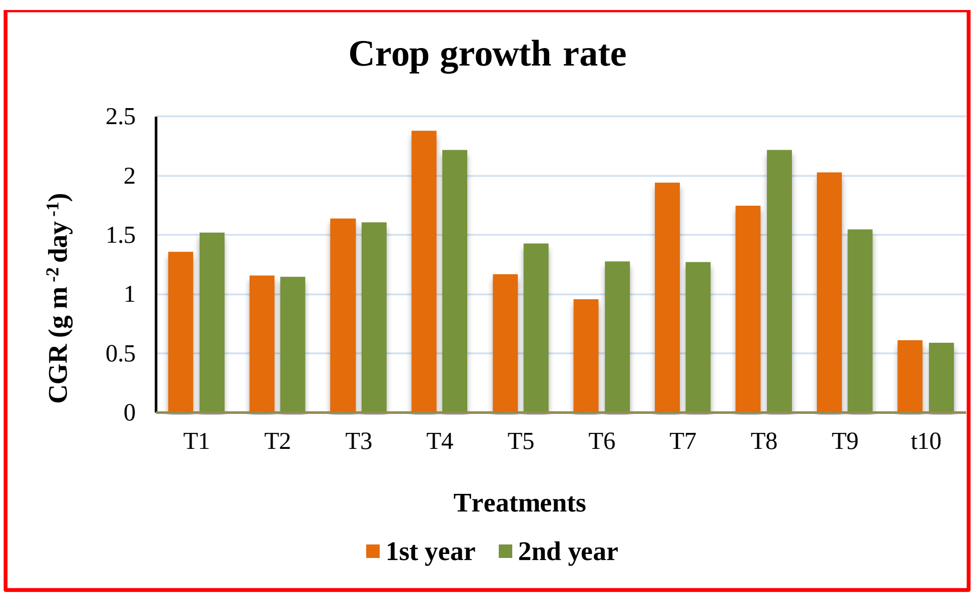


Fig 47. Effect of different treatments on crop growth rate of strawberry

transpiration rate are positively correlated by Putra *et al*. (2012). Earlier results showed that stomatal conductance value varied with the fertilizer combinations. FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:50:80:75 recorded maximum transpiration rate during the final stages of growth.

5.2.5.4 Leaf area index

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50 recorded maximum leaf area index. Absolute control recorded lowest leaf area index during the entire growth period (Fig. 46). LAI is influenced by increasing leaf number and leaf area. Earlier results showed that during 90 DAT, maximum number of leaves were recorded by plants applied with nutrient combination of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50. In later stages of growth also, plants applied with FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50 nutrient combinations recorded more number of leaves. This may be the reason for higher LAI.

5.2.5.5 Crop growth rate

Crop growth rate was recorded maximum in plants fertilized with nutrient combinations of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 20:50:40:100. Absolute control recorded lowest crop growth rate (Fig. 47).

5.2.5.6 Relative growth rate

Relative growth rate recorded was maximum in plants fertilized with FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 20:50:40:100 and FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100. Absolute control recorded lowest relative growth rate (Fig 48).

5.2.5.7 Net assimilation rate

Net assimilation rate was recorded maximum in plants fertilized with FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 10:75:40:75. FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 20:75:80:50 recorded lowest net assimilation rate (Fig 49).

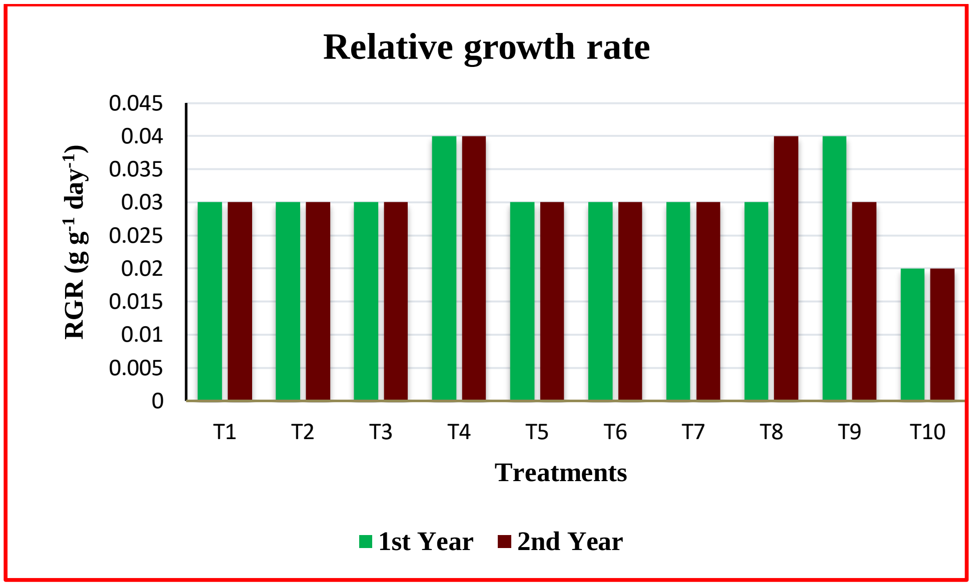


Fig 48. Effect of different treatments on relative growth rate of strawberry

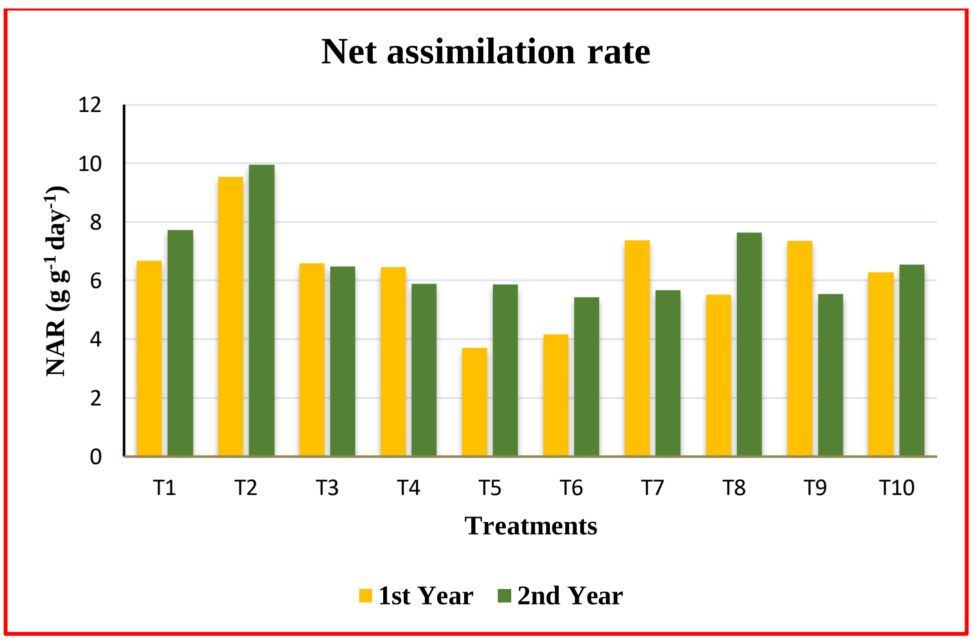


Fig 49. Effect of different treatments on net assimilation rate of strawberry

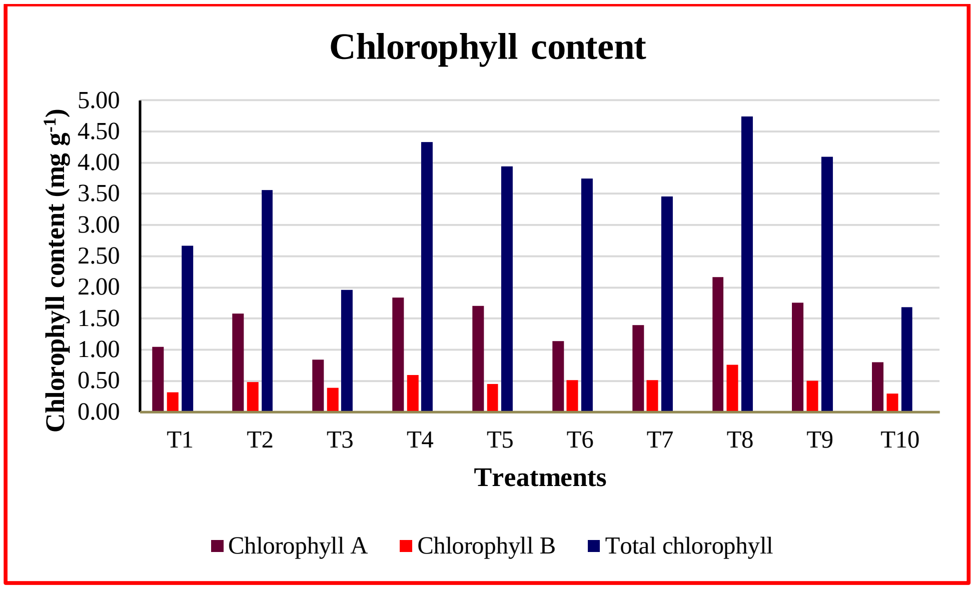


Fig 50. Effect of different treatments on chlorophyll content of strawberry

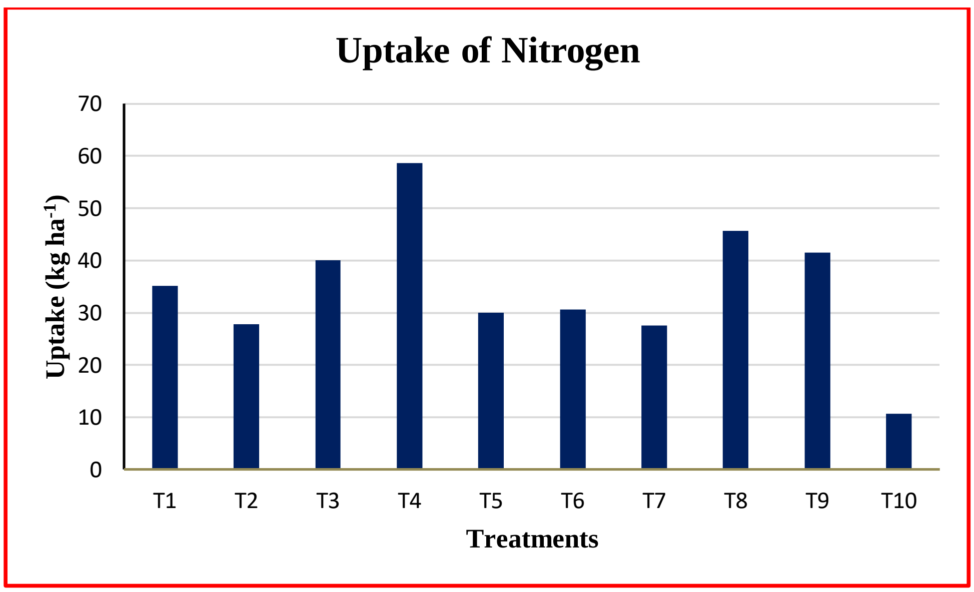


Fig 51. Effect of different nutrient combinations on plant nitrogen uptake

5.2.6 Analysis of plant sample

5.2.6.1 Chlorophyll a, b and total

The content of chlorophyll a, chlorophyll b and total chlorophyll was recorded maximum in leaves of plants applied with nutrient combination of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100 (Fig 50). Earlier results indicated that plants fertilized with nutrient combination of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100 yielded maximum. So this validates the result obtained in chlorophyll content.

5.2.6.2 Uptake of nutrients

For the sustainable production of strawberry, reducing the amount of fertilizers is important. Knowledge of amount of nutrients taken by the crop and its improvement helps in maintaining satisfactory yields and better quality fruits. In this present study, the nutrient content was estimated in the plant parts of strawberry with an intention to study the effect of different nutrient combinations on the mineral profile of the crop. The plant uptake values for N, P, K, Ca, Mg and Fe were found to be significantly different for different nutrient combinations. On contrary, the uptake values for S, Cu, Zn, Mn and B were not affected by different nutrient combinations.

Nutrient uptake depends on the concentration of respective nutrient in different plant parts and dry matter production. The partitioning of different nutrients between the plant part and economic part of any plant depends on the genetic makeup and the nutrient supply from the soil. In case of N, K, Ca, Mg and Fe uptake, nutrient combination of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 20:50:40:100 showed their superiority compared to all other nutrient combinations which was comparable with the nutrient combination of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100 (Fig. 51 and 52). This might have influenced higher yield in case of nutrient combination FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100.

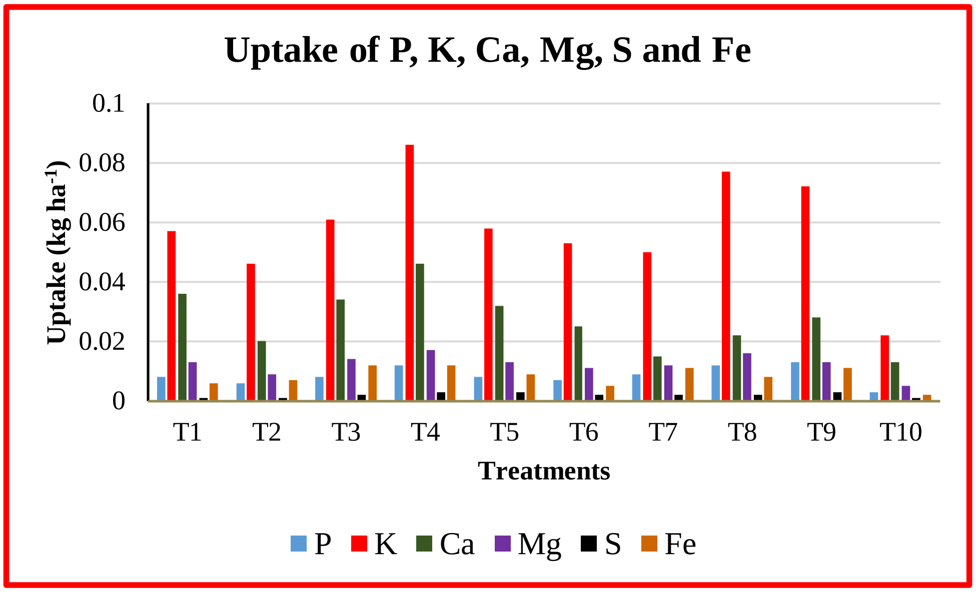


Fig 52. Effect of different nutrient combinations on plant nutrient uptake

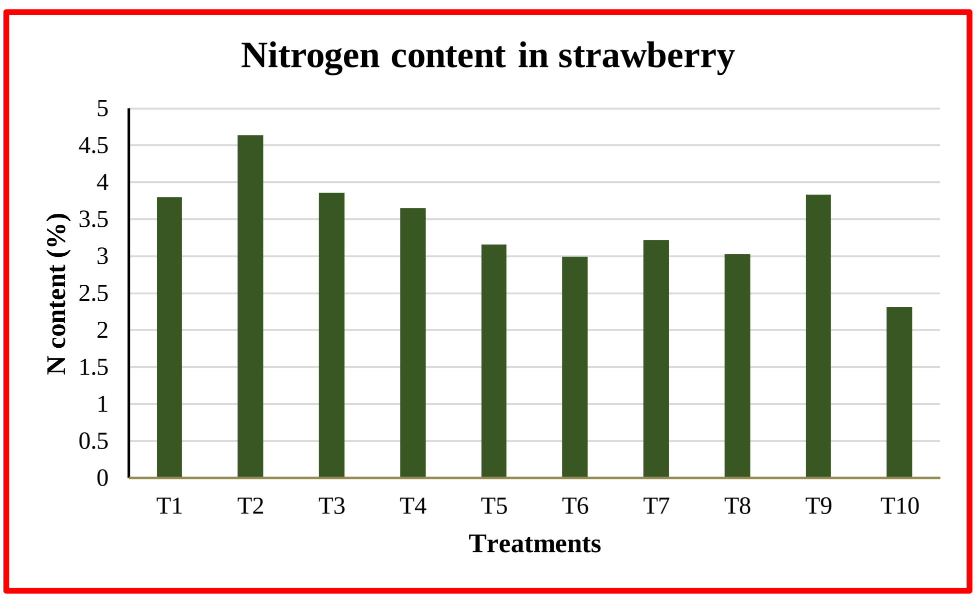


Fig 53. Effect of different nutrient combinations on nitrogen content of strawberry fruits

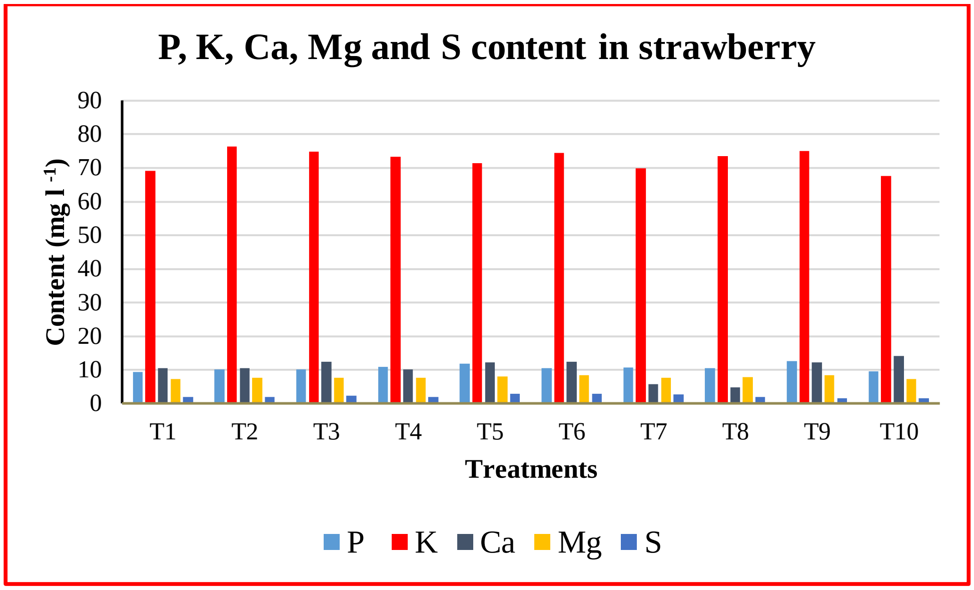


Fig 54. Effect of different nutrient combinations on P, K, Ca, Mg and S content in fruits

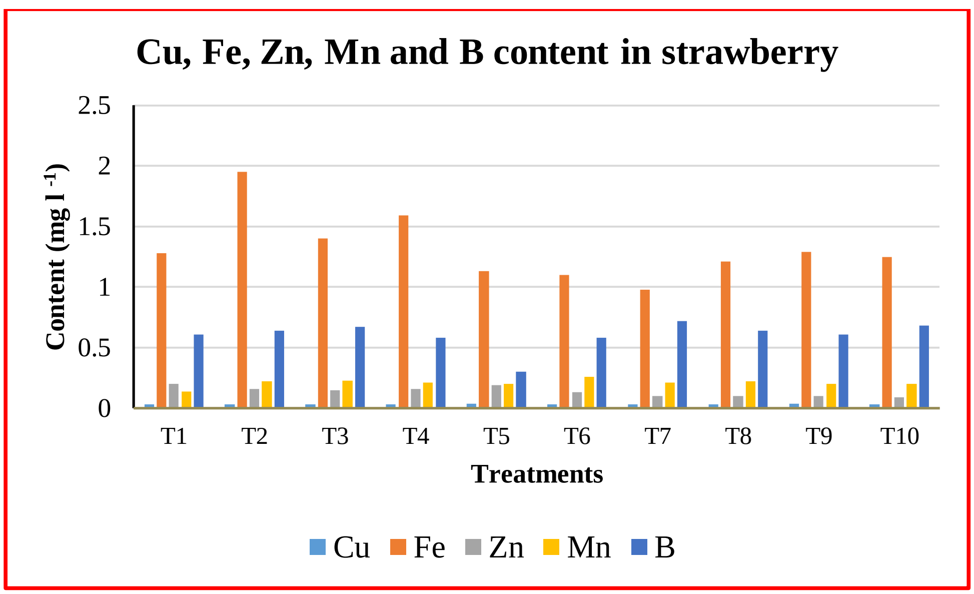


Fig 55. Effect of different nutrient combinations on Cu, Fe, Zn, Mn and B content in fruits

Plate 6. Strawberry fruits obtained from different nutrient combinations

5.2.6.3 Analysis of fruit

Nutrient content in fruits of strawberry is an important quality criterion, since it ultimately determines the quantity of nutrients consumed by human beings. In case of nitrogen content, fertilizer combination FYM (10 t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 75:40:75 recorded superiority in nitrogen (%). Phosphorus content was significantly higher in fertilizer combination FYM (30 t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 100:40:50. Potassium content varies from 67.60 mg l^{-1} to 76.36 mg l^{-1}. Maximum potassium content was recorded in the fertilizer combination FYM (10t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 75:40:75 which was comparable with FYM (30t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 100:40:50. Content of calcium in strawberry fruits ranged from 4.82 mg l^{-1} to 14.21 mg l^{-1}. The maximum calcium content was recorded in absolute control which was comparable with FYM (30t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 100:40:50 (12.33 mg l^{-1}). The maximum magnesium content was recorded in FYM (20t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 100:20:75 (8.53 mg l^{-1}) which was on par with FYM (30t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 100:40:50 (8.51 mg l^{-1}). The values of sulphur content among all the treatments were comparable and it differed from 1.68 mg l^{-1} to 2.94 mg l^{-1}. Nutrient combination FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50 recorded comparable values in case of macroelements such as P, K, Ca and Mg. This might have influenced the production of quality fruits by applying the fertilizer combination FYM (30t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 100:40:50.

Different fertilizer combinations had significant influence on the microelement content of strawberry fruits except in case of copper. All the treatment combinations having higher concentration of K content (75-100 kg ha^{-1}) showed their superiority in registering higher values for Boron content (Fig 53, 54 and 55).

5.2.7 Soil analysis

After soil analysis, it was observed that among the different nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100 recorded the optimum pH, electrical conductivity, higher organic carbon (%), available N, Ca and Mg compared to all other nutrient combinations which might have influenced the maximum production of strawberry (Table 58).

5.2.8 Economics of cultivation

Different costs incurred and returns calculated for strawberry cultivation using different nutrient combinations. Maximum benefit cost ratio was observed in treatment combinations FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100. The maximum yield and returns were obtained in this treatment combination and this may be the reason for maximum B/C ratio (Table 59, Appendix V).

5.3 Effect of spacing on growth and yield

5.3.1 Vegetative growth attributes

5.3.1.1 Plant height

In Central midlands, different spacings had a significant influence on plant height only on 4 MAP and 5 MAP. Among the spacings, during the later stages of the growth, 20 cm x 20 cm recorded maximum plant height (18.15 cm). The minimum plant height was recorded in plants planted at a spacing of 30 x 60 cm in later stages of growth (Fig. 56a). Earlier results revealed that closer spacing between the rows and between plants produced more vegetative growth compared to wider spacing. It is also natural that when more plants are accumulated per unit area, mutual shading will be more and this will lead the plants to grow taller. These results in the present study were similar with the findings of Petersen (1998); Legard *et al*. (2000); De Camacaro (2004); Paranjpe *et al*. (2008); Sonkar *et al*. (2012); Tariq *et al*. (2013) and Shahzad *et al*. (2018).

However in High ranges, different spacings had no significant effect on plant height (Fig 56b).

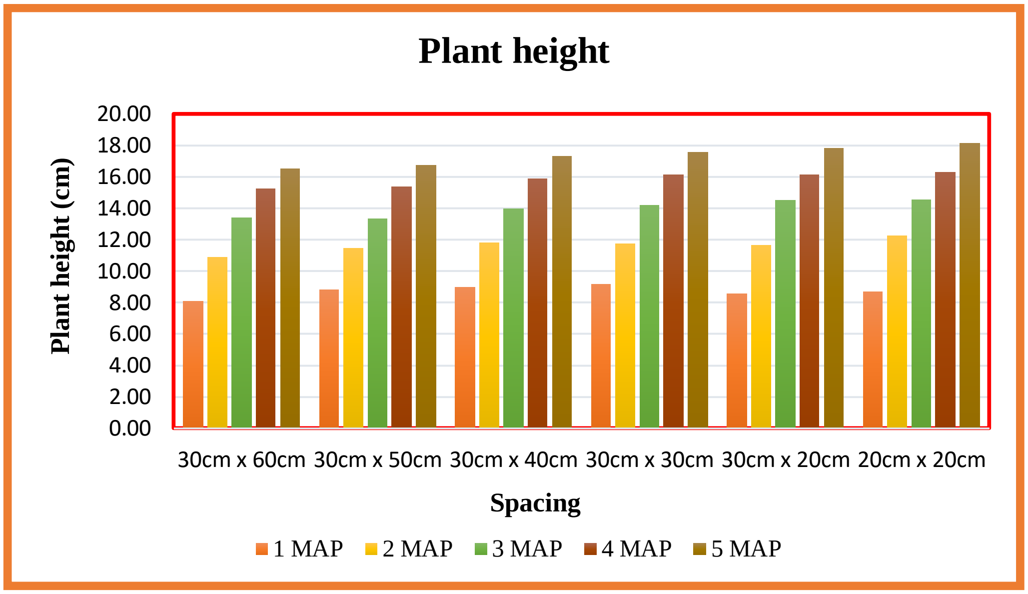


Fig 56a. Plant height of strawberry under different spacings at Central midlands

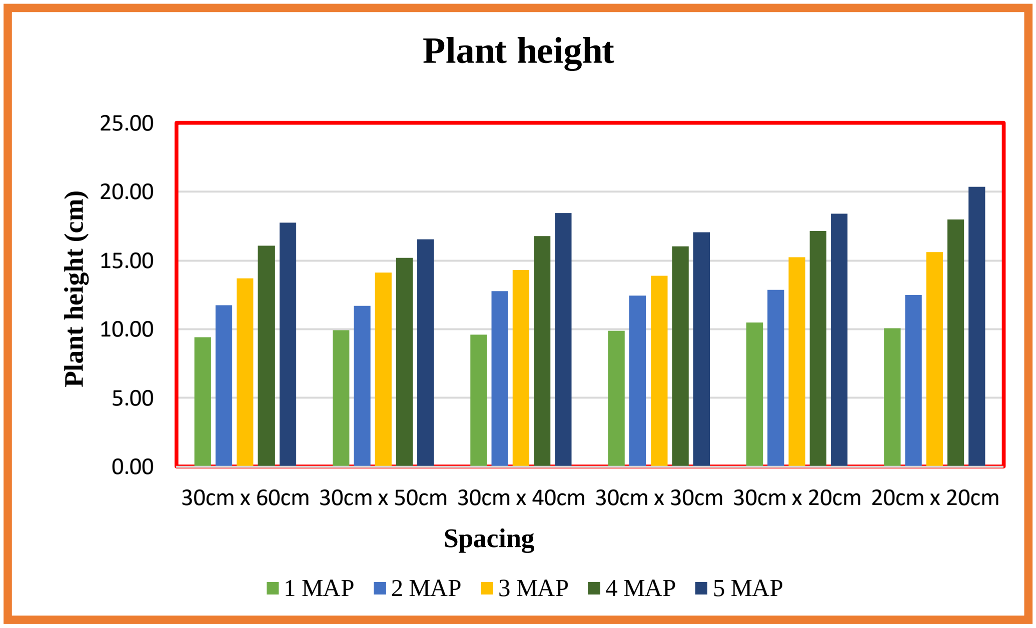


Fig 56b. Plant height of strawberry under different spacings in High ranges

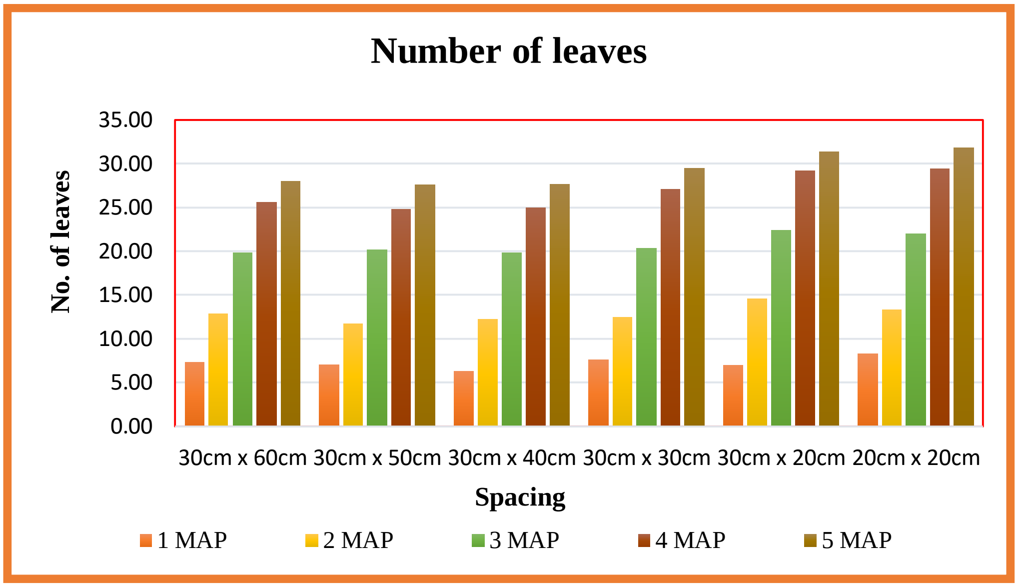


Fig 57a. Number of leaves per plant of strawberry under different spacings in Central midlands

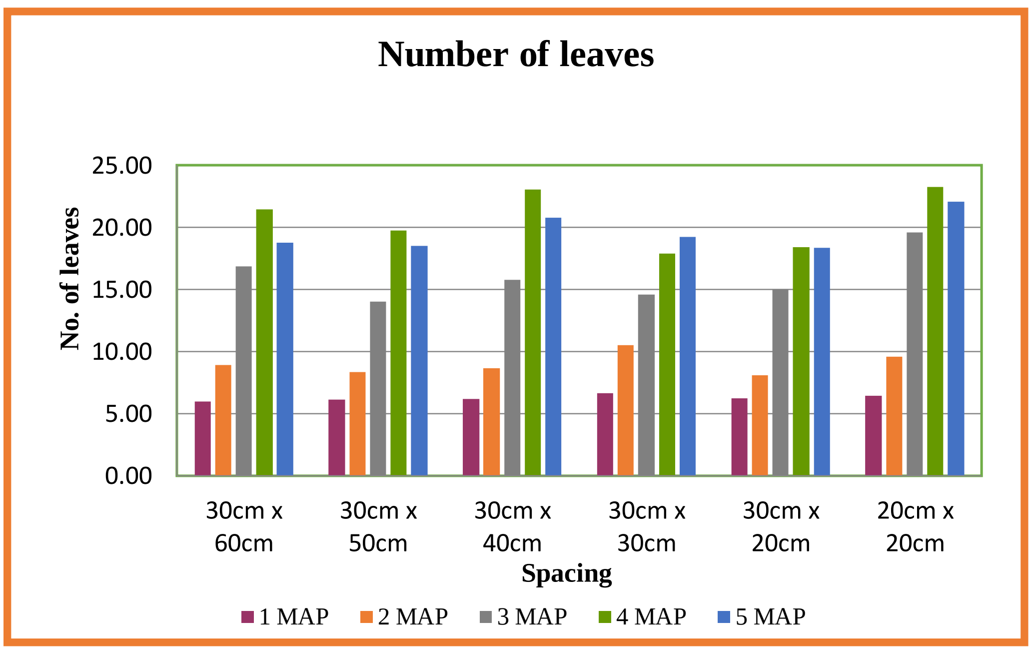


Fig 57b. Number of leaves per plant of strawberry under different spacings in High ranges

5.3.1.2 Number of leaves per plant

In Central midlands, different spacings had a significant influence on number of leaves per plant. Among the spacings, during the early stages of growth, 30 cm x 20 cm recorded maximum number of leaves per plant. However during the later stages of the growth, 20 cm x 20 cm recorded maximum number of leaves per plant. The minimum number of leaves per plant was recorded in plants planted at a spacing of 30 x 50 cm (Fig. 57a).

However in High ranges, different spacings had a significant influence in number of leaves during 2 MAP, 3 MAP and 4 MAP. Spacing of 20 cm x 20 cm recorded maximum number of leaves per plant. Lowest number of leaves was recorded by spacing of 30 cm x 50 cm (Fig 57b).

Earlier results revealed that closer spacing between the rows and between plants produced more vegetative growth compared to wider spacing. These results in the present study were similar with the findings of Hughes (1967); Petersen (1998); Legard *et al*. (2000); De Camacaro (2004); Paranjpe *et al*. (2008); Sonkar *et al.* (2012); Tariq *et al*. (2013); Shahzad *et al*. (2018).

5.3.1.3 Plant spread

In Central midlands, different spacings had a significant influence on plant spread except at 1 MAP. Among the spacings, 20 cm x 20 cm recorded maximum plant spread. However the minimum plant spread was recorded by a spacing of 30 cm x 60 cm (Fig 58a).

In High ranges, different spacings had a significant influence on plant spread during 1 MAP and 5 MAP. Maximum plant spread was recorded by 30 x 40 cm and 20 x 20 cm spacings. Lowest plant spread was recorded by 30 cm x 50 cm spacing (Fig 58b).

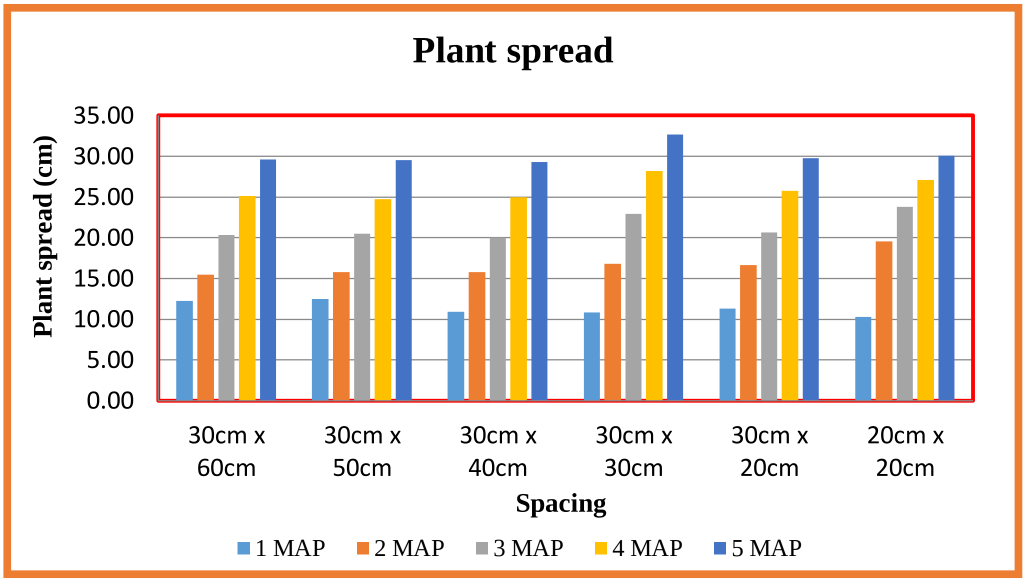


Fig 58a. Plant spread of strawberry under different spacings in Central midlands

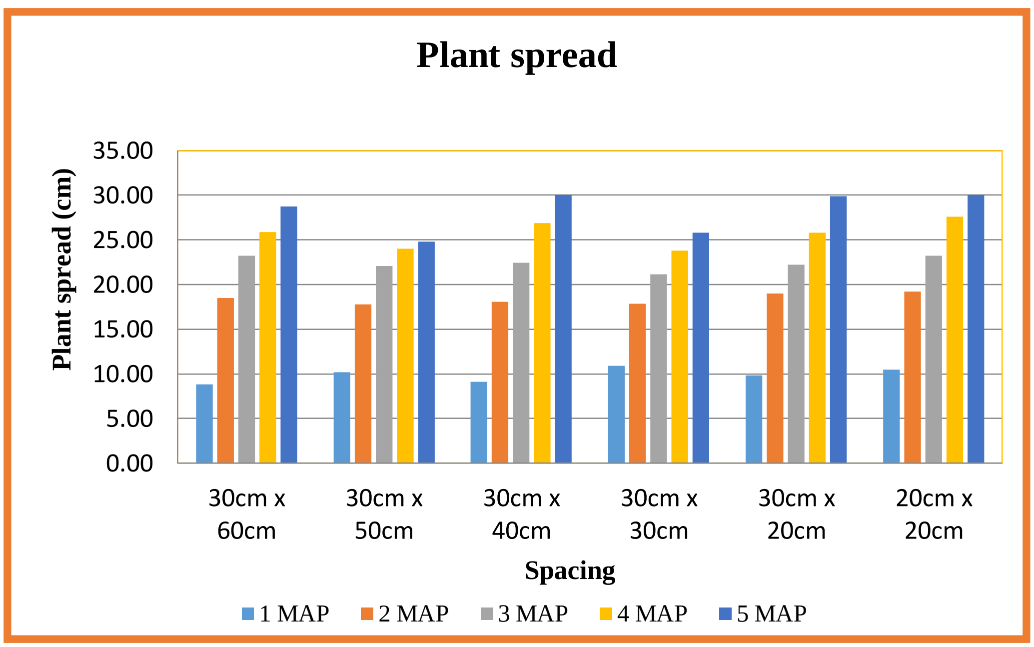


Fig 58b. Plant spread of strawberry under different spacings in High ranges

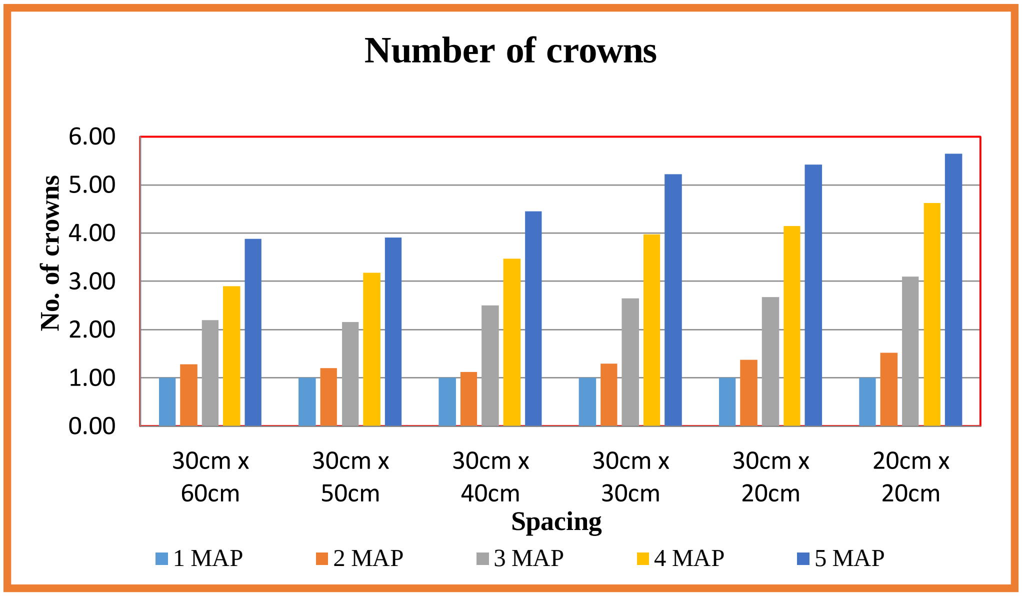


Fig 59a. Number of crowns of strawberry under different spacings in Central midlands

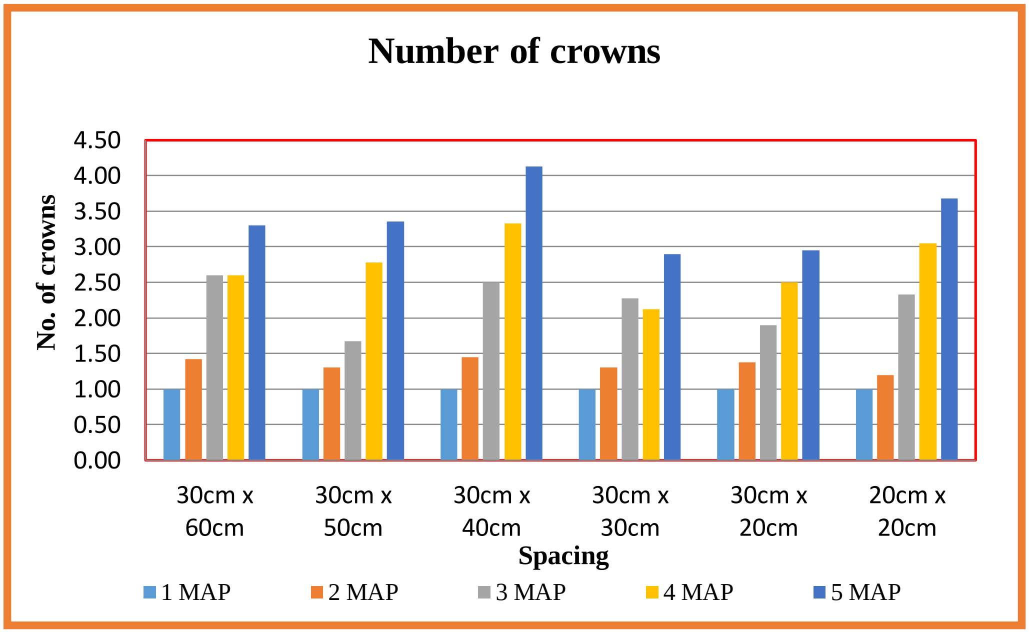


Fig 59b. Number of crowns of strawberry under different spacings in High ranges

Earlier results revealed that closer spacing between the rows and between plants (20 cm x 20 cm) produced more vegetative growth compared to wider spacing. This may be reason for more plant spread. These results in the present study were similar with the findings of Hughes (1967); Petersen (1998); Legard *et al.* (2000); De Camacaro (2004); Paranjpe *et al*. (2008); Sonkar *et al*. (2012); Tariq *et al*. (2013); Shahzad *et al*. (2018)**.**

5.3.1.4 Number of crowns

In Central midlands, different spacings had significant influence on number of crowns per plant in the later stages of growth. During the initial stages of growth, different spacings had no significant effect on number of crowns per plant. Spacing of 20 cm x 20 cm recorded maximum number of crowns. Minimum number of crowns was recorded by 30 cm x 60 cm (Fig 59a). Earlier results showed that spacing of 20 cm x 20 cm had resulted in maximum plant height and number of leaves. This might have a positive influence on increase in number of crowns per plant.

However in High ranges, 30 cm x 40 cm recorded the maximum number of crowns during the later stages of growth and 30 cm x 30 cm recorded minimum number of crowns per plant (Fig. 59b). Spacing of 30 cm x 40 cm resulted in maximum spread. Favourable environmental conditions influenced the plant spread might have a positive effect on number of crowns per plant also.

5.3.2 Flowering attributes

5.3.2.1 Days to first flowering

In Central midlands, different spacings had no significant influence on days to first flowering. However in High ranges also, spacing had no significant effect on days to first flowering (Fig. 60).

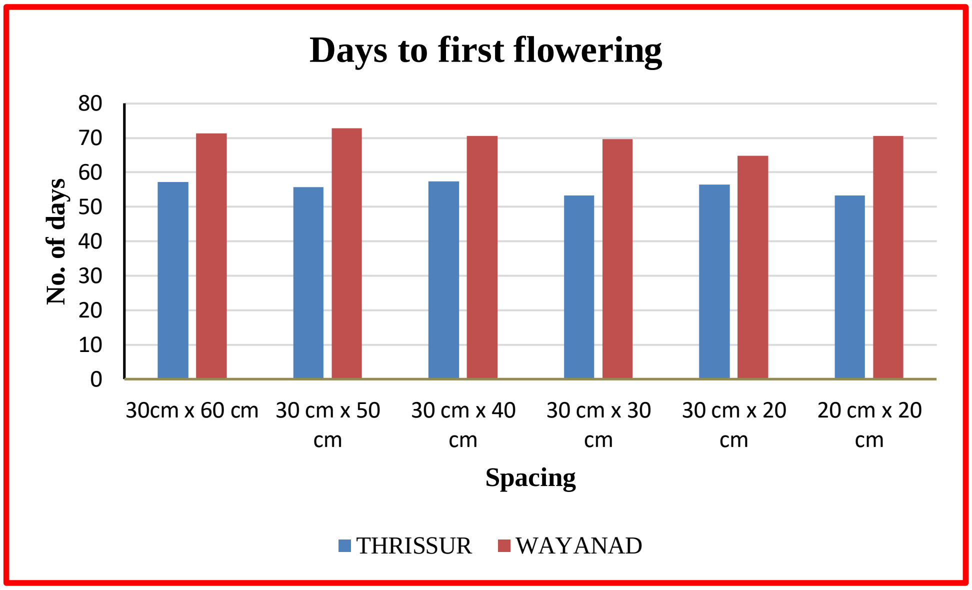


Fig 60. Number of days to first flowering of strawberry under different spacings

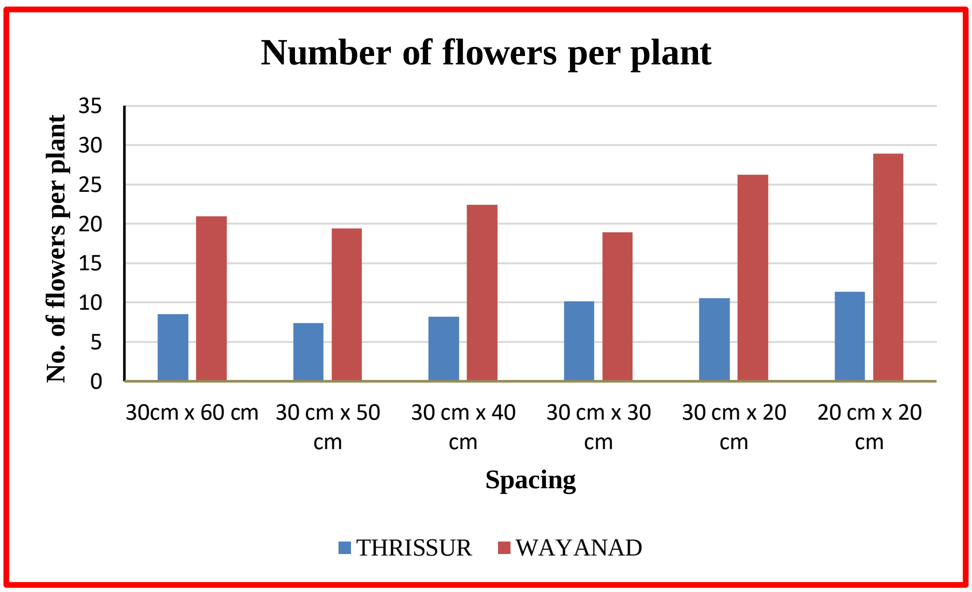


Fig 61. Number of flowers per plant of strawberry under different spacings

5.3.2.2 Number of flowers per plant

In Central midlands, different spacings had significant influence on the number of flowers per plant. Spacing of 20 cm x 20 cm recorded maximum number of flowers per plant. Minimum number of flowers per plant was recorded by 30 cm x 50 cm spacing. Earlier results indicated that plants grown under spacing of 20 cm x 20 cm recorded maximum plant height, number of leaves, plant spread and number of crowns. This might be the reason for maximum number of flowers per plant.

However in High ranges, spacing of 20 cm x 20 cm produced the maximum number of flowers per plant, while minimum number of flowers was recorded by spacing of 30 cm x 30 cm spacing (Fig. 61). Spacing of 20 cm x 20 cm recorded maximum number of leaves and plant spread. This might have influenced more number of flowers per plant.

5.3.2.3 Number of clusters per plant

In Central midlands, different spacings had significant influence on the number of clusters per plant. Spacing of 20 cm x 20 cm recorded maximum number of clusters per plant. Minimum number of clusters per plant was recorded by 30 cm x 40 cm spacing.

However in High ranges, spacing of 20 cm x 20 cm produced the maximum number of clusters per plant, while minimum number of clusters was recorded by spacing of 30 cm x 50 cm spacing (Fig. 62).

Earlier results indicated that spacing of 20 cm x 20 cm produced maximum number of flowers per plant in both locations. This might have lead to the increase in number of clusters per plant.

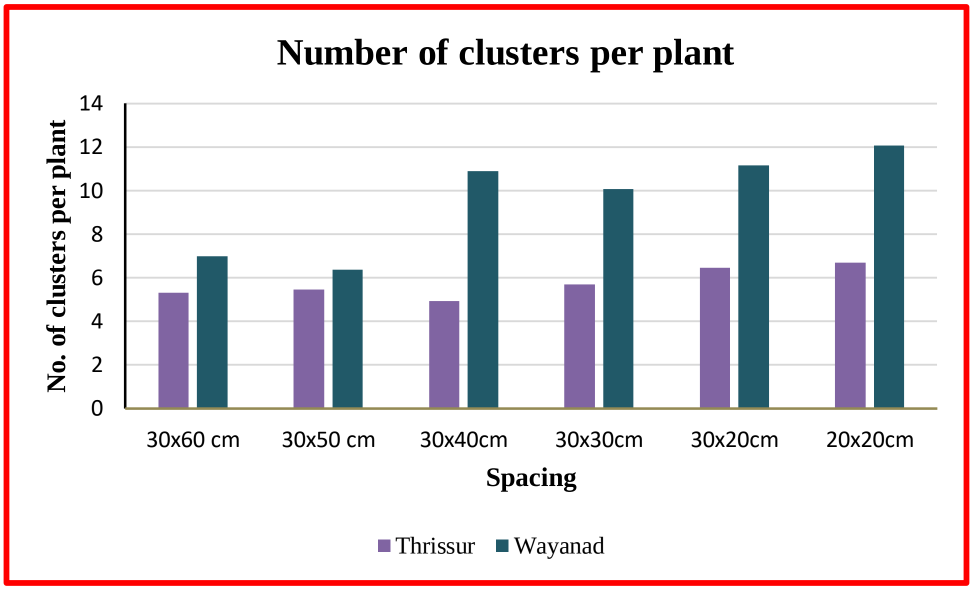


Fig 62. Number of clusters per plant of strawberry under different spacings

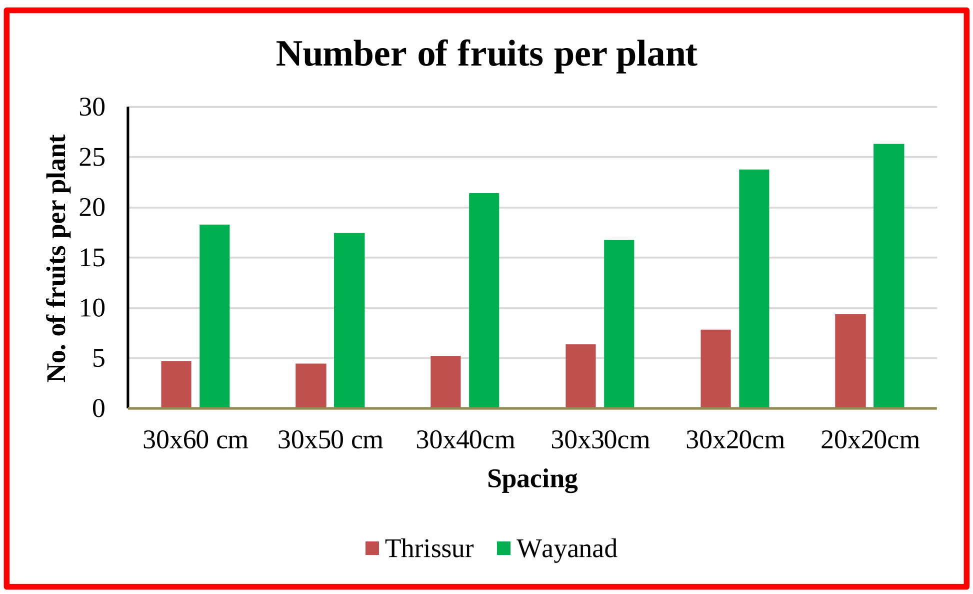


Fig 63. Number of fruits per plant of strawberry under different spacings

5.3.3 Yield attributes

5.3.3.1 Number of fruits per plant

In Central midlands, different spacings had significant influence on the number of fruits per plant. Spacing of 20 cm x 20 cm recorded maximum number of fruits per plant. Minimum number of fruits per plant was recorded by 30 cm x 50 cm spacing. As discussed earlier, plant height, number of leaves, plant spread, number of crowns, number of flowers and clusters per plant were maximum in plants grown at a row plant spacing of 20 cm x 20 cm. This may be the reason for maximum number of fruits per plant.

In High ranges, spacing of 20 cm x 20 cm produced the maximum number of fruits per plant, while minimum number of fruits was recorded by spacing of 30 cm x 30 cm spacing~~.~~ (Fig. 63). As discussed earlier, number of leaves, plant spread, number of flowers and clusters per plant were maximum in plants grown under a row plant spacing of 20 cm x 20 cm. This might have a positive influence on number of fruits per plant.

Hence in the same corollary, this result could be explained that spacings has influence on number of fruits per plant.

5.3.3.2 Fruit length

In Central midlands, different spacings had significant influence on the fruit length. Fruits harvested from plots under a spacing of 30 cm x 60 cm recorded maximum fruit length. Minimum fruit length was recorded by fruits harvested from plots under a spacing of 30 cm x 40 cm and 30 cm x 20 cm.

In High ranges also, plots with spacing of 30 cm x 60 cm produced fruits with maximum fruit length, while minimum fruit length was recorded in fruits harvested from plots with spacing of 20 cm x 20 cm (Fig. 64).

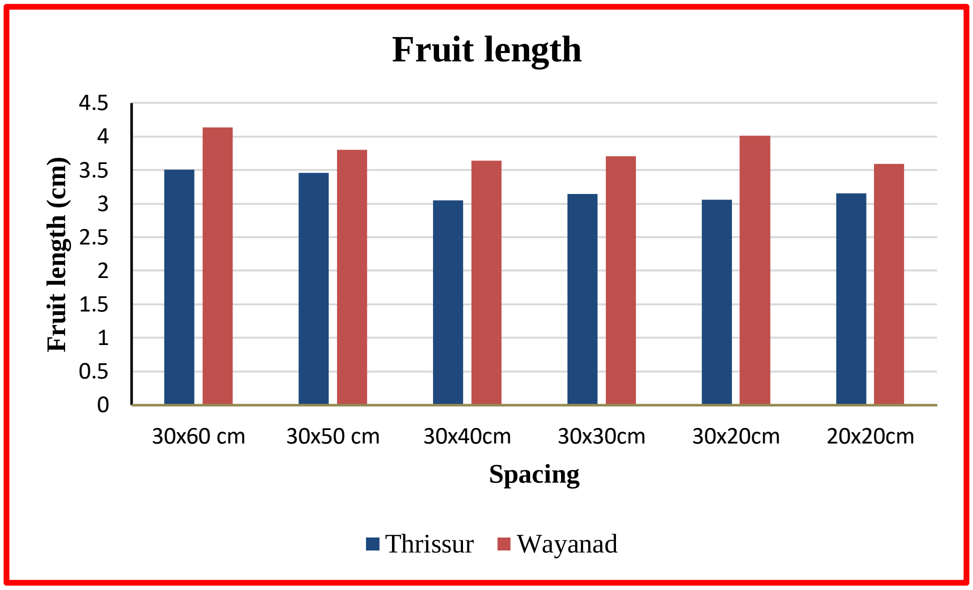


Fig 64. Fruit length of strawberry under different spacings

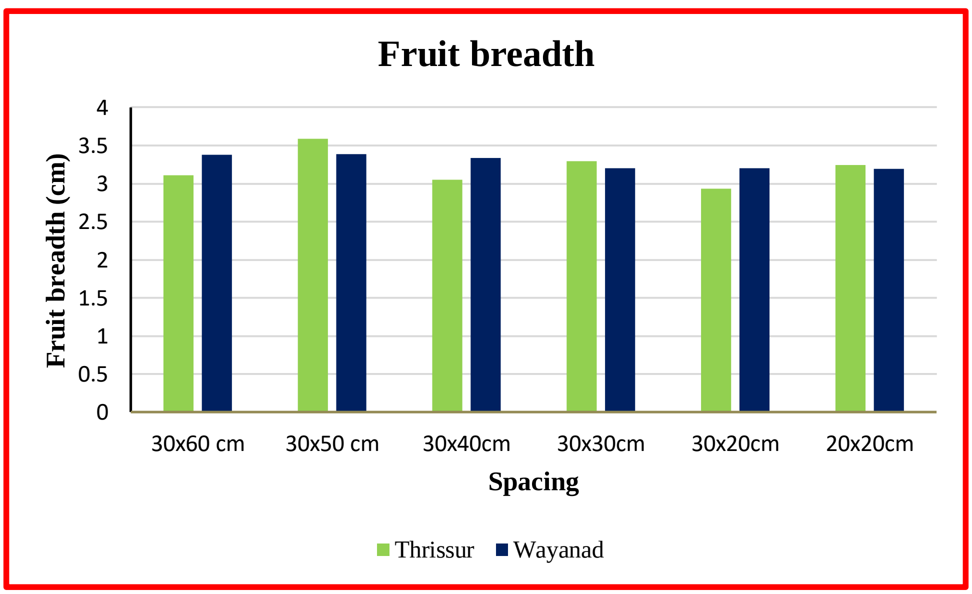


Fig 65. Fruit breadth of strawberry under different spacings

Wider spacings provide better space for root growth and distribution, optimum moisture availability, better nutrient uptake and finally translocate the nutrients to fruits which acts as sink. These absorbed nutrients might have been utilized by the fruits which resulted in increased size and weight of the fruits. These results agree with the earlier findings of Badiyala and Joolka (1983); Ahmad (2009) and Sonkar *et al.* (2012). On contrary, fruit size increased with closer spacing was reported by Ram *et al*. (2009).

5.3.3.3 Fruit breadth

In Central midlands, different spacings had significant influence on the fruit breadth. Maximum fruit breadth was observed in fruits harvested from plants grown under the spacing of 30 cm x 50 cm. Minimum fruit breadth was recorded by fruits harvested from 30 cm x 20 cm spacing plots. As discussed earlier, wider spacings had a positive influence on fruit length. This might have a positive influence on fruit breadth also.

However in High ranges, different spacing had no significant influence on fruit breadth (Table 67, Fig 69).

5.3.3.4 Average fruit weight per plant

In Central midlands, different spacings had significant influence on average fruit weight per plant. Fruits from plants grown under the spacing of 30 cm x 60 cm recorded maximum average fruit weight per plant. Minimum average fruit weight was recorded by fruits obtained from plots under 30 cm x 20 cm spacing. However in High ranges, different spacings had significant influence on average fruit weight per plant. Fruits from plants grown under the spacing of 30 cm x 60 cm recorded maximum average fruit weight per plant. Minimum average fruit weight was recorded by fruits obtained from plots under 30 cm x 20 cm spacing (Fig. 66).

Earlier results showed that in Central midlands and High ranges, fruits harvested from 30 cm x 60 cm plots recorded maximum fruit length. This might be the

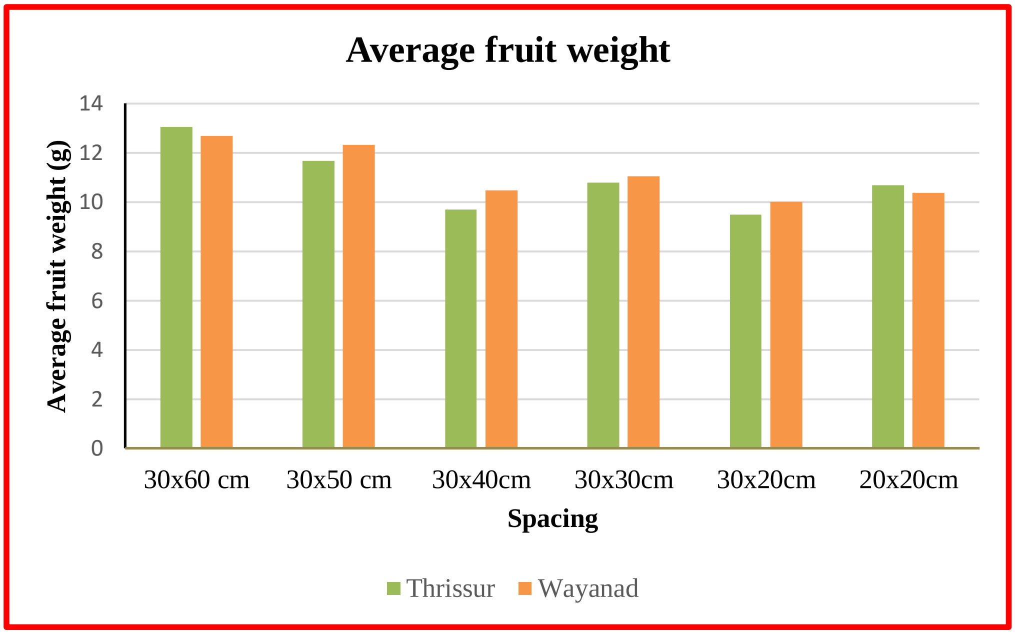


Fig 66. Average fruit weight of strawberry under different spacings

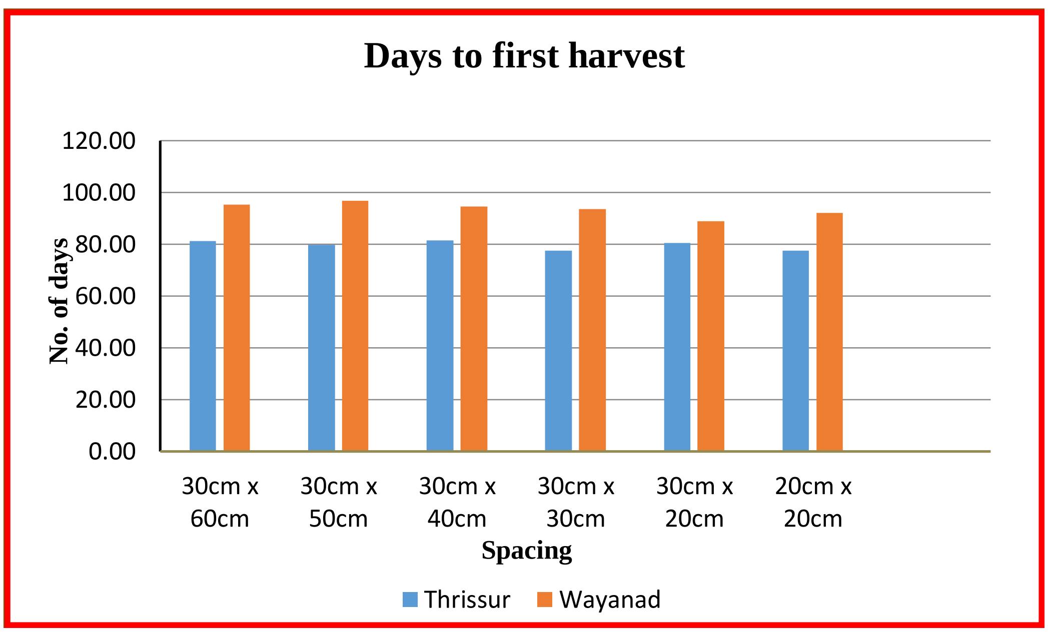


Fig 67. Number of days to first harvest of strawberry under different spacings

reason for maximum average fruit weight. In plots with closer spacing of 30 cm x 20 cm yielded fruits with minimum fruit length in Central midlands, while in High ranges, such plots with a closer spacing yielded fruits with minimum fruit breadth. This might be the reason for minimum average fruit weight for fruits obtained from closer spacing. These results agree with the earlier findings of Badiyala and Joolka (1983); Ahmad (2009) and Sonkar *et al*. (2012).

5.3.3.5 Days to first harvest

In Central midlands, different spacings had no significant influence on days to first harvest. However in High ranges also, spacings had no significant effect on days to first harvest (Fig. 67).

5.3.3.6 Days to final harvest

In Central midlands, different spacings had no significant influence on days to final harvest. However in High ranges also, spacings had no significant effect on days to final harvest (Fig 68).

5.3.3.7 Yield per plant

In Central midlands, plants grown under the spacing of 20 cm x 20 cm recorded the maximum yield per plant of 100.03 g per plant while minimum yield per plant of 50.71 g per plant was recorded by plants grown under the spacing of 30 cm x 40 cm. These findings were in conformity with the results of Shahzad *et al*. (2018) that yield per plant of strawberry is higher in 20 cm spacing compared to 30 cm or 50 cm.

In High ranges also, plants grown under the spacing of 20 cm x 20 cm recorded the maximum yield per plant of 271.69 g per plant while minimum yield per plant of 186.15 g per plant was recorded by plants grown under the spacing of 30 cm x 30 cm. (Fig 69).

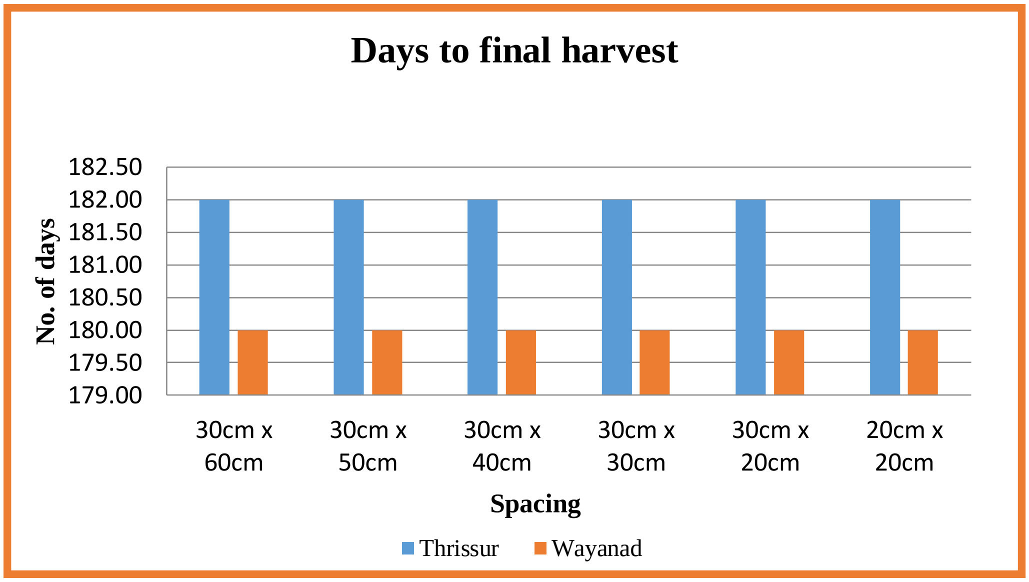


Fig 68. Number of days to final harvest of strawberry under different spacings

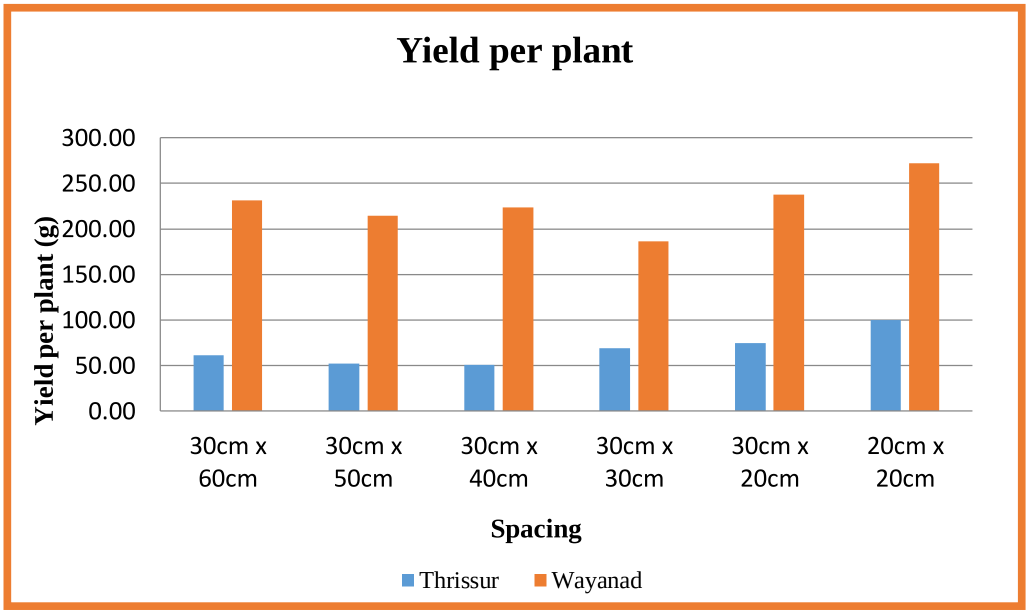


Fig 69. Yield per plant of strawberry under different spacings

The maximum number of fruits per plant was recorded by plants grown under the closer spacing of 20 cm x 20 cm in both locations might have a positive influence on yield per plant. Earlier results revealed that closer row spacing of 15 cm (Sharma, 2009) and plant spacing of 20 cm (Shahzad *et al*., 2018) gave better yield. Similar results on increased yield with closer spacing was earlier reported by Badiyala and Joolka (1983); Petersen (1998); Legard *et al*. (2000); De Camacaro *et al*. (2004); Paranjpe *et al*. (2008); Ahmad (2009); Umar *et al*. (2009); Ram *et al*. (2009); Sonkar *et al*. (2012) and Tariq *et al*. (2013).

5.3.4 Quality attributes

5.3.4.1 TSS

In Central midlands, fruits obtained from plants under spacing of 30 cm x 50 cm recorded the highest TSS content of 7.58 ^{0}Brix, while lowest TSS content of 4.64 ^{0}Brix was recorded by fruits obtained from plants under spacing of 30 cm x 30 cm. However, in High ranges, different spacings had no significant influence on TSS of strawberry (Fig 70).

TSS was significantly higher in wider spacing than closer spacing. The positive influence of wider spacing on TSS of strawberry was earlier reported by Aswathi and Badiyala (1993) and Tripathi *et al*. (2000). Contrary to it, Tariq *et al*. (2013) reported that closer spacing or high density planting of strawberry resulted in higher content of TSS in fruits.

5.3.4.2 Acidity

In Central midlands, different spacings had significant influence on acidity of strawberry fruits. The lowest titrable acidity was recorded by fruits harvested from plants under a spacing of 30 cm x 60 cm, while the highest acidity was recorded by fruits obtained from plants grown under a spacing of 30 cm x 40 cm and it ranges from

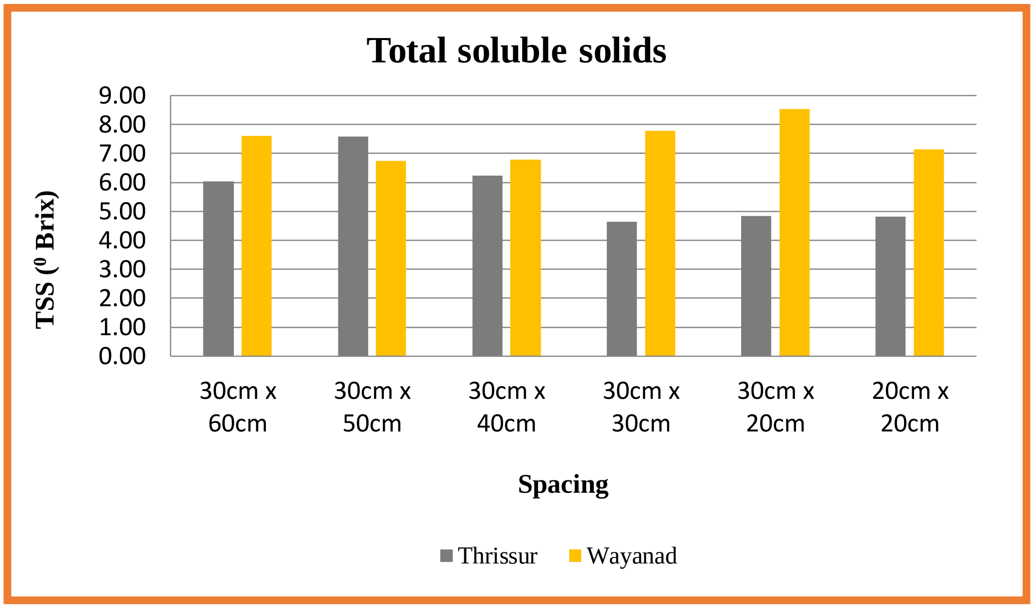


Fig 70. TSS of strawberry fruit under different spacings

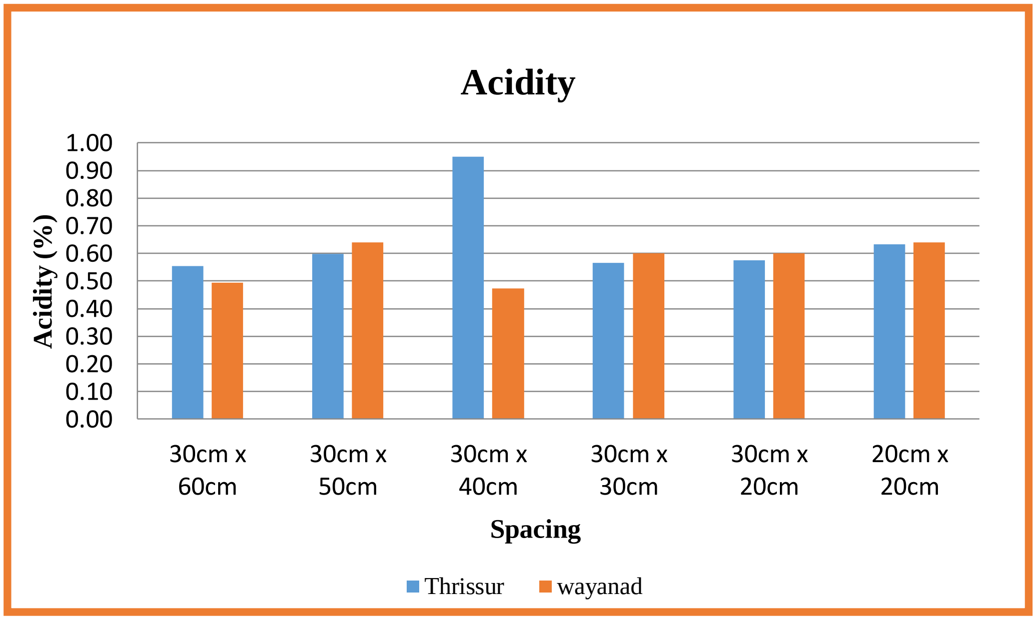


Fig 71. Acidity of strawberry fruit under different spacings

0.55 % to 0.95 %. In High ranges, different spacings had no significant effect on titrable acidity of fruits (Fig 71).

This result is in consonance with the earlier research findings by Sonkar *et al*. (2012) indicated that quality parameters such as acidity was significantly lower in fruits obtained from wider plant spacing than that obtained from narrow plant spacing.

5.3.4.3 TSS/Acidity

In Central midlands, maximum TSS/Acidity was recorded in fruits harvested from plants grown at a spacing of 30 cm x 50 cm. The minimum TSS/Acidity was recorded in fruits harvested from plants grown at a spacing of 30 cm x 40 cm. In High ranges, different spacings had no significant effect on TSS/Acidity (Fig 72).

Maximum TSS was recorded in fruits obtained from plants under a spacing of 30 cm x 50 cm. This might have a positive effect on TSS/acidity ratio of fruits obtained from 30 cm x 50 cm spacing. Highest acidity was recorded in fruits obtained from plants grown under a spacing of 30 cm x 40 cm. This might lead to low TSS/acidity ratio in fruits.

5.3.4.4 Total sugars

In Central midlands, different spacings had significant effect on total sugars content of strawberry. The maximum total sugars content was observed in fruits obtained from plants under spacing of 30 cm x 50 cm, while the lowest total sugars content was observed in fruits obtained from plants under spacing of 30 cm x 20 cm. In Central midlands, the highest TSS, TSS/acidity were higher in fruits obtained from plants grown under spacing of 30 cm x 50 cm. These might have a positive impact on total sugars content of strawberry.

However in High ranges, the total sugars content of strawberry was significantly higher in fruits obtained from plants under spacing of 30 cm x 60 cm,

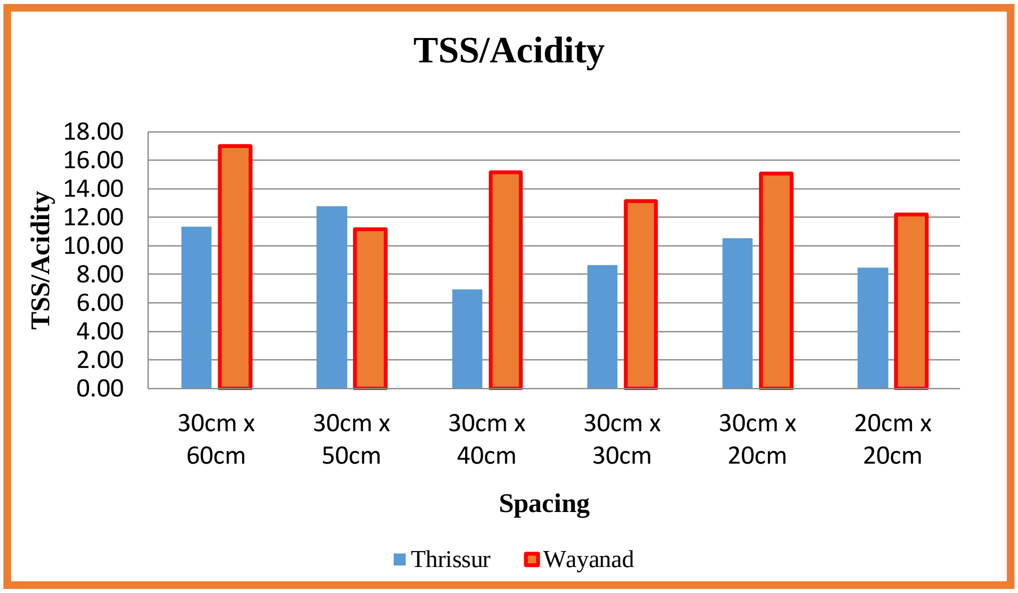


Fig 72. TSS/acidity of strawberry fruit under different spacings

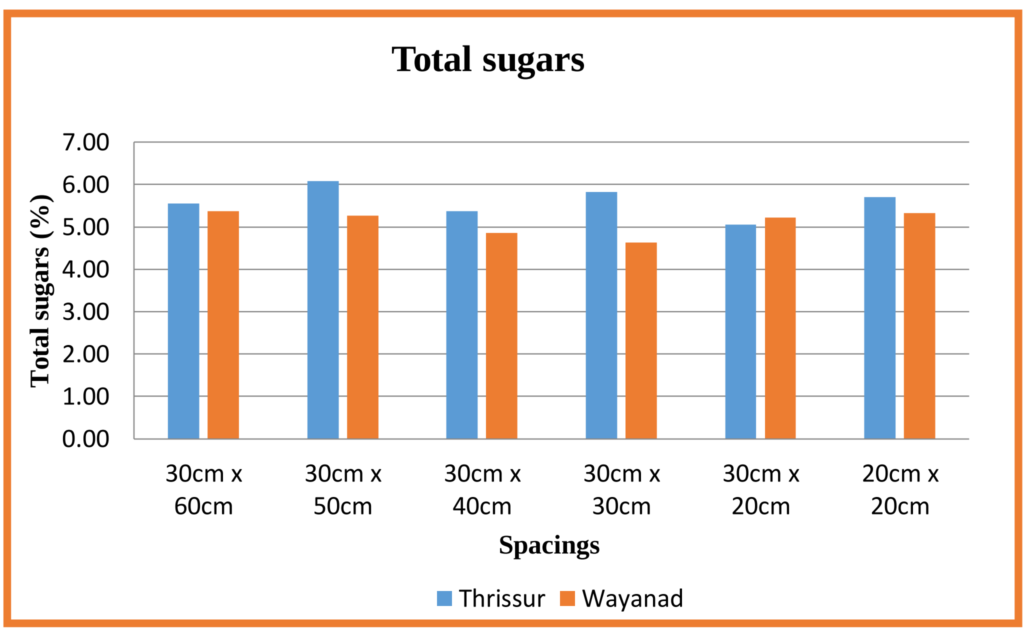


Fig 73. Total sugars of strawberry fruit under different spacings

while the lowest total sugars content was observed in fruits obtained from plants under wider spacing of 30 cm x 30 cm. (Fig 73). In High ranges, fruits obtained from wider spacing produced more quality fruits. Wider spacing gets sufficient light, nutrients and greater accumulation of photosynthates which leads to the production of quality fruits. Similar findings were given by Aswathi and Badiyala (1993); Tripathi *et al*. (2000); Sonkar *et al*. (2012).

5.3.4.5 Ascorbic acid

In Central midlands, different spacings had significant effect on ascorbic acid content of strawberry. Maximum ascorbic acid content was recorded in fruits obtained from plants grown under spacing of 30 cm x 60 cm. Minimum ascorbic acid was observed in fruits obtained from plants grown under the spacing of 20 cm x 20 cm. However in High ranges, Maximum ascorbic acid content was recorded in fruits obtained from plants grown under spacing of 30 cm x 50 cm and minimum ascorbic acid was observed in fruits obtained from plants grown under the spacing of 20 cm x 20 cm (Fig 74).

Plants grown under wider spacing get sufficient light, nutrients and greater accumulation of photosynthates which leads to the production of more ascorbic acid. Similar findings were given by Aswathi and Badiyala (1993); Tripathi *et al*. (2000); Sonkar *et al*. (2012).

5.3.4.6 Anthocyanin content

In Central midlands, different spacings had significant effect on anthocyanin content of strawberry. The maximum anthocyanin content was observed in fruits obtained from plants under spacing of 30 cm x 60 cm, while the lowest anthocyanin content was observed in fruits obtained from plants under spacing of 30 cm x 20 cm. However in High ranges, the anthocyanin content was significantly higher in fruits obtained from plants under spacing of 30 cm x 30 cm, while the lowest anthocyanin

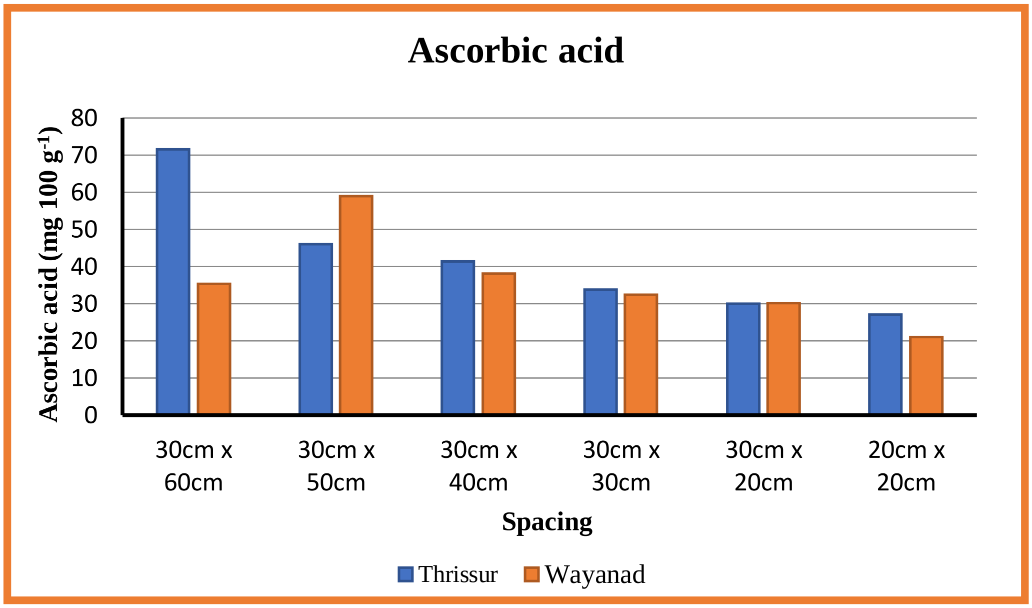


Fig 74. Ascorbic acid of strawberry fruit under different spacings

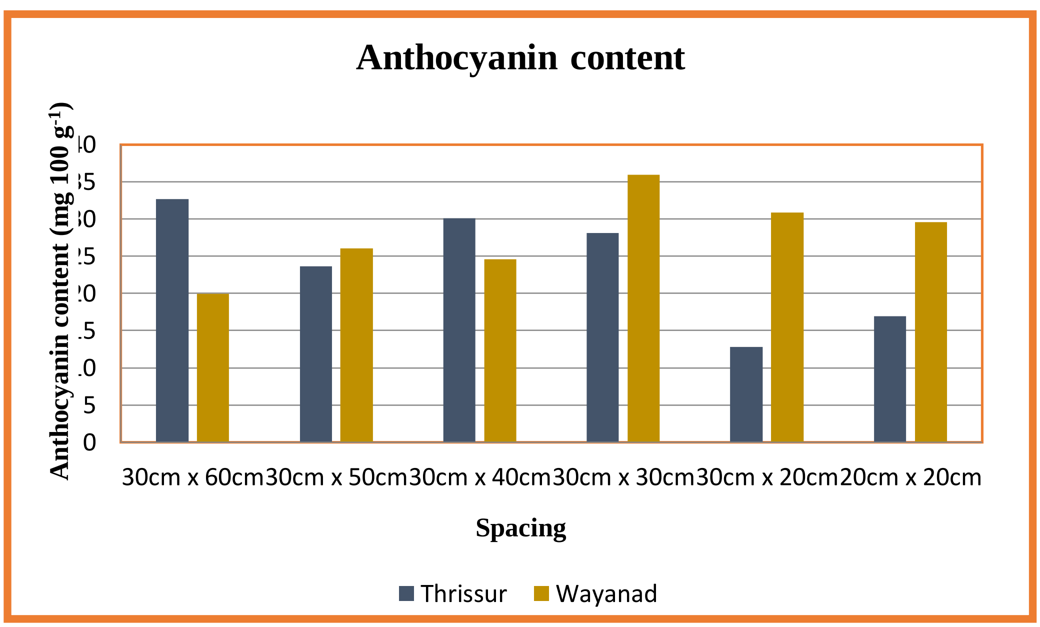


Fig 75. Anthocyanin content of strawberry fruit under different spacings

content was observed in fruits obtained from plants under wider spacing of 30 cm x 60 cm. (Fig. 75).

In Central midlands, the maximum air temperature is high and the soil temperature in wider spacing is even higher compared to closer spacings (Appendix III). When strawberry grown at a higher air temperature of upto 30 ^{0}C, it had a positive effect on anthocyanin accumulation. Similar findings were also reported in apple and pear (Wang and Camp, 2000; Marais *et al*., 2001). It might have be the reason for more anthocyanin content in wider spacing of 30 cm x 60 cm. However, in High ranges, the maximum air temperature is low and the effect on soil temperature is less. Earlier research findings made by Dixon and Paiva (1995); Winkel and Shirley (2002) concluded that anthocyuanins have apparent roles in plant stress – defence. In closer spacing, there is more stress for availability of nutrients. So both the impact of soil temperature and plant stress will be more pronounced in an average spacing of 30 cm x 30 cm. That may be the reason for maximum anthocyanin content in 30 cm x 30 cm.

5.3.4.7 Beta Carotene

In Central midlands, different spacings had significant effect on β-Carotene content of strawberry. Fruits obtained from plants under spacing of 30 cm x 30 cm recorded the maximum β-Carotene content and the lowest β-Carotene content was recorded by fruits of plants grown under spacing of 30 cm x 60 cm. However, in High ranges, fruits obtained from plants under spacing of 30 cm x 50 cm recorded the maximum β-Carotene content and the lowest β-Carotene content was recorded by fruits of plants grown under spacing of 30 cm x 40 cm. (Fig 76). When temperature increases, Beta carotene content decreases. This might be the reason for the lowest Beta carotene content in wider spacing, which had maximum soil temperature. Beta carotene content of same genotype varies significantly under different agro climatic conditions. These findings were supported by Munasinghe and Wansapala (2015).

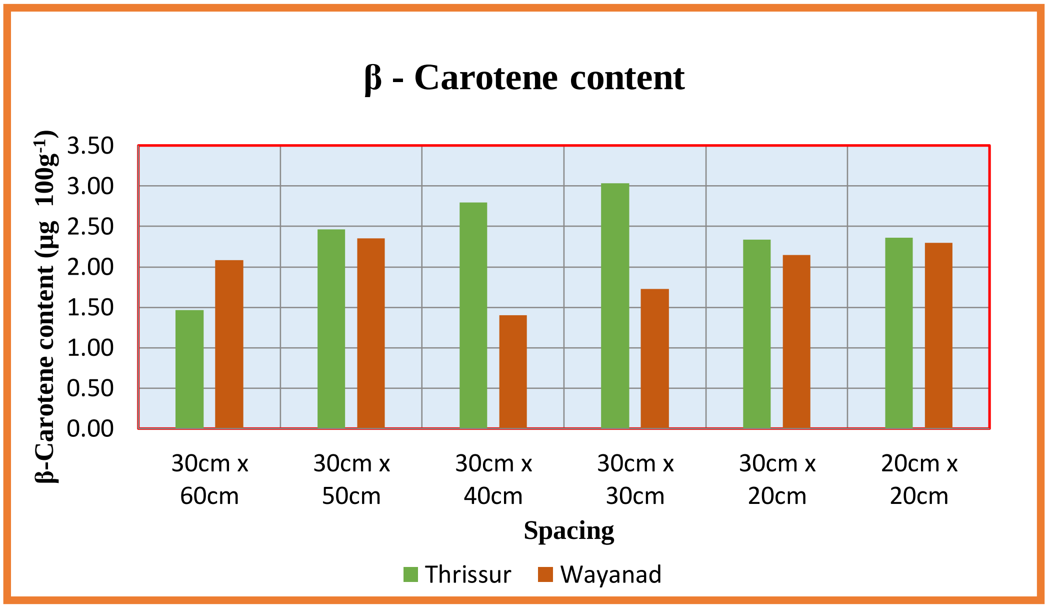


Fig 76. β-Carotene content of strawberry fruit under different spacings

5.3.4.8 Shelf life

In Central midlands, different spacings had no significant effect on shelf life of strawberry (Table 81). In High ranges also, shelf life was not influenced by any of the spacings. Fruits from plants grown under different spacings at both locations recorded same shelf life period of 3 days when stored at ambient temperature after harvest.

5.3.4.9 Colour

In Central midlands, all the fruits harvested from plants grown under different spacings were similar in colour of deep purplish pink of 61D (Table 80). Similar was the case in High lands also. Hence in the same corollary, spacings had no significant effect on colour of strawberry.

5.3.4.10 Sensory evaluation

From consumers' point of view, sensory qualities are very important. It is a result of a complex balance between appearance, colour, flavour, aroma, taste, texture, after taste. Overall acceptability of any fruit is based on all these characters (Table 83a and 83b).

In Central midlands, during first year, overall sensory score (56.35) was higher for fruits harvested from plants grown at a spacing of 30 cm x 50 cm. During second year also, overall sensory score (56.74) was higher for fruits harvested from plants grown at a spacing of 30 cm x 50 cm. Earlier results shown that plants under spacing of 30 cm x 50 cm produced fruits with higher TSS and total sugars. The fruits obtained from plants grown under spacing of 30 cm x 50 cm also showed maximum sensory score for taste (14.51), flavour (14.31), after taste (13.78) and overall acceptability (14.3)which might have influenced overall sensory quality of fruits. Evaluating all the qualities during both seasons of growth, strawberry fruits obtained from plants under spacing of 30 cm x 40 cm recorded maximum total score for appearance (14.48), aroma (14.10) and texture (14.02). The maximum score for colour (15.15) was recorded by fruits obtained from plants under spacing of 30 cm x 60 cm. It might be due to the presence of maximum anthocyanin content. So in Central midlands, better quality fruits were produced by plants under a wider spacing of 30 cm x 50 cm.

In High ranges, the total overall sensory score (118.17) was higher for fruits harvested from plants grown at a spacing of 30 cm x 60 cm. Planting under spacing of 30 cm x 60 cm recorded maximum total sugars content. Evaluating all the qualities during both seasons of growth, the maximum total score for taste (14.97), after taste (14.6) and overall acceptability (16.53) were recorded in fruits obtained from plants under spacing of 30 cm x 60 cm. The maximum total score for colour (16.3), flavour (14.4), aroma (14.3) and texture (14.7) were recorded in fruits obtained from plants

Plate 7. Strawberry planted in different spacings at Central midlands

Plate 8. Strawberry planted in different spacings of High ranges

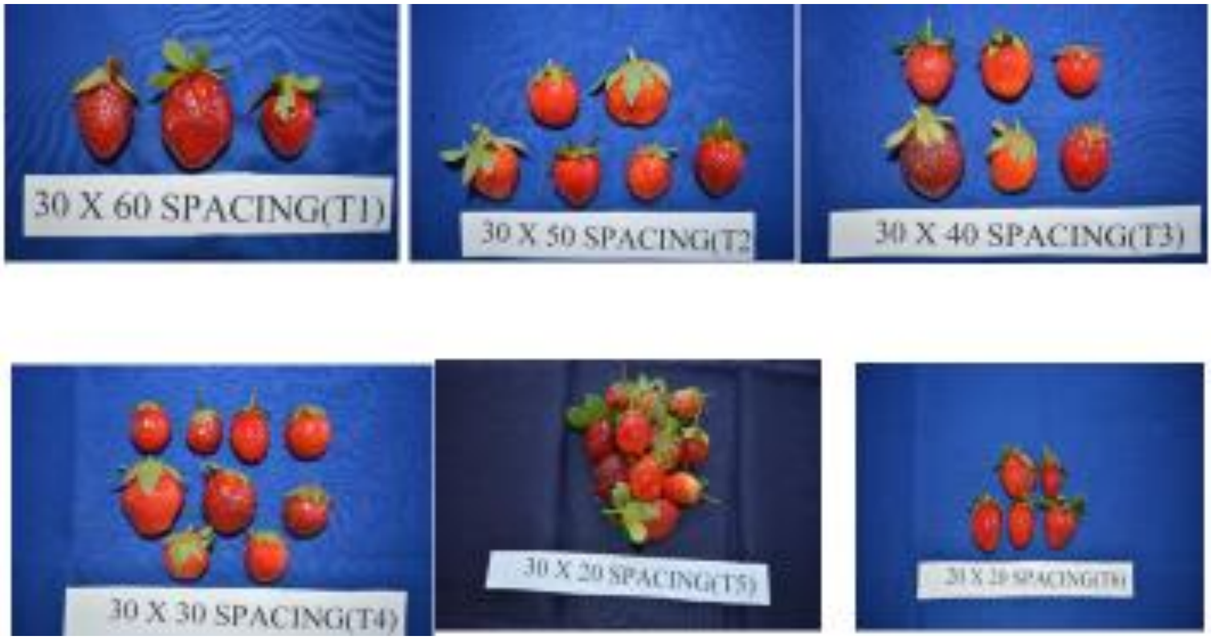


Plate 9. Strawberry fruits obtained from different spacings at Central midlands

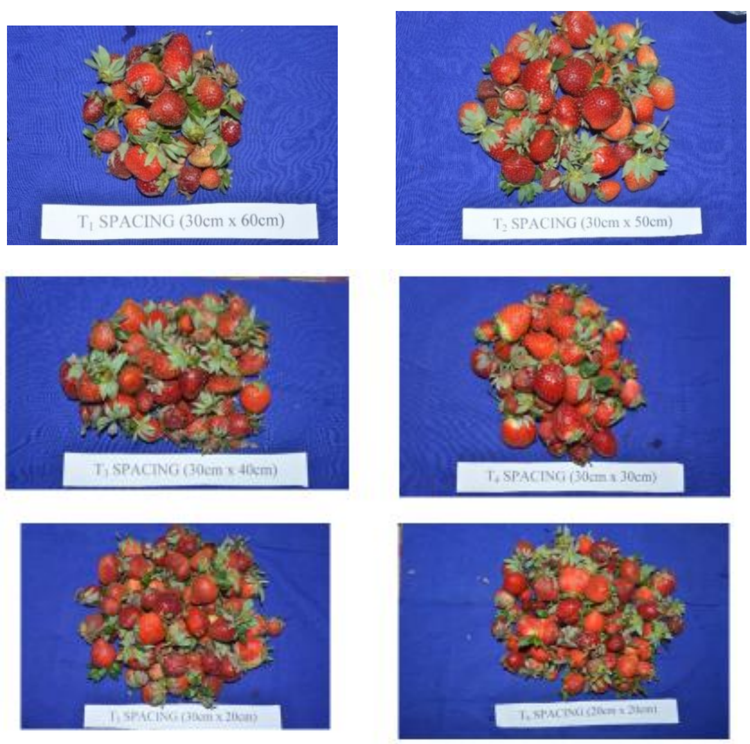


Plate 10. Strawberry fruits obtained from different spacings at High ranges

under spacing of 30 cm x 20 cm. So in Central midlands, better quality fruits were produced by plants under a wider spacing of 30 cm x 50 cm.

Hence in the same corollary, spacing had a significant effect in the sensory qualities of fruit. Fruits produced from plants grown under wider spacing produce better quality fruits. This was in accordance with earlier findings of Aswathi and Badiyala (1993) and Tripathi *et al*. (2000).

5.3.5 Pest and Disease incidence and severity

If the pest and disease severity is recorded using 1-9 scale (Mahajan *et al*. 2002), the infestation due to termites and infection due to Fusarium crown rot was recorded as severe/high attack in Central midlands. In High ranges, there were no severe pest or disease attacks. The difference in the incidence and severity of pests and diseases may be due to the difference in soil and agro climatic conditions prevailing in Central midlands and High ranges. Pests and diseases were controlled by adopting suitable control measures (Table 84).

5.3.6 Economics of cultivation

Various costs incurred and returns calculated for strawberry cultivation under different spacings in both locations (Table 85a and 85b). Among the different spacings, closer spacing of 20 cm x 20 cm recorded maximum benefit cost ratio in both Central midlands and High ranges. The yield and returns was found to be higher in closer spacing. The analysis of the data revealed that closer spacing is beneficial for strawberry cultivation in both locations.

5.4 Evaluating different growing systems for home-gardening

5.4.1 Vegetative growth attributes

5.4.1.1 Plant height

In Central midlands, different growing systems and growing media had significant influence on plant height during all stages of the growth. Among the growing systems, during the early stages of the growth, raised beds and grow bags recorded maximum plant height of strawberry. During the later stages of growth maximum plant height was recorded in plants grown in hanging pipes. Minimum plant height was recorded in plants grown in hanging bottles. Compared to hanging bottles, the volume and weight of the growing media hold in other growing systems are more. This might influenced vegetative growth (Fig 77a, Appendix VII).

However among different growing media, Soil: Cocopeat: Vermicompost (1:1:1) had significant effect on plant height during all stages of plant growth while plants grown in Cocopeat: Perlite: FYM (1:1:1) recorded minimum plant height (Fig. 77b). Concentration of organic carbon and macronutrients present in Soil: Cocopeat: Vermicompost (1:1:1) medium is more compared to all other media. This might be the reason for more vegetative growth (Appendix VIII). Earlier results revealed that vermicompost improved soil microbial and enzyme activity, cation exchange capacity and root activity which leads to a positive impact on growth of strawberry (Zhang, 2018).

Among the S x M interactions, hanging pipes with Soil: Cocopeat: Vermicompost (1:1:1) medium recorded maximum plant height.

5.4.1.2 Number of leaves per plant

In Central midlands, different growing systems and growing media had significant influence on number of leaves per plant. Among the growing systems, plants grown in grow bags recorded maximum number of leaves during the early stages of the growth. During the later stages of growth growing systems had no significant effect on number of leaves per plant. Minimum number of leaves per plant was recorded in plants grown in hanging bottles (Fig 78a).

However among different growing media, Soil: Cocopeat: Vermicompost (1:1:1) produced maximum number of leaves per plant during all stages of plant growth while plants grown in Cocopeat: Perlite: FYM (1:1:1) recorded minimum number of leaves per plant (Fig 78b). Earlier results revealed that vermicompost improved soil microbial and enzyme activity, cation exchange capacity and root

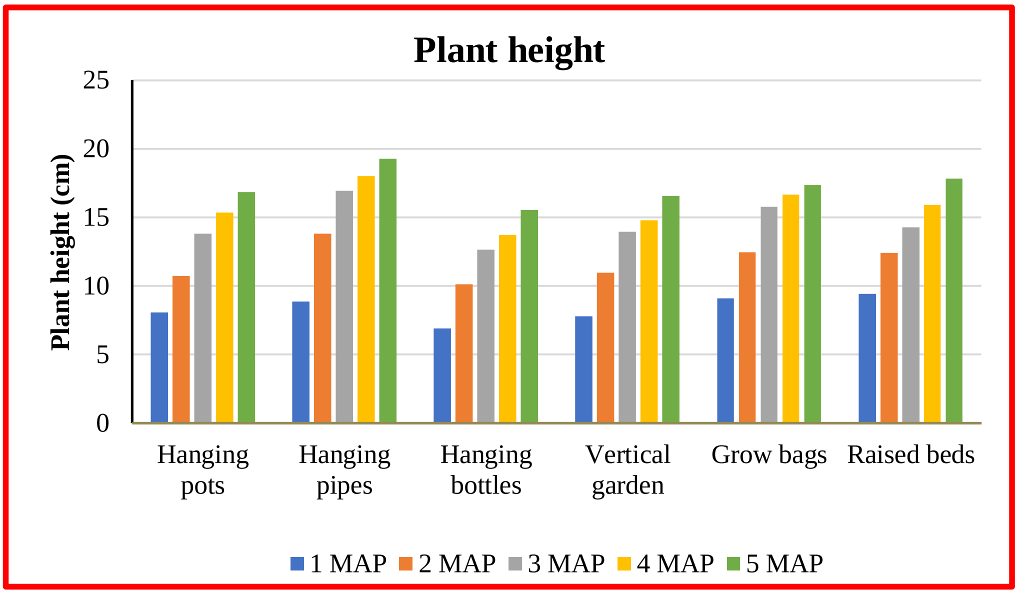


Fig 77a. Plant height of strawberry under different growing systems

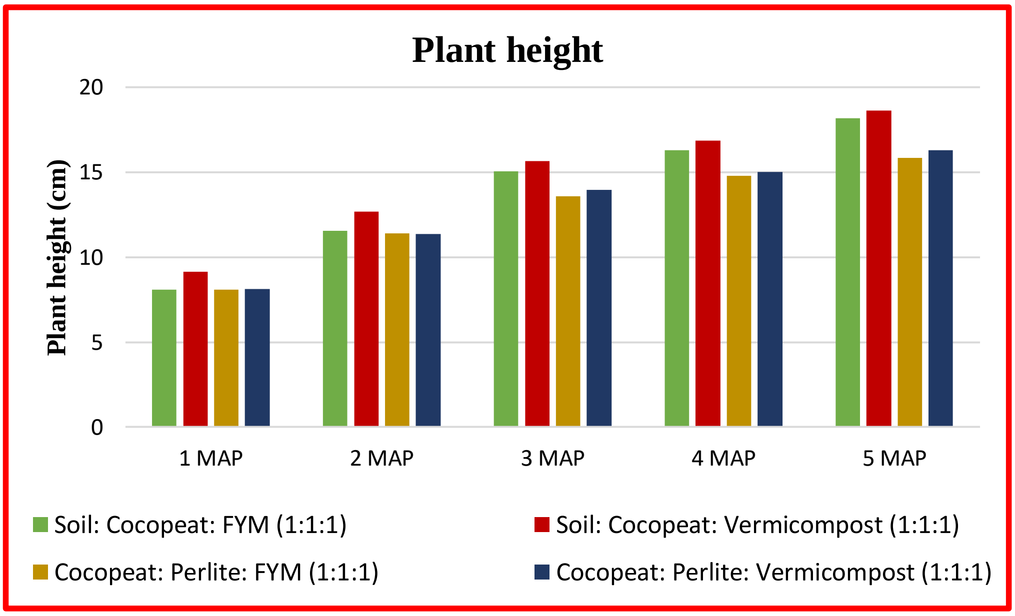


Fig 77b. Plant height of strawberry under different growing media

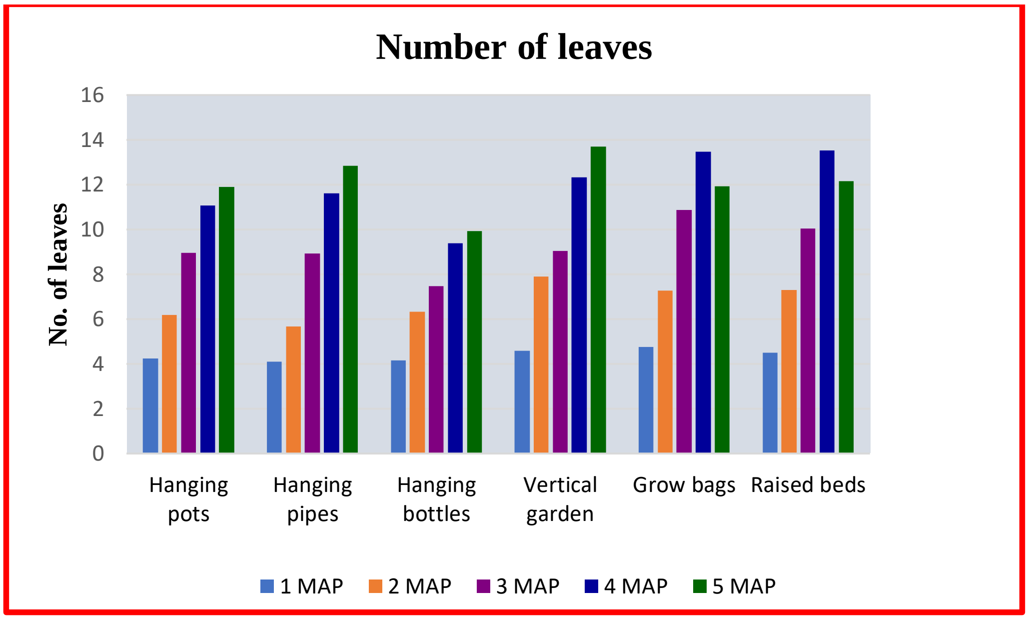


Fig 78a. Number of leaves of strawberry under different growing systems

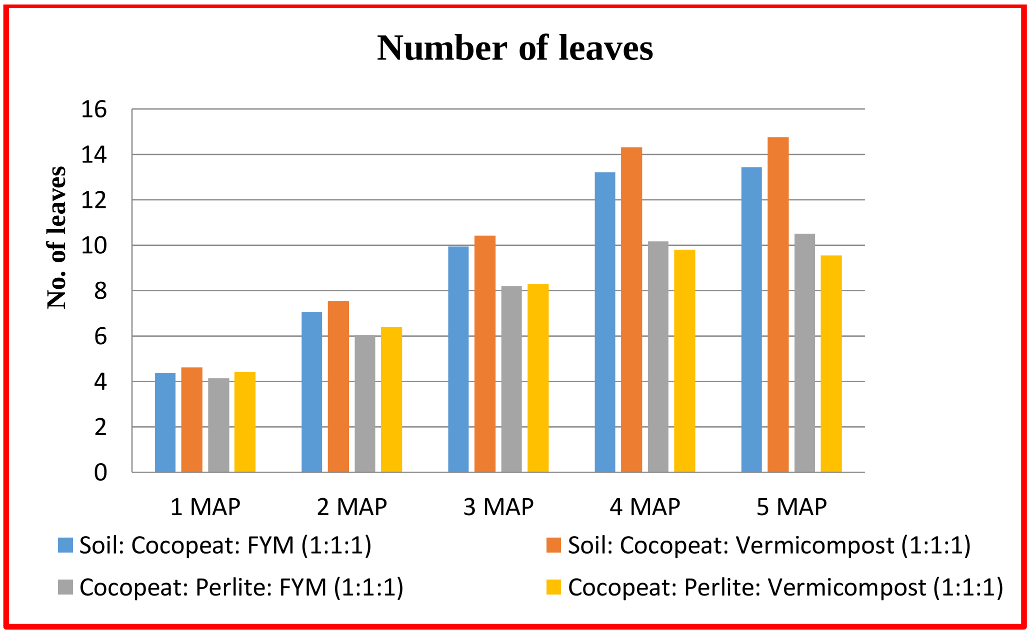


Fig 78b. Number of leaves of strawberry under different growing media

activity which leads to a positive impact on growth of strawberry (Zhang, 2018).

Among the S x M interactions, there were no significant effect on number of leaves per plant in the later stages of growth.

5.4.1.3 Plant spread

In Central midlands, different growing systems and growing media had significant influence on plant spread. Among the growing systems, raised beds recorded maximum plant spread. Minimum plant spread was recorded by plants grown in hanging bottles (Fig 79a). The volume occupied by growing media in a raised bed is more compared to all other growing systems. Raised beds provide congenial conditions for spreading of plants.

However among different growing media, Soil: Cocopeat: Vermicompost (1:1:1) produced maximum plant spread during all stages of plant growth. Minimum plant spread was recorded in plants grown in Cocopeat: Perlite: Vermicompost (1:1:1) during the later stages of the growth (Fig 79b). Soil: Cocopeat: Vermicompost (1:1:1) medium provided a slightly acidic condition which was favourable for the growth of strawberry (Appendix VIII). Earlier results also revealed that vermicompost improved soil microbial and enzyme activity, cation exchange capacity and root activity which leads to a positive impact on growth of strawberry (Zhang, 2018). Hence in corollary, raised beds with Soil: Cocopeat: Vermicompost (1:1:1) media enhances vegetative growth.

Among S x M interactions, raised beds with Soil: Cocopeat: Vermicompost (1:1:1) recorded maximum plant spread.

5.4.1.4 Number of crowns per plant

In Central midlands, different growing systems and growing media had significant influence on number of crowns per plant. Among the growing systems, vertical garden recorded maximum number of crowns per plant which was comparable with grow bags and raised beds. Minimum number of crowns per plant was recorded in plants grown in hanging bottles (Fig 80a).

However in different growing media, Soil: Cocopeat: Vermicompost (1:1:1) produced maximum number of crowns during all stages of plant growth. Minimum number of crowns per plant was recorded in plants grown in Cocopeat: Perlite: Vermicompost (1:1:1) (Fig 80b). Earlier results also revealed that vermicompost improved soil microbial and enzyme activity, cation exchange capacity and root activity which leads to a positive impact on growth of strawberry (Zhang, 2018).

The interaction effect of growing system and medium on number of crowns per plant was found to be maximum in vertical garden with Soil: Cocopeat: FYM (1:1:1) which was comparable with raised beds and grow bags with Soil: Cocopeat: Vermicompost (1:1:1) as growing medium.

5.4.2 Flowering attributes

5.4.2.1 Days to first flowering

In Central midlands, different growing systems had no significant influence on number of days to first flowering.

Among different growing media, Soil: Cocopeat: Vermicompost (1:1:1) and Soil : Cocopeat: FYM (1:1:1) recorded minimum number of days to first flowering, while maximum number of days to first flowering was recorded in Cocopeat: Perlite: Vermicompost (1:1:1) and it ranges from 66 – 73 days (Fig 81). Soil: Cocopeat: Vermicompost (1:1:1) and Soil: Cocopeat: FYM (1:1:1) media recorded more macronutrient content compared to other media. This might have lead to early flowering in strawberry (Zhang, 2018).

Among the interactions, the minimum number of days to first flowering was recorded with hanging pots and Soil: Cocopeat: FYM (1:1:1) as growing media, which was comparable with both grow bags and raised beds containing Soil: Cocopeat: Vermicompost (1:1:1) as growing medium.

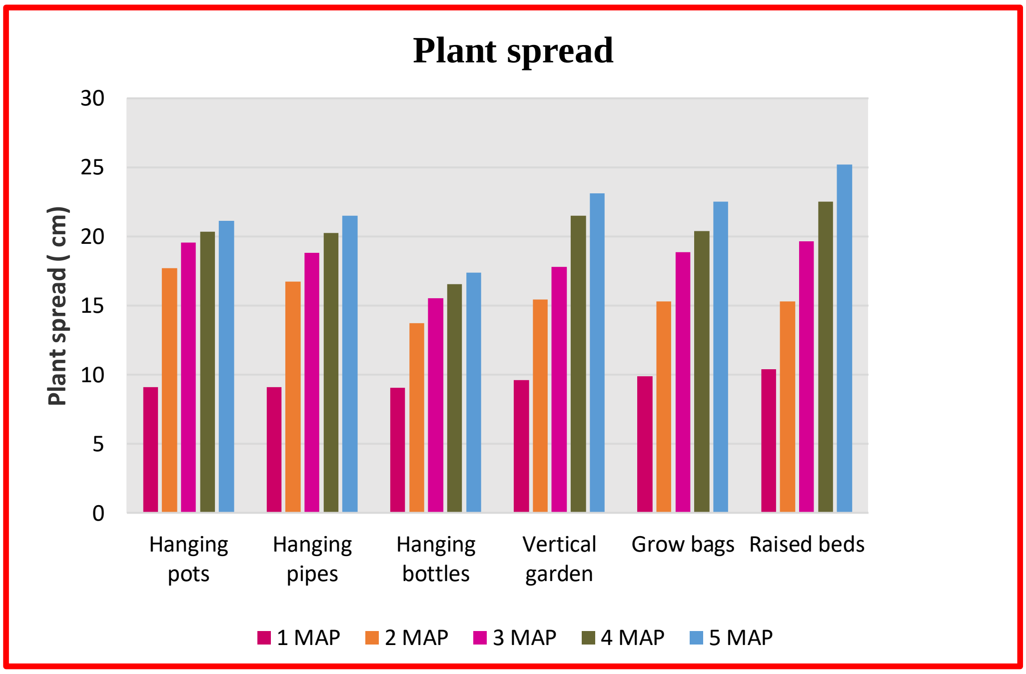


Fig 79a. Plant spread of strawberry under different growing systems

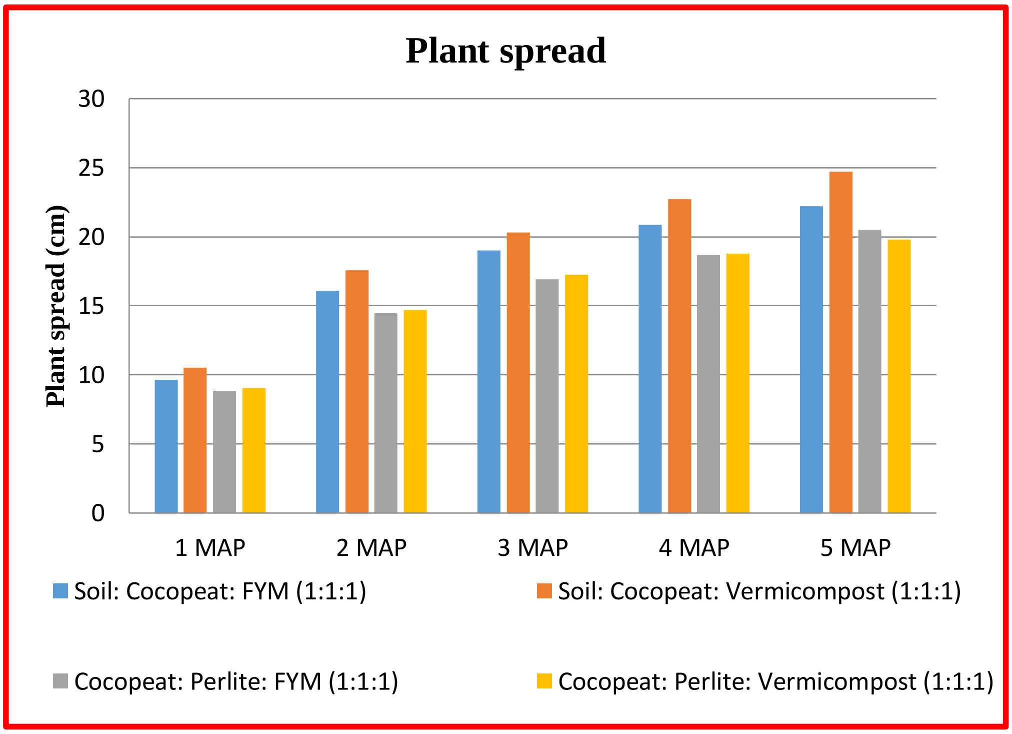


Fig 79b. Plant spread of strawberry under different growing media

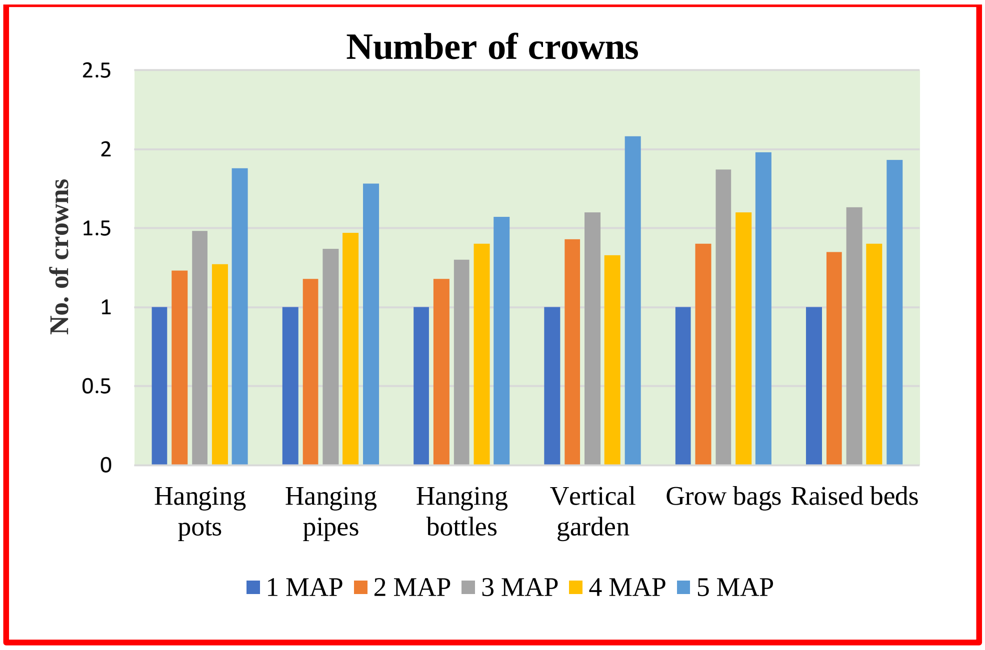


Fig 80a. Number of crowns of strawberry under different growing systems

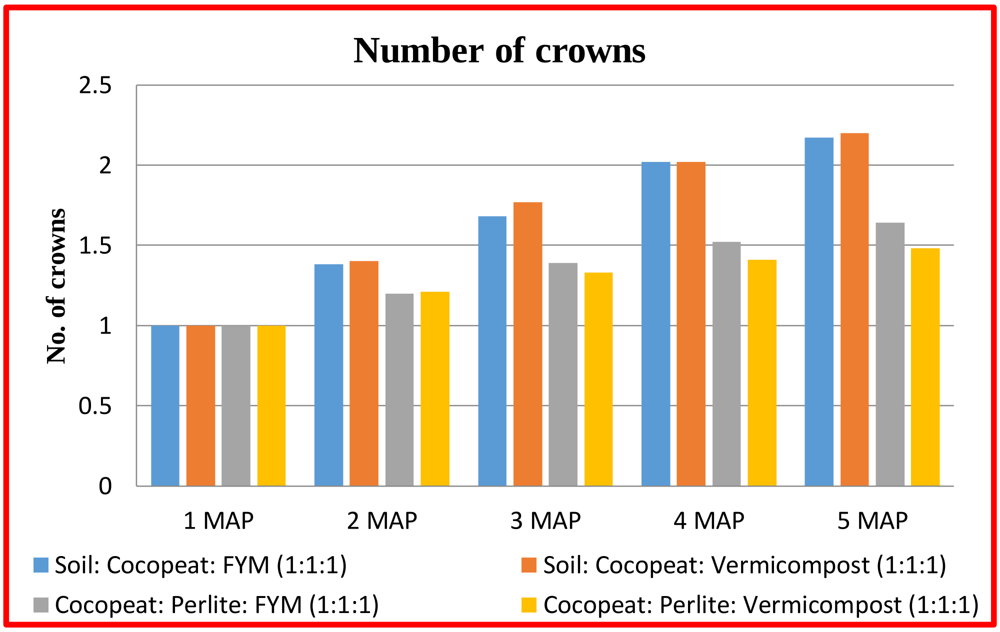


Fig 80b. Number of crowns of strawberry under different growing media

5.4.2.2 Number of clusters per plant

In Central midlands, different growing systems and media had significant influence on number of clusters per plant. Among the growing systems, raised beds recorded maximum number of clusters per plant while hanging bottles recorded minimum number of clusters per plant (Fig 82). Raised beds provide an ideal air-soil-water environment for vigorous strawberry root development (Poling, 2005). Conditions favourable for maximum plant spread in raised beds might have influenced in the production of more number of clusters per plant.

Among different growing media, Soil: Cocopeat: Vermicompost (1:1:1) recorded maximum number of clusters per plant. Cocopeat: Perlite: Vermicompost (1:1:1) recorded minimum number of clusters per plant. Earlier results showed that Soil: Cocopeat: Vermicompost (1:1:1) medium recorded maximum plant height, number of leaves, plant spread and number of crowns per plant. This might have influenced the production of more number of clusters per plant.

S x M interactions were found to be non significant.

5.4.2.3 Number of flowers per plant

In Central midlands, different growing systems and media had significant influence on number of flowers per plant. Among the growing systems, raised beds recorded maximum number of flowers per plant. Minimum number of flowers per plant was recorded in plants grown in hanging bottles. Among different growing media, Soil: Cocopeat: Vermicompost (1:1:1) recorded maximum number of flowers per plant (Fig 83).

The result indicated that raised beds with Soil: Cocopeat: Vermicompost (1:1:1) media produced more number of clusters per plant. This may lead to increase in the production of number of flowers per plant.

Among the interactions, raised beds with Soil: Cocopeat: Vermicompost (1:1:1) as growing medium recorded maximum number of flowers per plant.

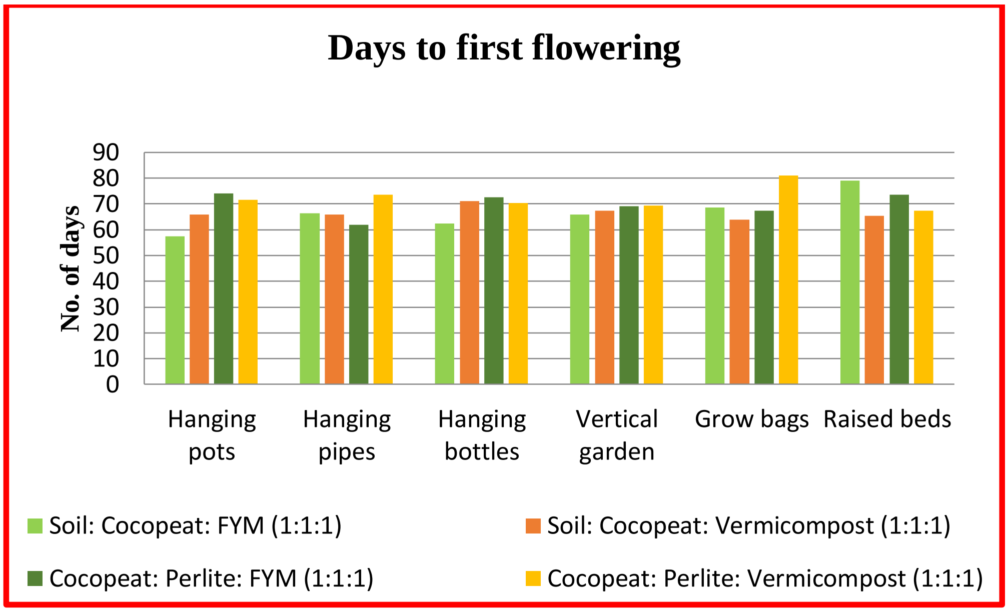


Fig 81. Days to first flowering of strawberry under different growing systems and growing media

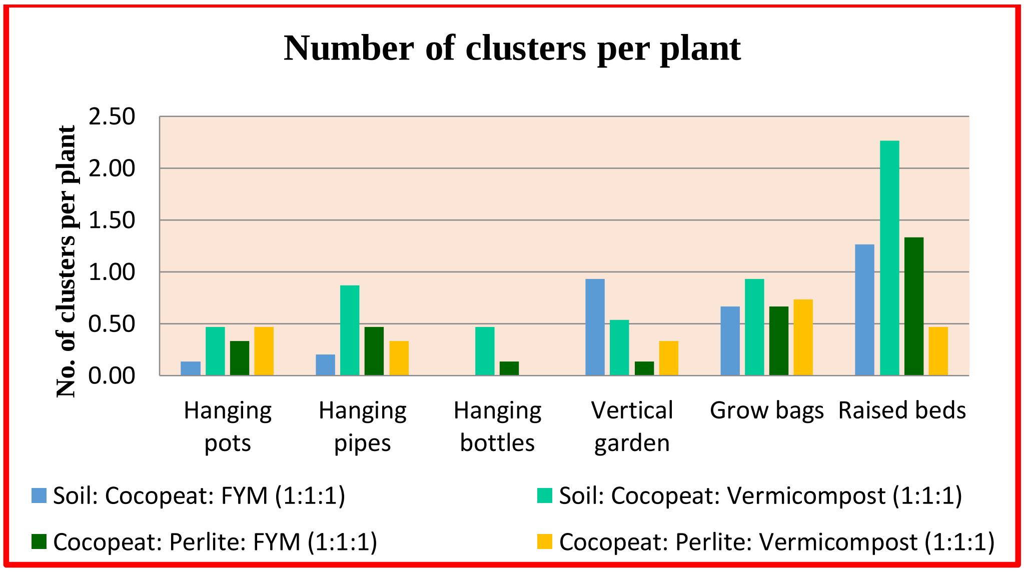


Fig 82. Number of clusters per plant of strawberry under different growing systems and growing media

5.4.3 Yield attributes

5.4.3.1 Number of fruits per plant

In Central midlands, different growing systems and media had significant influence on number of fruits per plant. Among the growing systems, raised beds recorded maximum number of fruits per plant. Minimum number of fruits per plant was recorded in plants grown in hanging bottles. Earlier results indicated that raised beds recorded maximum number of flowers and clusters per plant. This may be the reason for maximum number of fruits per plant.

Among different growing media, Soil: Cocopeat: Vermicompost (1:1:1) recorded maximum number of fruits per plant. Cocopeat: Perlite: FYM (1:1:1) recorded minimum number of fruits per plant (Fig 84). As discussed earlier, plant spread, number of clusters, number of flowers per plant were maximum in plants grown in raised beds with Soil: Cocopeat: Vermicompost (1:1:1) as growing media. This might have resulted in higher number of fruits per plant.

Among the interactions, raised beds with Soil: Cocopeat: Vermicompost (1:1:1) as growing medium recorded maximum number of fruits per plant.

5.4.3.2 Fruit length

In Central midlands, different growing systems and media had significant influence on fruit length. Among the growing systems, raised beds recorded maximum fruit length. Minimum fruit length was recorded in plants grown in hanging pots. The volume and weight of the growing media in a raised bed is very higher compared to other growing systems. This might have a positive influence on fruit length also.

Among different growing media, Soil: Cocopeat: Vermicompost (1:1:1) recorded maximum fruit length while Cocopeat: Perlite: Vermicompost (1:1:1) recorded minimum fruit length (Fig 85). Soil: Cocopeat: Vermicompost (1:1:1) provided maximum macronutrients and slightly acidic condition which is favourable for the growth of strawberry (Appendix VIII).

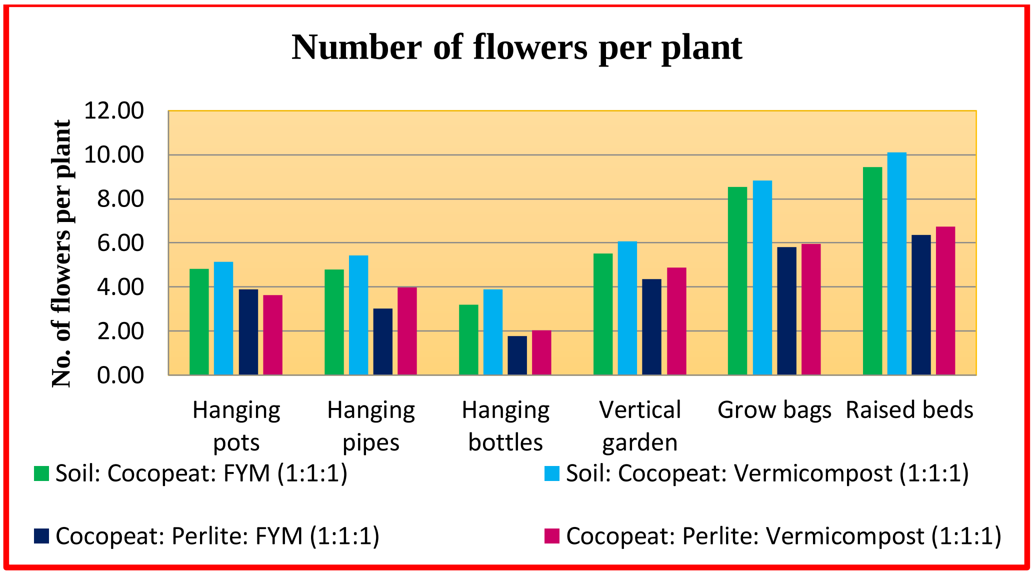


Fig 83. Number of flowers per plant of strawberry under different growing systems and growing media

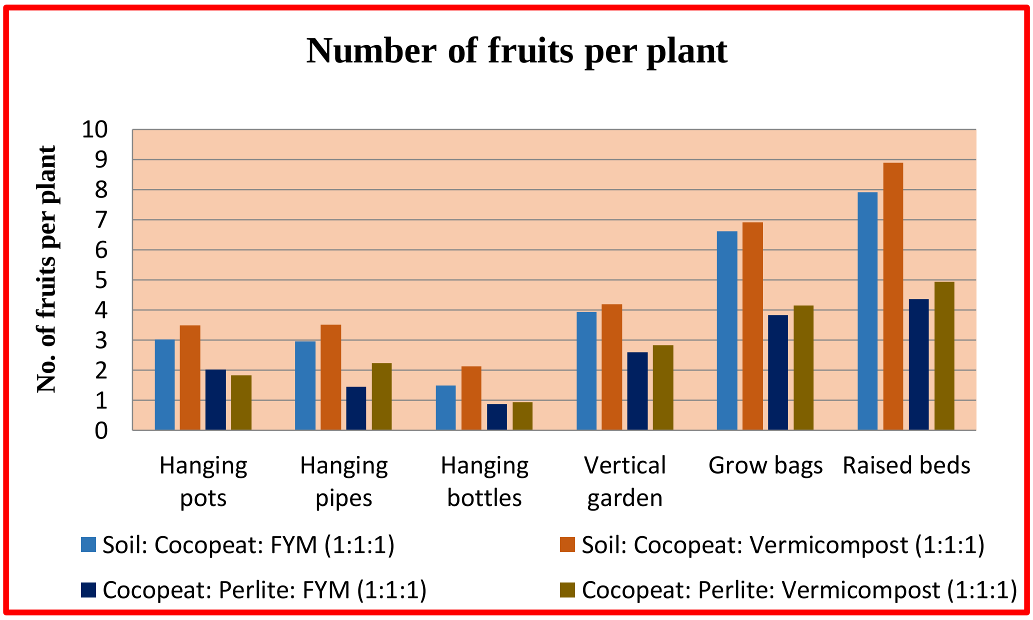


Fig 84. Number of fruits per plant of strawberry under different growing systems and growing media

S x M interactions were found to be non significant.

5.4.3.3 Fruit breadth

In Central midlands, different growing systems and media had significant influence on fruit breadth. Among the growing systems, raised beds recorded maximum fruit breadth. Minimum fruit breadth was recorded in plants grown in hanging pots. As discussed earlier, the positive influence of raised beds on fruit length might have influenced fruit breadth also.

Among different growing media, Soil: Cocopeat: FYM (1:1:1) recorded maximum fruit breadth while Cocopeat: Perlite: FYM (1:1:1) recorded minimum fruit breadth (Fig 86). Earlier research works revealed that since perlite contains no organic matter, it had no significant effect on growth of strawberry (Ercisli *et al.*, 2005). This might be the reason for minimum fruit breadth in media containing perlite.

Among the interactions, hanging bottles with Soil: Cocopeat: FYM (1:1:1) recorded maximum fruit breadth which was comparable with raised beds, grow bags and vertical garden containing Soil: Cocopeat: FYM (1:1:1) as growing medium.

5.4.3.4 Average fruit weight per plant

In Central midlands, different growing systems and media had significant influence on average fruit weight per plant. Among the growing systems, raised beds recorded maximum average fruit weight per plant. Minimum average fruit weight per plant was recorded in plants grown in hanging pots. As discussed earlier, the fruits obtained from plants grown in raised beds had maximum fruit length and fruit breadth. This might have a positive influence on average fruit weight per plant.

Among different growing media, Soil: Cocopeat: Vermicompost (1:1:1) recorded maximum average fruit weight per plant while Cocopeat: Perlite: FYM (1:1:1) recorded minimum average fruit weight per plant (Fig 87). The growing

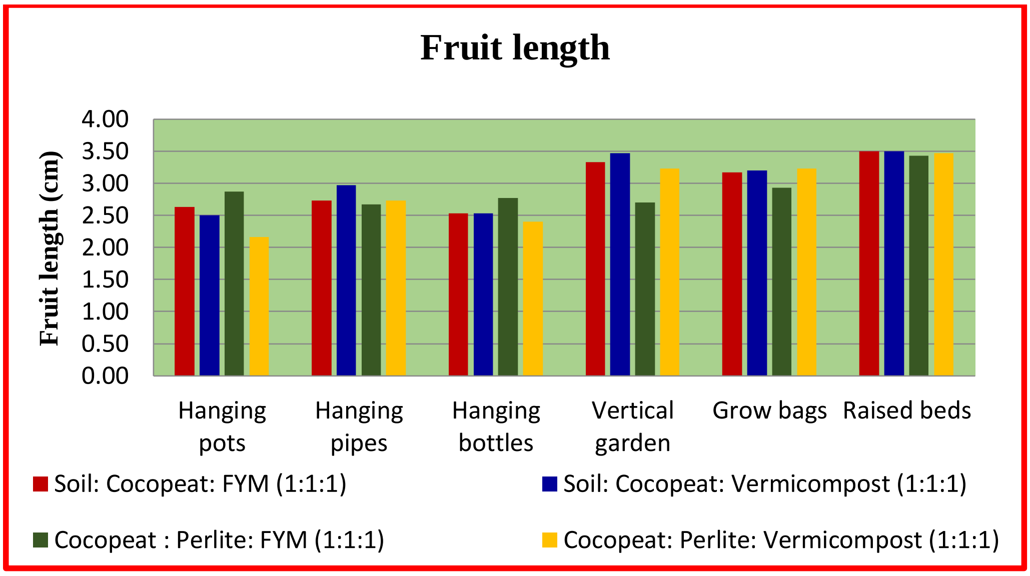


Fig 85. Fruit length of strawberry under different growing systems and growing media

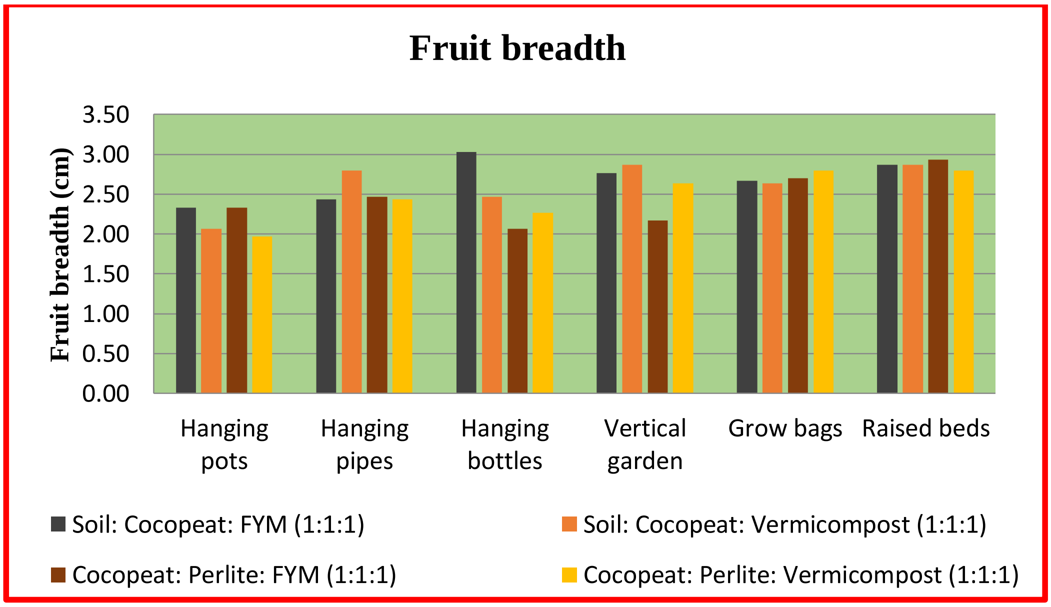


Fig 86. Fruit breadth of strawberry under different growing systems and growing media

media Soil: Cocopeat: Vermicompost (1:1:1) recorded maximum fruit length and this might have been an impact on average fruit weight per plant.

S x M interactions were found to be non significant.

5.4.3.5 Days to first harvest

In Central midlands, different growing systems had no significant influence on number of days to first harvest.

Among different growing media, Soil: Cocopeat: Vermicompost (1:1:1) and Soil: Cocopeat: FYM (1:1:1) recorded minimum number of days to first harvest while Cocopeat: Perlite: Vermicompost (1:1:1) recorded maximum number of days to first harvest (Fig 88). As discussed earlier, both Soil: Cocopeat: Vermicompost (1:1:1) and Soil: Cocopeat: FYM (1:1:1) recorded minimum number of days to first flowering. This might have lead to early harvest of strawberry.

Among interactions, hanging pots with Soil: Cocopeat: FYM (1:1:1) recorded minimum number of days to first harvest. As discussed earlier, hanging pots with Soil: Cocopeat: FYM (1:1:1) recorded minimum number of days to first flowering. This may be the reason for early harvesting of strawberry fruits.

5.4.3.6 Days to final harvest

In Central midlands, different growing systems had significant influence on number of days to final harvest. Among the growing systems, hanging pots recorded maximum number of days to final harvest. Minimum number of days to final harvest was recorded in plants grown in grow bags.

Growing media had no significant effect on number of days to final harvest (Fig 89).

Among interactions, hanging pots with Cocopeat: Perlite: Vermicompost (1:1:1) recorded maximum number of days to final harvest. As discussed earlier, Cocopeat: Perlite: Vermicompost (1:1:1) recorded late flowering and this might be the reason for late harvesting of strawberry.

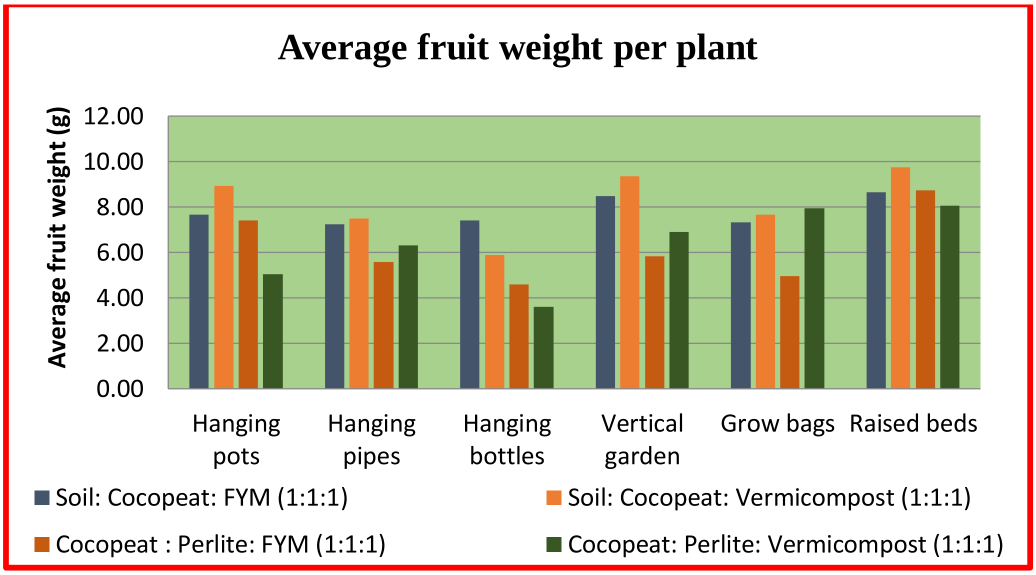


Fig 87. Average fruit weight per plant of strawberry under different growing systems and growing media

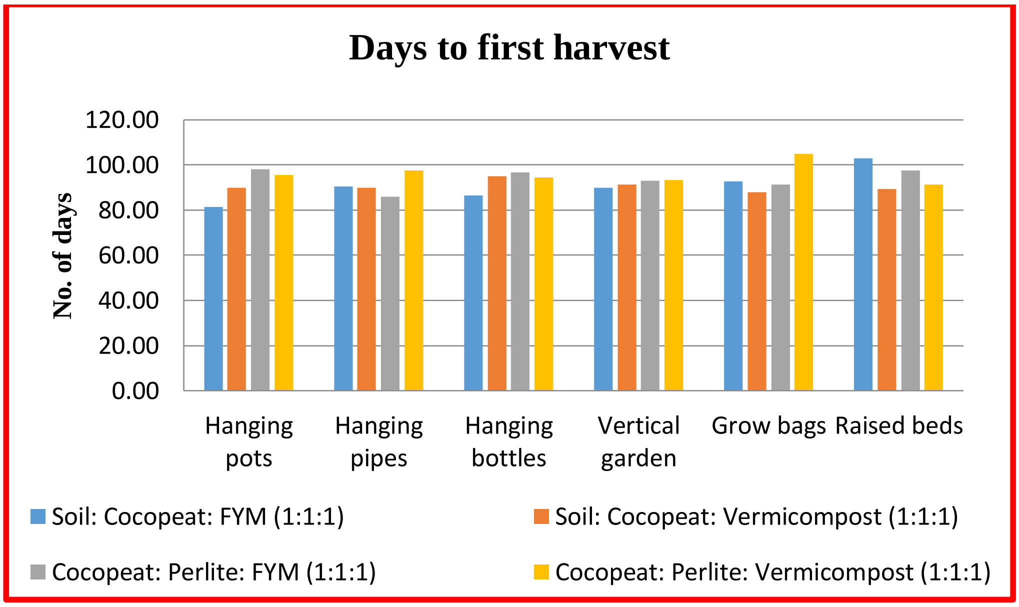


Fig 88. Days to first harvest of strawberry under different growing systems and growing media

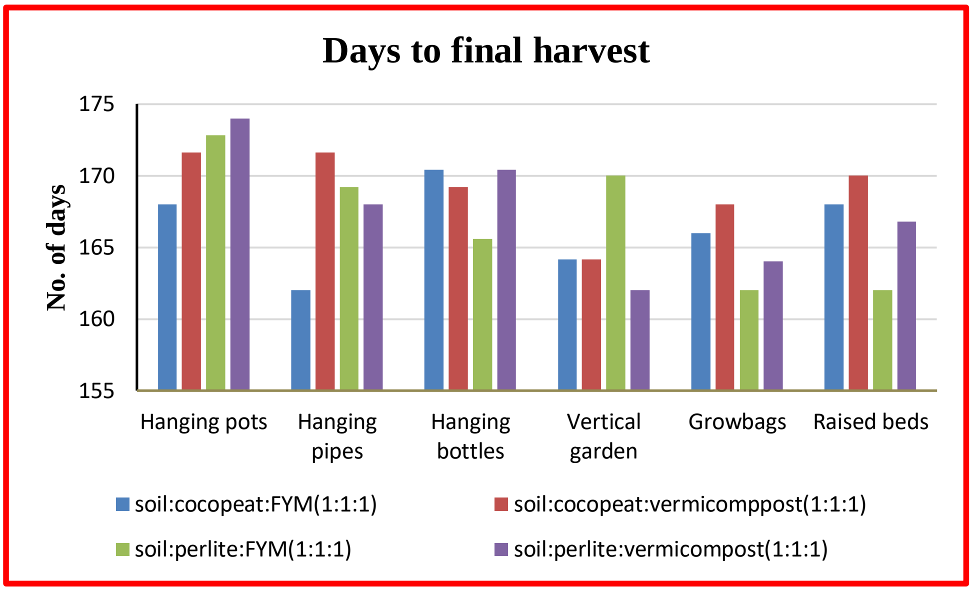


Fig 89. **Days to final harvest of strawberry under different growing systems and growing media**

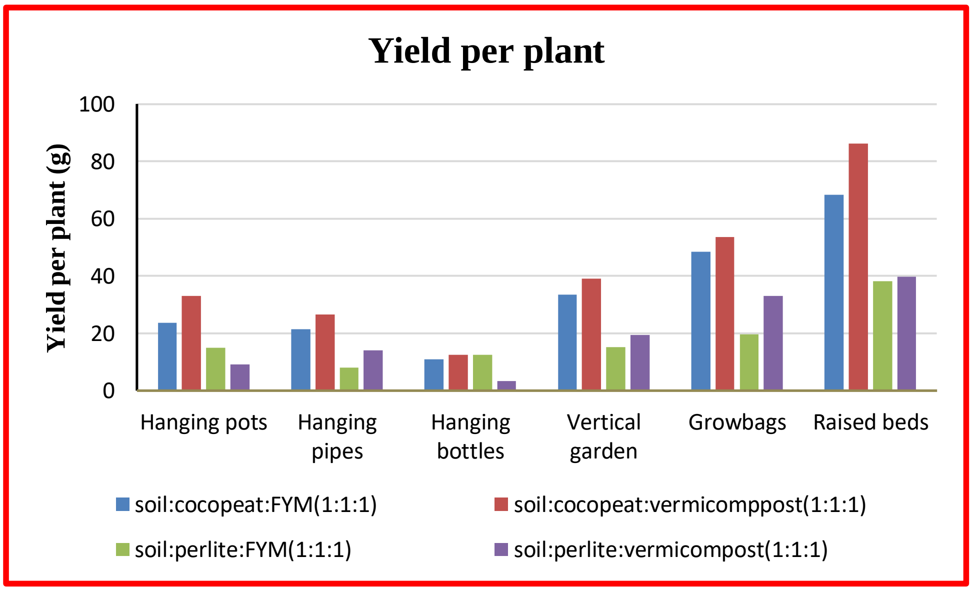


Fig 90. **Yield per plant of strawberry under different growing systems and growing media**

5.4.3.7 Yield per plant

In Central midlands, different growing systems and media had significant influence on yield per plant. Among the growing systems, raised beds recorded maximum yield per plant (58.15 g). Minimum yield per plant was recorded in plants grown in hanging bottles (9.89 g). As discussed earlier, plant spread, number of clusters, number of flowers and number of fruits per plant were maximum in plants grown in raised beds. This may be the reason for maximum yield per plant in raised beds.

Among different growing media, Soil: Cocopeat: Vermicompost (1:1:1) recorded maximum yield per plant while Cocopeat: Perlite: FYM (1:1:1) recorded minimum yield per plant and it ranges from 18.08 g to 41.87 g (Fig 90). As discussed earlier, maximum plant height, number of leaves, plant spread, number of crowns per plant, number of clusters, number of flowers and number of fruits per plant were recorded in plants grown in Soil: Cocopeat: Vermicompost (1:1:1) as growing media. This may be the reason for maximum yield.

Among interactions, raised beds with Soil: Cocopeat: Vermicompost (1:1:1) recorded maximum yield per plant. Ealier results indicated that growing system, raised beds and growing medium, Soil: Cocopeat: Vermicompost (1:1:1) recorded maximum yield per plant.

5.4.4 Quality attributes

5.4.4.1 TSS

In Central midlands, different growing systems and media had significant influence on TSS content of fruits. Among the growing systems, raised beds recorded maximum TSS content of fruits (5.83 ^{0}Brix). Minimum TSS content of fruits was recorded in plants grown in grow bags. As discussed earlier, raised beds holded maximum growing media by weight and volume (Appendix VII). Thus supply of nutrients to individual fruit increases and it might have influenced the increased TSS content also.

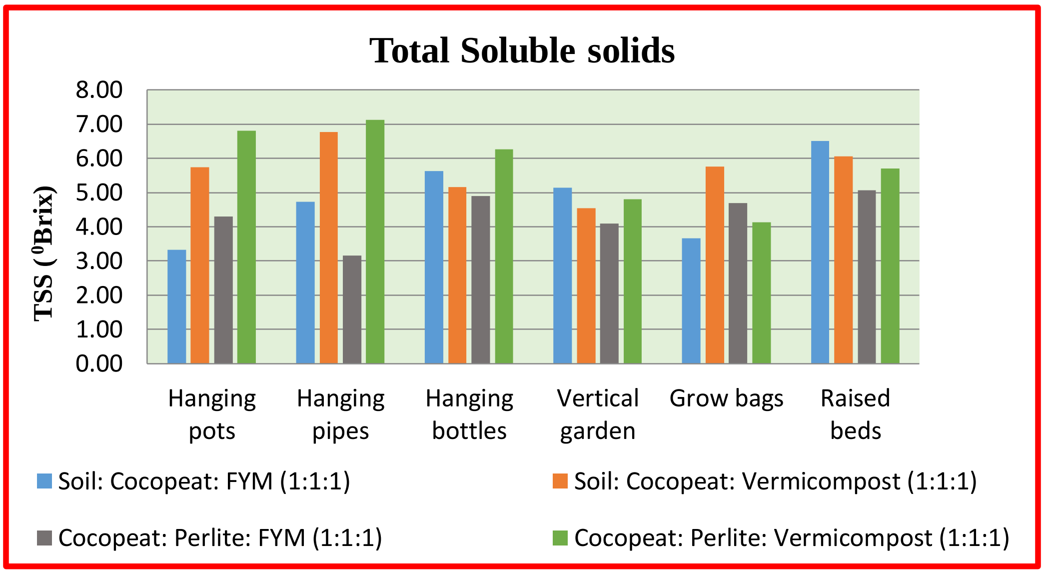


Fig 91. **TSS content of strawberry fruits under different growing systems and growing media**

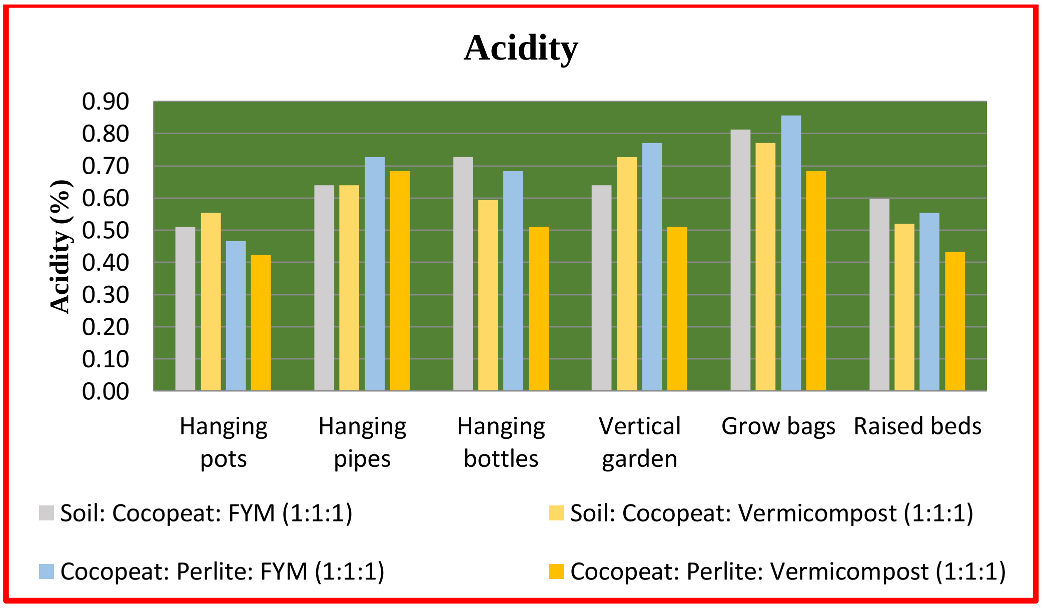


Fig 92. **Acidity of strawberry fruits under different growing systems and growing media**

Among different growing media, Cocopeat: Perlite: Vermicompost (1:1:1) recorded maximum TSS content of fruits while minimum TSS content of fruits was recorded in Cocopeat: Perlite: FYM (1:1:1) (Fig 91). Plants grown in medium Cocopeat: Perlite: Vermicompost (1:1:1) recorded late flowering and took maximum number of days to first harvesting. Thus the plants got the maximum time for accumulation of better sugars in the fruits which might have resulted in increased TSS in plants grown under Cocopeat: Perlite: Vermicompost (1:1:1) medium. The positive effect of Cocopeat: Perlite: Vermicompost (1:1:1) medium on TSS was earlier reported by Ameri *et al*. (2012) in strawberry.

Among the interactions, hanging pipes with Cocopeat: Perlite: Vermicompost (1:1:1) recorded maximum TSS content. Earlier results indicated that Cocopeat: Perlite: Vermicompost (1:1:1) recorded maximum TSS which might have a positive effect.

5.4.4.2 Acidity

In Central midlands, different growing systems and media had significant influence on acidity of fruits. Among the growing systems, hanging pots recorded minimum acidity of fruits. Maximum acidity of fruits was recorded in plants grown in grow bags. As discussed earlier, hanging pots recorded maximum number of days to final harvest. Thus the plants got the maximum time for accumulation of better sugars in the fruits which might have resulted in lower acidity of fruits.

Among different growing media, Cocopeat: Perlite: Vermicompost (1:1:1) recorded minimum acidity of fruits while maximum acidity of fruits was recorded in Cocopeat: Perlite: FYM (1:1:1) medium (Fig 92). Fruits produced from plants grown in Cocopeat: Perlite: Vermicompost (1:1:1) medium recorded maximum TSS content. Fruits harvested with high TSS have lower acid content. This might be the reason for minimum acidity of fruits grown in Cocopeat: Perlite: Vermicompost (1:1:1).

S x M interactions were found to be non significant.

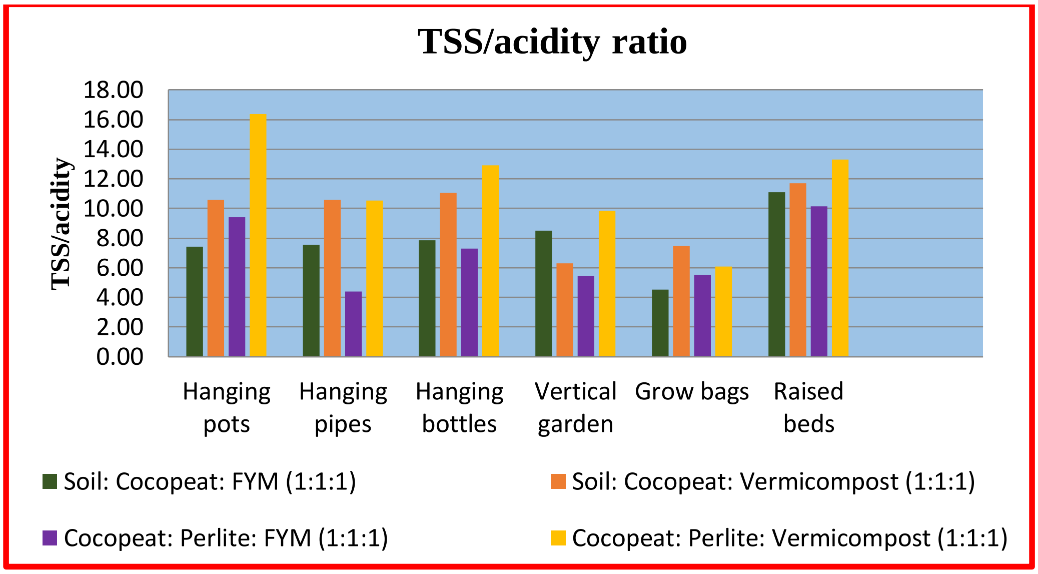


Fig 93. TSS/acidity ratio of strawberry fruits under different growing systems and growing media

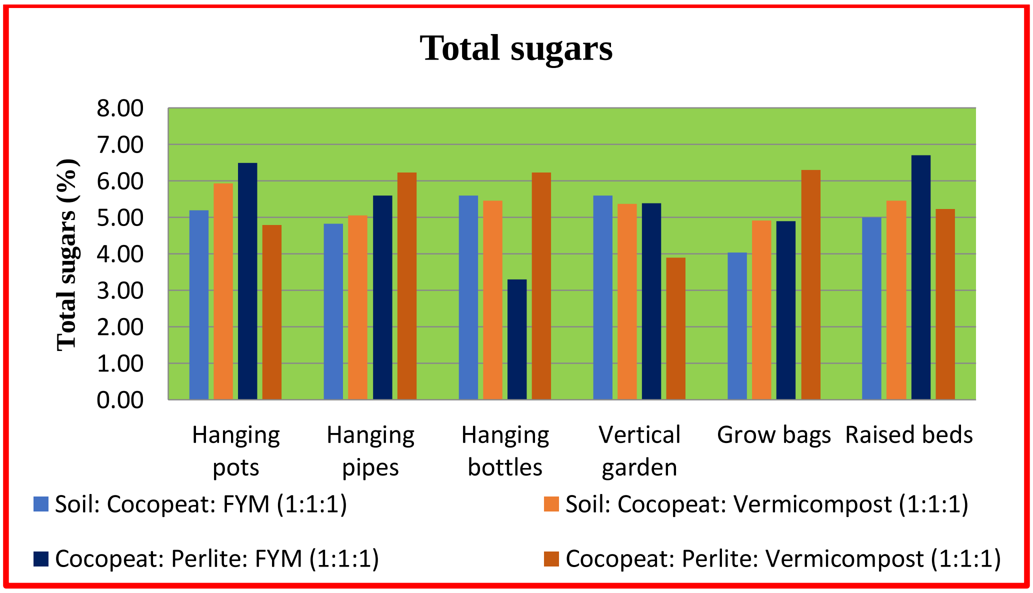


Fig 94. Total sugars of strawberry fruits under different growing systems and growing media

5.4.4.3 TSS/Acidity

In Central midlands, different growing systems and media had significant influence on TSS/Acidity ratio of fruits. Among the growing systems, raised beds recorded maximum TSS/Acidity ratio of fruits. Minimum TSS/Acidity ratio of fruits was recorded in plants grown in grow bags. Earlier result indicated maximum TSS recorded in raised beds which might be the reason for maximum TSS/Acidity ratio.

Among different growing media, Cocopeat: Perlite: Vermicompost (1:1:1) recorded maximum TSS/Acidity ratio of fruits while minimum TSS/Acidity ratio of fruits was recorded in Cocopeat: Perlite: FYM (1:1:1) medium (Fig 93). Fruits produced from plants grown in Cocopeat: Perlite: Vermicompost (1:1:1) medium recorded maximum TSS content and lowest acidity. This might be the reason for maximum TSS/Acidity ratio of fruits harvested from plants grown in Cocopeat: Perlite: Vermicompost (1:1:1) medium.

S x M interactions were found to be non significant.

5.4.4.4 Total sugars

In Central midlands, different growing systems and media had significant influence on total sugar content of strawberry fruits. Among the growing systems, hanging pots recorded maximum total sugars content of strawberry fruits. Minimum total sugars content of fruits was recorded in plants grown in grow bags. Earlier result indicated days to final harvest was recorded maximum in hanging pots. So the plants grown in hanging pots got maximum time for accumulation of better sugars in the fruits which might have resulted in lower acidity of fruits which might be the reason for maximum total sugars content.

Among different growing media, Cocopeat: Perlite: Vermicompost (1:1:1) recorded maximum total sugars content of fruits while minimum total sugars content of fruits was recorded in Soil : Cocopeat: FYM (1:1:1) medium (Fig 94). Fruits produced from plants grown in Cocopeat: Perlite: Vermicompost (1:1:1) medium recorded maximum TSS content and lowest acidity. This might be the reason for maximum total sugars content of fruits harvested from plants grown in Cocopeat: Perlite: Vermicompost (1:1:1) medium.

Among S x M interactions, total sugars content were found to be maximum in raised beds with Cocopeat: Perlite: FYM (1:1:1) as growing medium.

5.4.4.5 Ascorbic acid content

In Central midlands, different growing systems and media had significant influence on ascorbic acid content of strawberry fruits. Among the growing systems, hanging bottles recorded maximum ascorbic acid content of strawberry fruits. Minimum ascorbic acid content of fruits was recorded in plants grown in hanging pots. Earlier result indicated plants in hanging bottles had no clusters and minimum number of fruits. At same light levels, when the crop load increases, the assimilates available to individual fruit decreases. The development of secondary and tertiary fruits demands more assimilates (Watson *et al.,* 2002). Hanging bottles had more primary flowers and lesser number of secondary and tertiary flowers. This might be the reason for more ascorbic acid content in fruits harvested from hanging bottles. Fruits harvested from hanging pots had minimum fruit length and fruit breadth. So naturally surface area was minimum and lower ascorbic acid content.

Among different growing media, Cocopeat: Perlite: FYM (1:1:1) recorded maximum ascorbic acid content of fruits while minimum ascorbic acid content of fruits was recorded in Soil : Cocopeat: Vermicompost (1:1:1) medium (Fig 95). Medium contain both cocopeat and Perlite which are hydrophilic in nature and absorbs more moisture and improve ascorbic acid. These findings were earlier observed in vegetables (Nilsson, 1979). Different levels of farm yard manure have also been reported to enhance the ascorbic acid contents in strawberries (Bhat, 1999).

Among interactions, hanging bottles with Cocopeat: Perlite: FYM (1:1:1) recorded maximum ascorbic acid content of fruits.

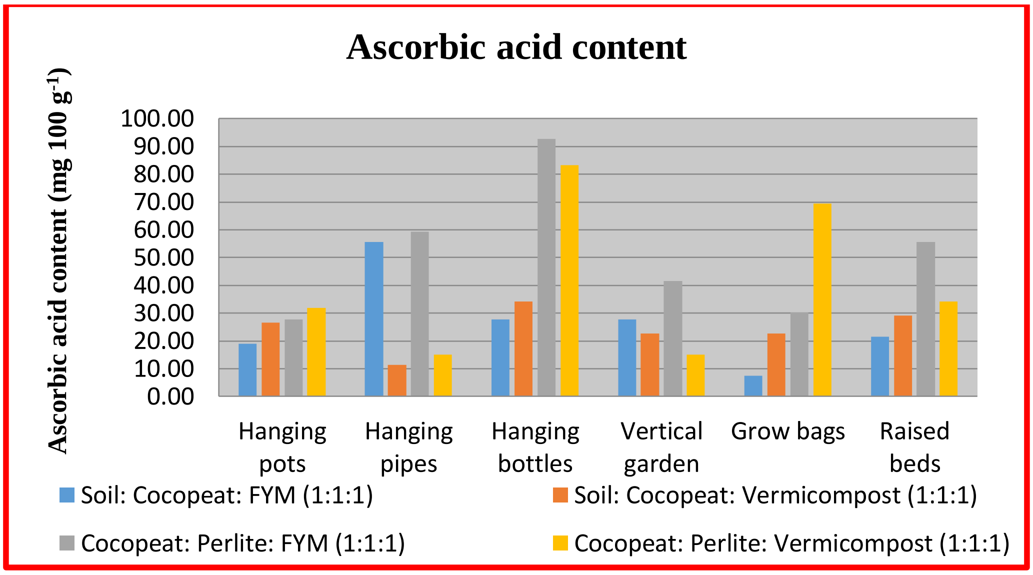


Fig 95. Ascorbic acid content of strawberry fruits under different growing systems and growing media

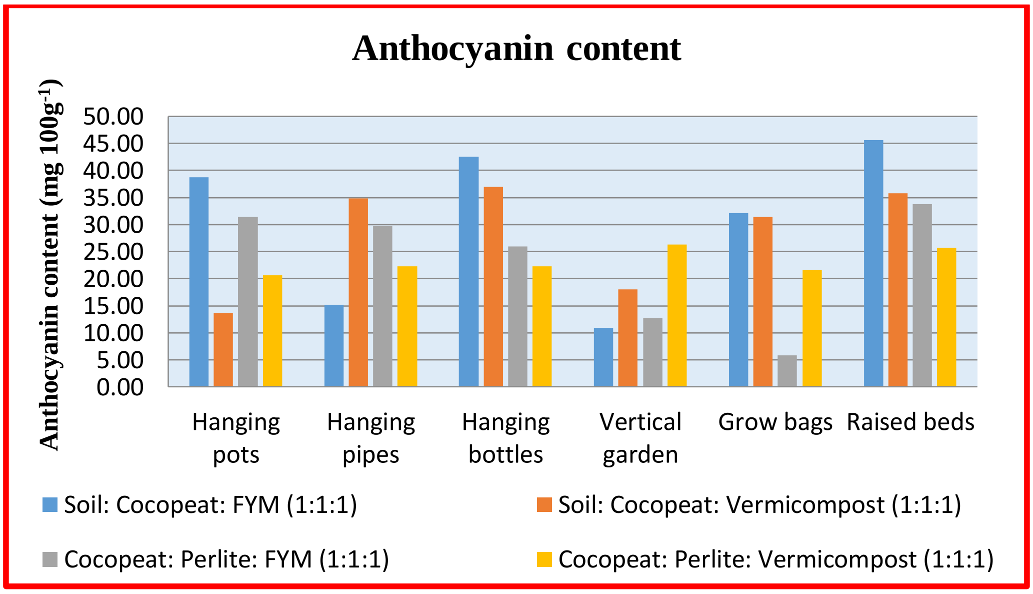


Fig 96. Anthocyanin content of strawberry fruits under different growing systems and growing media

5.4.4.6 Anthocyanin content

In Central midlands, different growing systems and media had significant influence on anthocyanin content of strawberry fruits. Among the growing systems, raised beds recorded maximum anthocyanin content of strawberry fruits. Minimum anthocyanin content of fruits was recorded in plants grown in vertical garden. In raised beds, plants were grown in holes of plastic mulches and this would raise the soil temperature and had a positive impact on anthocyanin content of fruits. These findings were supported by Truax and Gagnon (1992); Wang and Camp (2000); Marais *et al*. (2001); Moor *et al*. (2005).

Among different growing media, Soil: Cocopeat: FYM (1:1:1) recorded maximum anthocyanin content of fruits while minimum anthocyanin content of fruits was recorded in Cocopeat: Perlite: Vermicompost (1:1:1) medium (Fig 96). In case of growing media, the availability of moisture might be less in soil: cocopeat: FYM (1:1:1) compared to all other media. Thus the plants are under more stress. Increased stress might have a positive influence in anthocyanin content (Moor *et al.*, 2005).

Among interactions, raised beds with Soil: Cocopeat: FYM (1:1:1) recorded maximum anthocyanin content of fruits. Earlier results indicated that both raised beds and Soil: Cocopeat: FYM (1:1:1) recorded maximum anthocyanin content

5.4.4.7 β - Carotene content

In Central midlands, different growing systems and media had significant influence on β - Carotene content of strawberry fruits. Among the growing systems, hanging bottles recorded maximum β - Carotene content of strawberry fruits. Minimum β - Carotene content of fruits was recorded in plants grown in grow bags. In hanging bottles, the number of fruits harvested was minimum. When the crop load decreases, the assimilates available to individual fruit increases (Watson *et al.*, 2002). These might be the reason for more β - Carotene content.

Among different growing media, Soil: Cocopeat: FYM (1:1:1) recorded

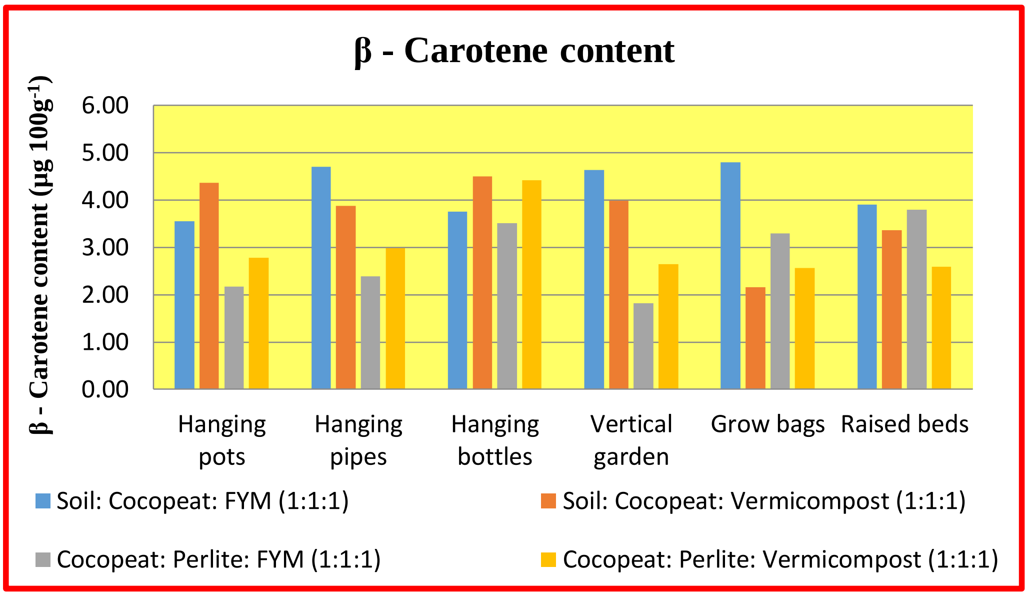


Fig 97. β - Carotene content of strawberry fruits under different growing systems and growing media

maximum β - Carotene content of fruits while minimum β - Carotene content of fruits was recorded in Cocopeat: Perlite: FYM (1:1:1) medium (Fig 97).

Among interactions, grow bags with Soil: Cocopeat: FYM (1:1:1) recorded maximum β- Carotene content of fruits.

5.4.4.8 Shelf life

Growing systems and growing media had no significant effect on shelf life of strawberry.

5.4.4.9 Colour

Growing systems and growing media had no significant effect on colour of strawberry.

5.4.4.10 Sensory evaluation

The maximum total sensory score was recorded by raised beds with Soil: Cocopeat: FYM (1:1:1) as growing medium. Raised beds recorded maximum TSS and TSS/acidity. Quality attributes such as anthocyanin and β - Carotene content were recorded maximum when using Soil: Cocopeat: FYM (1:1:1) as growing medium. So in combination of raised beds with Soil: Cocopeat: FYM (1:1:1) recorded maximum sensory score (57.84).

5.4.5 Pests and diseases

No severe attack of pests and diseases was observed during the period of investigation.

5.4.6 Economics of cultivation

The benefit cost ratio was found to be maximum in raised beds with Soil: Cocopeat: Vermicompost (1:1:1) as growing medium (S_6M_2). Earlier results indicated that the above interaction recorded maximum number of flowers, fruits and yield per plant. This might resulted in maximum benefit. Since there is no cost incurred for structures in case of raised beds, the benefit: cost is maximum.

A) Hanging pipes

B) Hanging bottles C) Vertical garden

Plate 11. Strawberry planted in different growing systems

D) Hanging pots

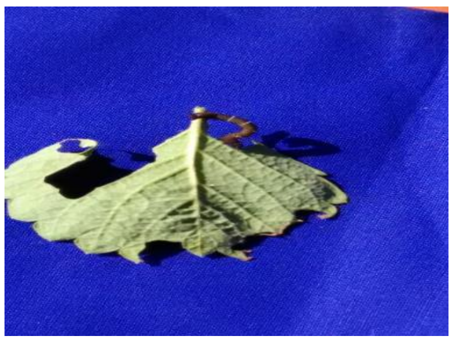
E) Grow bags

F) Raised beds

Plate 12. Different growing systems Contd..

Termites

(Coptotermes formosanus)

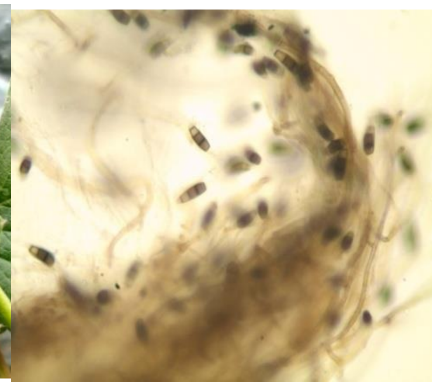


Black looper
(Hyposidra talaca)

Hairy Caterpillar
(Orygia postica)

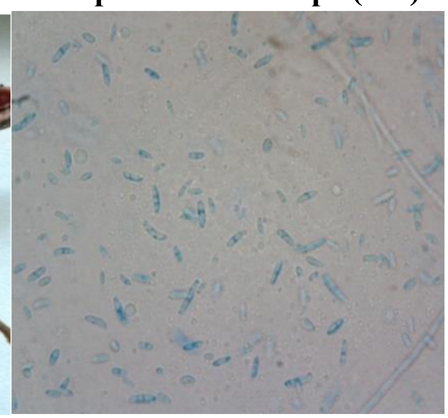
Mealy bug
(Pseudococcidae longispinus)

Plate 13. Pests of strawberry



Alternaria leaf spot

Alternaria alternata magnified in Compound microscope (40x)



Fusarium crown rot

F*usarium oxysporum* magnified in Compound microscope (40x)

Pestalotiopsis leaf spot

Pestalotiopsis longisetula magnified in Compound microscope (40x)

Plate 14. Diseases of strawberry

Summary

6. SUMMARY

The study on “production dynamics of strawberry (*Fragaria* x *ananassa* Duch.) in Kerala” was undertaken with the objective to evaluate the performance of different varieties of strawberry in the tropical and sub-tropical climatic conditions of Kerala and to standardize the nutrient requirement and spacing of strawberry and also for developing growing systems for homestead cultivation. The study was conducted over a period of two seasons September 2016- March 2017 and September 2017- March 2018**,** respectively in open field in two locations of Kerala i.e., College of Agriculture (Central mid-lands) and RARS, Ambalavayal (High ranges). The entire works was divided into four experiments and are presented below.

6.1 Evaluation of strawberry varieties

6.2 Nutrient management in strawberry

6.3 Effect of spacing on growth and yield

6.4 Evaluating different growing systems for home-gardening

6.1 Evaluation of strawberry varieties

Commercially cultivated strawberry varieties such as Hadar, Sweet Charlie, Sabrina, Sabrina-1, Crystal, Winter Dawn, Gili and Barak were used for the study. One month old tissue culture plants of strawberry were planted in the last week of September in Central mid-lands and High ranges.

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

In Central mid-lands, Sabrina-1 recorded maximum plant height compared to all other varieties. In High ranges, Winter Dawn recorded the maximum plant height.

Winter Dawn recorded significantly high number of leaves per plant in both locations.

In Central mid-lands, Sabrina-1 recorded maximum plant spread compared to all other varieties. In High ranges, Hadar recorded the maximum plant spread.

Winter Dawn recorded significantly high number of crowns per plant in both locations.

In Central mid-lands, Winter Dawn recorded minimum number of days to first flowering compared to all other varieties. In High ranges, Gili recorded the minimum number of days to first flowering.

Winter Dawn recorded significantly higher number of clusters per plant in both locations.

Winter Dawn recorded significantly maximum number of flowers per plant in both locations.

Winter Dawn recorded significantly high number of fruits per plant in both locations.

Winter Dawn recorded significantly maximum fruit length in both locations.

In Central mid-lands, Sabrina-1 recorded maximum fruit breadth compared to all other varieties. In High ranges, Sabrina recorded the maximum fruit breadth.

In Central mid-lands, Sabrina-1 recorded maximum average fruit weight compared to all other varieties. In High ranges, Winter Dawn recorded maximum average fruit weight.

In Central mid-lands, Winter Dawn recorded minimum number of days to first harvest compared to all other varieties. In High ranges, Gili recorded the minimum number of days to first harvest.

Winter Dawn recorded significantly maximum number of days to final harvest in both locations.

Winter Dawn recorded significantly maximum yield per plant in both locations.

In Central mid-lands, Gili recorded maximum TSS of strawberry. Hadar recorded significantly higher TSS content in High ranges.

In Central mid-lands, Sweet Charlie recorded minimum acidity compared to all other varieties. In High ranges, Sweet Charlie and Sabrina recorded the lowest acidity content of fruits.

In Central mid-lands, Sweet Charlie recorded maximum TSS/acidity compared to all other varieties. In High ranges, Sweet Charlie recorded maximum TSS/acidity of strawberry fruits.

In Central mid-lands, Sabrina-1 recorded maximum total sugar content compared to all other varieties. In High ranges, variety Gili recorded maximum total sugars of strawberry.

In Central mid-lands, Winter Dawn recorded maximum ascorbic acid content compared to all other varieties. In High ranges, variety Crystal recorded maximum ascorbic acid content of strawberry.

Variety Crystal recorded maximum anthocyanin content in both locations.

In Central mid-lands, Sabrina-1 recorded maximum β- Carotene content compared to all other varieties. In High ranges, variety Hadar recorded maximum β-Carotene content of strawberry.

Varieties had no significant influence on shelf life on both locations.

Variety Crystal showed no significant difference in colour of strawberry in both locations.

In Central mid-lands, total sensory score was found to be maximum in varieties Winter Dawn and Sabrina-1. In High ranges, total sensory score was highest with variety Sweet Charlie.

The infestation due to termites and fusarium crown rot were recorded as severe/high in Central midlands where as in High ranges, there were no severe pest or disease attacks.

Variety Winter Dawn recorded maximum benefit cost ratio in both locations.

In overall, it is concluded that variety Winter Dawn is suitable for both Central midlands and High ranges as it has maximum vegetative growth, yield and better quality fruits.

6.2 Nutrient management in strawberry

The study was undertaken at College of Agriculture, Vellanikkara (Central mid-lands) from September 2016- March 2017 and September 2017- March 2018. Strawberry variety “Winter Dawn” was used for the study. One month old strawberry plants were planted in open field at a spacing of 30 cm x 40 cm. The experiment was laid in RBD with 9 treatments along with one control and 3 replications. Observations on vegetative growth, flowering, yield, quality attributes, postharvest study and pest and disease were recorded. The salient features of the study could be summarized as follows.

Effect of different nutrient combinations on the growth, yield and quality of strawberry was studied. One month old tissue culture plants of Winter Dawn variety was taken for study in Central mid-lands of Kerala.

Among the different nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 (T_8) recorded maximum plant height.

Among the different nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 (T_8) recorded maximum number of leaves per plant.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 (T_8) recorded maximum plant spread.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 (T_8) recorded maximum number of crowns per plant.

Different nutrient combinations had no significant effect on the number of days to first flowering.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 (T_8) produced more number of clusters per plant.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 (T_8) produced more number of flowers per plant.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 (T_8) produced higher number of fruits per plant.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:100:40:50 (T_9) recorded maximum fruit length.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 10:50:20:50 (T_1) recorded maximum fruit breadth.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 10:50:20:50 (T_1) recorded maximum average fruit weight per plant

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 (T_8) recorded the minimum number of days to first harvest.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 10:100:80:100 (T_3) recorded the maximum number of days to final harvest.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 produced maximum yield per plant.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 produced maximum TSS content of fruits.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 20:50:40:100 (T_4) recorded lowest acidity of fruits.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 recorded maximum TSS/acidity ratio of fruits.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:100:40:50 (T_9) recorded maximum total sugars of fruits.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50 (T_9) recorded maximum ascorbic acid content of fruits.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:50:80:75 (T_7) recorded maximum anthocyanin content of fruits.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 10:100:80:100 (T_3) recorded maximum β - Carotene content of fruits.

Different nutrient combinations had no significant effect on shelf life of strawberry.

Different nutrient combinations had no significant effect on colour of strawberry.

The total sensory score was highest for fruits produced by plants fertilized with nutrient combination of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50 (T_9).

Maximum photosynthetic rate was exhibited by plants fertilized with FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 10:50:20:50 (T_1).

The stomatal conductance was observed maximum in plants fertilized with nutrient combinations as FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 10:100:80:100 (T_3) and FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 20:50:40:100 (T_4) and FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100 (T_8).

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:50:80:75 recorded maximum transpiration rate.

Among the nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50 (T_9) recorded maximum leaf area index.

Crop growth rate recorded was maximum in plants fertilized with nutrient combinations of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 20:50:40:100 (T_4).

Relative growth rate was recorded maximum in plants fertilized with FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 20:50:40:100 (T_4).

Net assimilation rate was recorded maximum in plants fertilized with FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 10:75:40:75 (T_2).

The content of chlorophyll a, chlorophyll b and total chlorophyll was recorded maximum in leaves of plants applied with nutrient combination of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100 (T_8).

In case of N, K, Ca, Mg and Fe uptake, nutrient combination of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 20:50:40:100 showed their superiority compared to all other nutrient combinations which was comparable with the nutrient combination of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100. Maximum P uptake was recorded in the nutrient combination FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100 also.

In case of nitrogen content in strawberry fruits, fertilizer combination FYM (10 t ha^{-1}), N, P_2O_5, K_2O @ 75:40:75 kg ha^{-1} recorded superiority in nitrogen (%). Nutrient combination FYM (t ha^{-1}), N, P_2O_5, K_2O @ 30:100:40:50 kg ha^{-1} recorded comparable values in case of macroelements such as P, K, Ca and Mg.

After soil analysis, it was observed that among the different nutrient combinations, FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100 recorded the optimum pH, electrical conductivity, higher organic carbon (%), available N, Ca and Mg compared to all other nutrient combinations.

Maximum benefit cost ratio was observed in treatment combinations FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:75:20:100.

Only pests like termites and diseases like Fusarium crown rot were come under high/severe attack.

It is concluded that in Central midlands, the nutrient combinations of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:75:20:100 recorded maximum vegetative growth, flowering attributes and yield per plant. Application of nutrient combination of FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1} @ 30:100:40:50 recorded better quality fruits.

6.3 Effect of spacing on growth and yield

The study was undertaken at College of Agriculture, Vellanikkara (Central midlands) and Regional Agricultural Research Station, Ambalavayal (High Ranges) from September 2016 - March 2017 and September 2017 - March 2018. Strawberry variety “Winter Dawn” was used for the study. One month old strawberry plants were planted in open field depends on the spacing. The experiment was laid in RBD with 6 treatments and 4 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, among the spacings, 20 cm x 20 cm (T_6) recorded maximum plant height. In High ranges, different spacings had no significant effect on plant height.

In Central midlands, among the spacings, 20 cm x 20 cm (T_6) recorded maximum number of leaves per plant. In High ranges also, spacing 20 cm x 20 cm recorded maximum number of leaves per plant.

In Central mid-lands, among the spacings, 20 cm x 20 cm recorded maximum plant spread. In High ranges, different spacings had a significant influence on plant spread during 1 MAP and 5 MAP. Maximum plant spread was recorded by 30 x 40 cm and 20 x 20 cm spacings.

In Central mid-lands, spacing of 20 cm x 20 cm recorded maximum number of crowns per plant. However in High ranges, 30 cm x 40 cm (T_3) recorded the maximum number of crowns during the later stages of growth.

Different spacings had no significant influence on days to first flowering in both locations.

In Central midlands, spacing of 20 cm x 20 cm recorded maximum number of clusters per plant. However in High ranges also, spacing of 20 cm x 20 cm produced the maximum number of clusters per plant.

In Central midlands, spacing of 20 cm x 20 cm recorded maximum number of flowers per plant. In High ranges also, spacing of 20 cm x 20 cm produced the maximum number of flowers per plant.

Strawberry plants accommodated with 20 cm x 20 cm had higher number of floweres plant^{-1} in both locations.

Spacing of 20 cm x 20 cm recorded maximum number of fruits per plant in Central mid-lands and High ranges.

In Central midlands, fruits harvested from plots under a spacing of 30 cm x 60 cm recorded maximum fruit length. However in High ranges, plots with spacing of 30 cm x 60 cm produced fruits with maximum fruit length.

In Central midlands, maximum fruit breadth was observed in fruits harvested from plants grown under the spacing of 30 cm x 50 cm. In High ranges, different spacing had no significant influence on fruit breadth.

In Central midlands, fruits from plants grown under the spacing of 30 cm x 60 cm recorded maximum average fruit weight per plant. In High ranges, maximum average fruit weight per plant was recorded in fruits from spacing of 30 cm x 60 cm.

Different spacings had no significant influence on days to first harvest in both locations.

Different spacings had no significant influence on days to final harvest in both locations.

Spacing of 20 cm x 20 cm recorded maximum yield per plant in both Central mid-lands and High ranges.

In Central midlands, fruits obtained from plants under spacing of 30 cm x 50 cm (T_2) recorded the highest TSS content. In High ranges, spacings had no significant influence on TSS content of fruits.

In Central mid-lands, the lowest titrable acidity was recorded by fruits harvested from plants under a spacing of 30 cm x 60 cm. However, in High ranges, spacings had no significant influence on acidity content of fruits.

In Central midlands, maximum TSS/Acidity was recorded in fruits harvested from plants grown at a spacing of 30 cm x 50 cm (T_2). However, in High ranges, spacings had no significant influence on TSS/acidity content of fruits.

In Central midlands, the maximum total sugars content was observed in fruits obtained from plants under spacing of 30 cm x 50 cm (T_2). However in High ranges, the total sugars content was significantly higher in fruits obtained from plants under spacing of 30 cm x 60 cm.

In Central midlands, maximum ascorbic acid content was recorded in fruits obtained from plants grown under spacing of 30 cm x 60 cm (T_1). In High ranges, maximum ascorbic acid content was recorded in fruits obtained from plants grown under spacing of 30 cm x 50 cm (T_2).

In Central midlands, the maximum anthocyanin content was observed in fruits obtained from plants under spacing of 30 cm x 60 cm (T_1). In High ranges, the anthocyanin content was significantly higher in fruits obtained from plants under spacing of 30 cm x 30 cm (T_4).

In Central midlands, fruits obtained from plants under spacing of 30 cm x 30 cm (T_4) recorded the maximum β-Carotene content. In High ranges, fruits obtained from plants under spacing of 30 cm x 50 cm (T_2) recorded the maximum β-Carotene content.

Different spacings had no significant influence on shelf life of strawberry fruits in both locations.

Different spacings had no significant influence on colour of strawberry fruits in both locations.

In Central mid-lands, the highest overall sensory score was recorded in fruits obtained from plants grown under a spacing of 30 cm x 50 cm (T_2). In High ranges, the total overall sensory score was higher for fruits harvested from plants grown at a spacing of 30 cm x 60 cm (T_1).

Spacing of 20 cm x 20 cm recorded maximum benefit cost ratio in both locations.

The pests like termites and disease due to fusarium crown rot were severe in Central mid-lands. Others are minor pests. In High ranges, there were no severe pest or disease attacks during the period of study.

It is concluded that a closer spacing of 20 cm x 20 cm recorded maximum vegetative growth and yield in both Central mid-lands and High ranges. However a wider spacing of 30 cm x 50 cm yielded better quality fruits in Central mid-lands and a spacing of 30 cm x 60 cm yielded better quality fruits in High ranges.

6.4 Evaluating different growing systems for home-gardening

The study was undertaken at College of Agriculture, Vellanikkara (Central mid-lands) from September 2017- March 2018. Outperforming Strawberry variety "Winter Dawn" from experiment I was used for the study. There were 6 growing systems and 4 growing media taken for the study. Design of the experiment was CRD with 3 replications. One month old strawberry plants were planted in open field. Observations on vegetative growth parameters, flower traits, yield, quality attributes, postharvest study, pest and disease were recorded and analyzed. The salient features of the study could be summarized as follows.

Among the growing systems, raised beds and grow bags were recorded maximum plant height during the early stages of the growth. In the later stages of the growth, hanging pipes recorded maximum plant height. Among different growing media, Soil: Cocopeat: Vermicompost (1:1:1) had significant effect on plant height during all stages of plant growth. Among the S x M interactions, hanging pipes with Soil: Cocopeat: Vermicompost (1:1:1) medium recorded maximum plant height.

Among the growing systems, plants grown in grow bags recorded maximum number of leaves during the early stages of the growth. During the later stages of growth, growing systems had no significant effect on number of leaves per plant. Among the different growing media, Soil: Cocopeat: Vermicompost (1:1:1) produced maximum number of leaves per plant during all stages of plant growth. Among the S x M interactions, there was no significant effect on number of leaves per plant in the later stages of growth.

Among the growing systems, raised beds recorded significantly maximum plant spread. Among different growing media, Soil: Cocopeat: Vermicompost (1:1:1) produced maximum plant spread during all stages of plant growth. Among S x M interactions, raised beds with Soil: Cocopeat: Vermicompost (1:1:1) recorded maximum plant spread.

Among the growing systems, vertical garden recorded maximum number of crowns per plant. Among different growing media, Soil : Cocopeat : Vermicompost (1:1:1) produced maximum number of crowns during all stages of plant growth. Among the interactions, maximum number of crowns was recorded in vertical garden with Soil: Cocopeat: FYM (1:1:1), which was comparable with raised beds and grow bags with Soil: Cocopeat: Vermicompost (1:1:1) as growing medium.

Different growing systems had no significant influence on number of days to first flowering. Among different growing media, Soil : Cocopeat : Vermicompost (1:1:1) and Soil : Cocopeat : FYM (1:1:1) recorded minimum number of days to first flowering. Among interactions, earliness in flowering was recorded with hanging pots and Soil: Cocopeat: FYM (1:1:1) as growing media, which was comparable with both grow bags and raised beds containing Soil: Cocopeat: Vermicompost (1:1:1) as growing medium.

Among the growing systems, raised beds recorded maximum number of clusters per plant. Among different growing media, Soil : Cocopeat : Vermicompost (1:1:1) recorded maximum number of clusters per plant. S x M interactions were found to be non significant.

Among the growing systems, raised beds recorded maximum number of flowers per plant. Among different growing media, Soil : Cocopeat : Vermicompost (1:1:1) recorded maximum number of flowers per plant. Among the interactions, raised beds (S_6) and grow bags (S_5) with Soil: Cocopeat: Vermicompost (1:1:1) as well as Soil: Cocopeat: FYM (1:1:1) recorded maximum number of flowers per plant.

Among the growing systems, raised beds recorded maximum number of fruits per plant. Among different growing media, Soil : Cocopeat : Vermicompost (1:1:1) recorded maximum number of fruits per plant. Among the interactions, raised beds (S_6)

and grow bags (S_5) with Soil : Cocopeat : Vermicompost (1:1:1) as well as Soil: Cocopeat: FYM (1:1:1) recorded maximum number of fruits per plant.

Among the growing systems, raised beds recorded maximum fruit length. Among different growing media, Soil : Cocopeat : Vermicompost (1:1:1) recorded maximum fruit length. S x M interactions were found to be non significant.

Among the growing systems, raised beds recorded maximum fruit breadth. Among different growing media, Soil: Cocopeat: FYM (1:1:1) recorded maximum fruit breadth. Among the interactions, hanging bottles X Soil : Cocopeat : FYM (1:1:1) (S_3XM_1) recorded maximum fruit breadth.

Among the growing systems, raised beds recorded maximum average fruit weight per plant. Among different growing media, Soil : Cocopeat : Vermicompost (1:1:1) recorded maximum average fruit weight per plant. S x M interactions were found to be non significant.

Different growing systems had no significant influence on number of days to first harvest. Among different growing media, Soil : Cocopeat : Vermicompost (1:1:1) and Soil : Cocopeat : FYM (1:1:1) recorded minimum number of days to first harvest. Among interactions, hanging pots with Soil : Cocopeat : FYM (1:1:1) recorded minimum number of days to first harvest.

Among the growing systems, hanging pots recorded maximum number of days to final harvest. Growing media had no significant influence on number of days to final harvest. Among interactions, hanging pots with Cocopeat : Perlite : Vermicompost (1:1:1) recorded maximum number of days to final harvest.

Among the growing systems, raised beds recorded maximum yield per plant. Among different growing media, Soil : Cocopeat : Vermicompost (1:1:1) recorded maximum yield per plant. Among the interactions, raised beds (S_6) and grow bags (S_5)

with Soil : Cocopeat : Vermicompost (1:1:1) as well as Soil : Cocopeat : FYM (1:1:1) recorded maximum yield per plant.

Among the growing systems, raised beds recorded maximum TSS content of fruits. Among different growing media, Cocopeat : Perlite : Vermicompost (1:1:1) recorded maximum TSS content of fruits. Among the interactions, hanging pipes with Cocopeat : Perlite : Vermicompost (1:1:1) recorded maximum TSS content.

Among the growing systems, hanging pots recorded minimum acidity of fruits. Among different growing media, Cocopeat : Perlite : Vermicompost (1:1:1) recorded maximum acidity content of fruits. S x M interactions were found to be non significant.

Among the growing systems, raised beds recorded maximum TSS/acidity ratio of fruits. Among different growing media, Cocopeat : Perlite : Vermicompost (1:1:1) recorded maximum TSS/acidity ratio. S x M interactions were found to be non significant.

Among the growing systems, hanging pots recorded maximum total sugars content of strawberry fruits. Among different growing media, Cocopeat : Perlite : Vermicompost (1:1:1) recorded maximum total sugars content. Among S x M interactions, total sugars content were found to be maximum in raised beds with Cocopeat: Perlite: FYM (1:1:1) as growing medium.

Among the growing systems, hanging bottles recorded maximum ascorbic acid content of strawberry fruits. Among different growing media, Cocopeat : Perlite : FYM (1:1:1) recorded maximum ascorbic acid content of fruits. Among interactions, hanging bottles with Cocopeat : Perlite : FYM (1:1:1) recorded maximum ascorbic acid content of fruits.

Among the growing systems, raised beds recorded maximum anthocyanin content of strawberry fruits. Among different growing media, Soil : Cocopeat : FYM (1:1:1) recorded maximum anthocyanin content of fruits. Among interactions, raised beds with Soil : Cocopeat : FYM (1:1:1) recorded maximum anthocyanin content of fruits.

Among the growing systems, hanging bottles recorded maximum β-Carotene content of strawberry fruits. Among different growing media, Soil : Cocopeat : FYM (1:1:1) recorded maximum β- Carotene content of fruits. Among interactions, grow bags with Soil : Cocopeat : FYM (1:1:1) recorded maximum β- Carotene content of fruits.

Different growing systems and growing media had no significant influence on shelf life of strawberry.

Different growing systems and growing media had no significant influence on colour of strawberry.

The total sensory score was found to be maximum in fruits obtained from raised beds with Soil : Cocopeat : FYM @ 1:1:1 as growing media.

The maximum benefit cost ratio was observed in raised beds with Soil : Cocopeat : Vermicompost @ 1:1:1 as growing media.

In Central mid-lands, among the growing systems, raised beds recorded maximum plant spread, number of crowns, earliness in flowering, number of flowers, number of fruits and yield per plant which was comparable with grow bags. In Central mid-lands raised beds as well as grow bags can be used as best growing systems for growing strawberry.

In Central mid-lands, among different growing media, Soil : Cocopeat : Vermicompost @ 1: 1:1 recorded maximum vegetative attributes, flowering attributes and yield attributes. Soil : Cocopeat : FYM @ 1: 1:1 and Cocopeat : Perlite : Vermicompost @ 1: 1:1 recorded maximum quality attributes of strawberry.

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Appendix-I

Score card for organoleptic evaluation

Name of the judge: Date:

Characteristics	Scores						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Appearance							
Colour							
Flavour							
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

Appendix-II

Biotic stress susceptibility

Scale of susceptability	Pest/Disease incidence
1	Very low or no visible sign of susceptability
3	Low
5	Intermediate
7	High
9	Very high

Appendix III

Weather data at Central midlands

Parameters	**2016-2017**						
	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Max Temp (^{0} C)	30.3	31.5	32.9	32.4	34.1	36.0	36.1
Min Temp (^{0} C)	23.6	22.7	22.2	22.3	22.9	23.2	24.7
Max RH (%)	95	93	83	85	68	70	**85**
Min RH (%)	69	68	54	52	37	31	48
Wind speed (km h^{-1})	1.8	1.0	1.9	2.9	5.3	6.6	2.2
Rainfall (mm)	86.0	37.3	13.8	52.9	0	0	13.2
Sunshine hours (h)	4.8	5.5	5.8	6.5	7.6	8.7	7.4
Evapotranspiration (mm)	87.8	86.9	90.9	103.1	145.4	158.3	140.0
Light intensity (lux)	79870.5	80510.9	87920.7	90800.4	87800.1	74880.2	79080.8

Parameters	2017-2018						
	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Max Temp (^{0} C)	31.5	31.7	33.0	32.4	33.5	35.7	36.7
Min Temp (^{0} C)	22.9	22.3	21.8	21.1	20.9	22.5	24.0
Max RH (%)	94	93	87	63	68	63	79
Min RH (%)	74	70	58	49	37	30	39
Wind speed (km h^{-1})	0.7	0.2	1.9	5.1	5.4	5.7	3.3
Rainfall (mm)	413.9	183.4	58.3	11.5	0	5.2	33.2
Sunshine hours (h)	4.2	4.9	6.4	7.3	8.2	9.5	8.0
Evapotranspiration (mm)	82.8	72.8	89.5	119.4	135.5	157.9	155.2
Light intensity (lux)	79778	80420	88900	92864.4	88560.2	74620.3	78083.9

Appendix IV

Weather data at High ranges

Parameters	**2016-2017**						
	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Max Temp (^{0} C)	26.1	27.6	28.8	27.8	28.5	30.6	30.3
Min Temp (^{0} C)	21.7	20.8	18.9	16.6	17.0	19.2	20
Max RH (%)	94.0	94	94.0	93.0	87.0	89.0	91
Min RH (%)	79.0	79	71.0	71.0	51.0	36.0	54
Wind speed (km h^{-1})	2.4	2.1	2.2	2.4	3.5	3.7	2.5
Rainfall (mm)	151.7	71.2	20.6	0.5	0	33.1	0
Sunshine hours (h)	3.8	6.2	6.2	5.7	7.3	9.0	7.0
Evapotranspiration (mm)	69.8	95.2	89.5	95.7	115.2	141	140.8
Light intensity (lux)	93720.3	94100.2	94403.1	106493	102015	87717.6	85300.3

Parameters	2017-2018						
	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Max Temp (^{0} C)	26.3	26.2	27.2	26.6	27.6	29.9	30.8
Min Temp (^{0} C)	21.5	19.9	18.6	15.7	16.8	18.5	20.8
Max RH (%)	97.0	95.0	93	92	91.0	88	91
Min RH (%)	81.0	77	68	55	48	39	48
Wind speed (km h^{-1})	2.0	1.8	3.4	4.5	2.0	2.5	2.1
Rainfall (mm)	61.1	142.4	6	7.7	0.9	0	6.3
Sunshine hours (h)	3.3	3.1	5.3	5.6	7.3	8.5	7.3
Evapotranspiration (mm)	66.1	75.4	91.5	110.3	112.2	129.7	140.5
Light intensity (lux)	93820.5	94150.1	94020.2	107500	103000	88800.4	85420.5

Appendix V

Benefit Cost ratio of Experiments (I- IV)

Benefit Cost ratio of Experiment I in Location I (Central mid-lands)- 100m^2 for six months

Varieties	Rent on land	Labour charge	Planting material	Mulch	Fertilizer	FYM	Bio-fungicides	Chemicals	Irrigation charges	Total cost (C)	Benefit (B)	B/C ratio
V_1	50	5M+5W 5x525+5x 425=4750	410x12= 4920	2300	1897.48	1000	800	1020	250	16987.48	3991.35	0.23
V_2	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	1215.65	0.07
V_3	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	7439.45	0.44
V_4	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	530.95	0.03
V_5	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	1215.65	0.07
V_6	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	9128.65	0.54
V_7	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	338.25	0.02
V_8	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	1379.65	0.08

Benefit Cost ratio of Experiment I in Location II (High ranges)- 100m^2 for six months

Treatments	Rent on land	Labour charge	Planting material	Mulch	Fertilizer	FYM	Bio-fungicides	Chemicals	Irrigation charges	Total cost (C)	Benefit (B)	B/C ratio
V_1	50	5M+5W 5x525+5x 425=4750	410x12= 4920	2300	1897.48	1000	800	1020	250	16987.48	27744.7	1.63
V_2	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	18011.3	1.06
V_3	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	30883.25	1.82
V_4	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	12525.5	0.74
V_5	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	20315.5	1.20
V_6	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	38517.45	2.27
V_7	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	2956.1	0.17
V_8	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	9881	0.58

Benefit Cost ratio of Experiment II in Location I (Central mid-lands)- 100m^2 for six months

Treatments	Rent on land	Labour charge	Planting material	Mulch	Fertilizer	FYM	Bio-fungicides	Chemicals	Irrigation charges	Total cost (C)	Benefit (B)	B/C ratio
T_1	50	5M+5W 5x525+5x425 =4750	410x12= 4920	2300	522.6	1000	800	1020	250	15612.6	9149.15	0.59
T_2	50	4750	4920	2300	1002.45	1000	800	1020	250	16092.45	11822.35	0.73
T_3	50	4750	4920	2300	1947.91	1000	800	1020	250	17037.91	8966.7	0.53
T_4	50	4750	4920	2300	1019.55	2000	800	1020	250	17109.55	12320.5	0.72
T_5	50	4750	4920	2300	1897.48	2000	800	1020	250	17987.48	8837.55	0.49
T_6	50	4750	4920	2300	554.73	2000	800	1020	250	16644.73	11387.75	0.68
T_7	50	4750	4920	2300	1915.81	3000	800	1020	250	19005.81	12777.65	0.67
T_8	50	4750	4920	2300	586.02	3000	800	1020	250	17,926.02	16383.6	0.91
T_9	50	4750	4920	2300	1902.4	3000	800	1020	250	18,992.4	15559.5	0.82
T_{10}	50	4750	4920	2300	0	0	800	1020	250	14090	2214	0.16

Benefit Cost ratio of Experiment III in Location I (Central mid-lands)- 100m^2 for six months

Varieties	Rent on land	Labour charge	Planting material	Mulch	Fertilizers	FYM	Bio-fungicides	Chemicals	Irrigation charges	Total cost (C)	Benefit (B)	B/C ratio
T_1	50	5M+5W 5x525+5x425 =4750	410x12 =4920	2300	1897.48	1000	800	1020	250	16987.48	12587	0.74
T_2	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	10635.4	0.63
T_3	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	10395.55	0.61
T_4	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	14069.15	0.83
T_5	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	15266.35	0.90
T_6	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	20506.15	1.21

Benefit Cost ratio of Experiment III in Location II (High ranges)- 100m^2 for six months

Treatments	Rent on land	Labour charge	Planting material	Mulch	Fertilizers	FYM	Bio-fungicides	Chemicals	Irrigation charges	Total cost (C)	Benefit (B)	B/C ratio
T_1	50	5M+5W 5x525+5x425 =4750	410x12= 4920	2300	1897.48	1000	800	1020	250	16987.48	47451.35	2.79
T_2	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	43980.7	2.59
T_3	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	45893.35	2.70
T_4	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	38160.75	2.25
T_5	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	48759.25	2.87
T_6	50	4750	4920	2300	1897.48	1000	800	1020	250	16987.48	55696.45	3.28

Benefit Cost ratio of Experiment IV in Location I (Central mid-lands) - 100m^2 for six months

Treatments	Rent on land	Labour charge	Planting material	Others	Fertilizers	Media	Bio-fungicides	Chemicals	Irrigation charges	Total cost (C)	Benefit (B)	B/C ratio
S_1M_1	10	75	45x12=540	45*8= 360	183.07	105.8	20	20	100	1413.7	533.7	0.38
S_1M_2	10	75	540	360	183.07	171.0	20	20	100	1479.07	745.88	0.50
S_1M_3	10	75	540	360	183.07	173.22	20	20	100	1580.32	335.25	0.21
S_1M_4	10	75	540	360	183.07	238.42	20	20	100	1799.39	207.23	0.12
S_2M_1	10	75	540	900	183.07	49.95	20	20	100	1673.02	483.30	0.29
S_2M_2	10	75	540	900	183.07	75.78	20	20	100	1698.85	598.05	0.35
S_2M_3	10	75	540	900	183.07	68.48	20	20	100	1691.55	179.33	0.11
S_2M_4	10	75	540	900	183.07	93.96	20	20	100	1717.03	318.38	0.19
S_3M_1	10	50	540	180	183.07	52.9	20	20	100	1155.97	248.63	0.22
S_3M_2	10	50	540	180	183.07	85.8	20	20	100	1188.87	281.48	0.24
S_3M_3	10	50	540	180	183.07	86.61	20	20	100	1189.68	283.73	0.24
S_3M_4	10	50	540	180	183.07	119.21	20	20	100	1222.28	76.50	0.06
S_4M_1	10	75	540	3000	183.07	132.25	20	20	100	4080.32	753.98	0.18
S_4M_2	10	75	540	3000	183.07	213.9	20	20	100	4161.97	878.18	0.21
S_4M_3	10	75	540	3000	183.07	216.53	20	20	100	4164.6	344.25	0.08
S_4M_4	10	75	540	3000	183.07	298.0	20	20	100	4246.07	436.50	0.10
S_5M_1	10	75	540	540	183.07	343.35	20	20	100	1831.42	1092.60	0.60
S_5M_2	10	75	540	540	183.07	530.1	20	20	100	2018.17	1207.35	0.60
S_5M_3	10	75	540	540	183.07	682.65	20	20	100	2170.72	440.55	0.20
S_5M_4	10	75	540	540	183.07	869.4	20	20	100	2357.47	742.50	0.31
S_6M_1	10	75	540	0	183.07	400	20	20	100	1348.07	1539.68	1.14
S_6M_2	10	75	540	0	183.07	480	20	20	100	1428.07	1940.85	1.36
S_6M_3	10	75	540	0	183.07	545	20	20	100	1493.07	857.70	0.57
S_6M_4	10	75	540	0	183.07	625	20	20	100	1573.07	895.50	0.57

Appendix VI

Soil temperature (^{0} C) in Experiment III (Location I)

Treatments	December	January	February	March
30 cm x 60 cm	25.5	26.7	28.6	32.5
30 cm x 50 cm	24.7	26.6	27.3	28.5
30 cm x 40 cm	25.5	25.5	27.5	32.0
30 cm x 30 cm	24.4	25.0	26.6	30.5
30 cm x 20 cm	23.4	24.0	26.5	31.5
20 cm x 20 cm	23	23.5	24.2	31.0

PRODUCTION DYNAMICS OF STRAWBERRY (*Fragaria x ananassa* Duch.) IN KERALA

by

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ABSTRACT OF THE THESIS

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ABSTRACT

Strawberry is a unique soft fruit crop known for its tantalizing aroma, bright red colour, juicy texture, sweetness and high nutritive value. This is a highly remunerative crop and give quickest returns with in a short period of six months. Temperature and photoperiod are the most important environmental factors that affect the transition from vegetative to flowering phase of strawberry. Previous studies conducted in the department have proved that strawberry can be grown in the plains as well as in hills of Kerala during September to March even in the open condition. The suitable genotypes and good management practices are of paramount importance for successful cultivation of strawberry. With this brief background, the present investigation titled "Production dynamics of strawberry (*Fragaria x ananassa* Duch.) in Kerala" was undertaken to identify suitable cultivars, better nutrient management, better spacing, suitable growing systems and media for the homestead cultivation of Kerala. Total of four experiments were designed for the study.

The study was conducted using eight strawberry varieties under two different agroclimatic zones of Kerala. In Central mid-lands, *cv*. Winter Dawn recorded signficantly higher number of leaves and number of crowns per plant, whereas in High ranges, *cv*. Winter Dawn was found significantly superior for maximum plant height, number of leaves and number of crowns per plant. The attributes *viz.*, number of clusters, flowers and fruits per plant were recorded in *cv*. Winter Dawn which was followed by *cv*. Sabrina-1 in both locations. Maximum harvesting period was recorded in *cv*. Winter Dawn in Central mid-lands while it was maximum in *cv*. Sabrina-1 in High ranges. Quality attributes such as TSS/acidity ratio was recorded maximum in *cv*. Sweet Charlie under both locations. Winter Dawn recorded maximum ascorbic acid content in both locations while *cv*. Crystal recorded maximum anthocyanin content. Maximum β-Carotene content was recorded in *cv*. Sabrina-1 in Central mid-lands while it was maximum in *cv*. Hadar in High ranges. Evaluating all the parameters during crop period, both

Sabrina-1 and Winter Dawn showed stability in their sensory qualities in Central mid-lands. In High ranges, it was recorded in *cv*. Sweet Charlie.

Nine different nutrient combinations were studied using *cv*. Winter Dawn in Central mid-lands of Kerala. Among the different nutrient combinations, FYM (30 t ha^{-1}), N, P_2O_5, K_2O @ 75:20:100 kg ha^{-1} (T_8) recorded maximum vegetative attributes, number of flowers, fruits and yield per plant (79.92 g) and quality parameters such as TSS and TSS/acidity ratio. Maximum content of total sugars, ascorbic acid and highest sensory score were recorded in the nutrient combination FYM (30 t ha^{-1}), N, P_2O_5, K_2O @ 100:40:50 kg ha^{-1} (T_9). Physiological attributes such as leaf area index was found to maximum in the nutrient combination FYM (t ha^{-1}), N, P_2O_5, K_2O kg ha^{-1}@ 30:100:40:50 (T_9)**,** while the relative growth rate was recorded maximum in FYM (30 t ha^{-1}), N, P_2O_5, K_2O @ 75:20:100 kg ha^{-1} (T_8) and 20 t $ha^{-\mathbf{1}}$, 50:40:100 kg ha^{-1} (T_4). Among the nutrients, uptake was maximum in nitrogen and it ranges from 10.66 to 58.65 kg ha^{-1}. The nutrient potassium which favours fruit formation was found maximum in the nutrient combination FYM (30 t ha^{-1}), N, P_2O_5, K_2O @ 75:20:100 kg ha^{-1} (T_8) which ultimately resulted in maximum yield per plant. Different nutrient combinations had significant difference on nutrient content of strawberry fruits except copper content. The highest B/C ratio (0.91) was recorded for the nutrient combination, FYM (30 t ha^{-1}), N, P_2O_5, K_2O @ 75:20:100 kg ha^{-1} (T_8).

Six different spacing trials were studied using strawberry *cv*. Winter Dawn in both Central mid-lands and High ranges. Vegetative attributes *viz.*, plant height, number of leaves and number of crowns were maximum in closer spacing of 20 cm x 20 cm in both Central mid-lands and High ranges which have led to the maximum production of flowers, clusters, fruits and yield per plant (100.03 g; 271.69 g) in both locations. Quality attributes *viz.*, TSS, TSS/acidity ratio and total sugars were found maximum in wider spacing of 30 cm x 50 cm (T_2) in Central mid-lands. In High ranges, maximum total sugars was recorded at a spacing of 30 cm x 60 cm (5.37 %) while maximum ascorbic acid and β-Carotene content were recorded at a spacing of 30 cm x 50 cm (T_2). The total sensory score was found maximum in 30 cm x 50 cm (T_2) in Central mid-lands while it was maximum in 30 cm x 60 cm (T_1) in High ranges. Closer spacing of 20 cm x 20 cm did not have significant influence the quality attributes however it recorded highest B/C ratio in both Central mid-lands (1.21) and High ranges (3.28).

Six different growing systems *viz.*, hanging pots, hanging pipes, hanging bottles, vertical garden, grow bags and raised beds and four different growing media *viz.*, Soil: Cocopeat: FYM, Soil: Cocopeat: Vermicompost, Cocopeat: Perlite: FYM and Cocopeat: Perlite: Vermicompost in 1:1:1 ratio were studied using *cv*. Winter Dawn in Central mid-lands. Vegetative attributes *viz.*, plant height, number of leaves, plant spread and number of crowns were recorded maximum in growbags and raised beds with growing medium, Soil: Cocopeat: Vermicompost (1:1:1) which led to the maximum production of number of flowers, clusters, fruits and yield per plant (86.26 g). Quality attributes *viz.*, TSS, TSS/acidity ratio and total sugars were recorded maximum in raised beds with growing medium Cocopeat: Perlite: Vermicompost (1:1:1). The overall sensory score was found maximum in fruits grown in raised beds with medium Soil: Cocopeat: FYM (1:1:1). The highest B/C ratio (1.36) was recorded with raised beds with Soil: Cocopeat: Vermicompost (1:1:1) as growing medium.

On evaluation, it is found that *cv*. Winter Dawn showed significantly superior performance in vegetative, flowering, fruit and yield attributes with resistance to serious pests and diseases. Hence, it can be recommended as a best variety for strawberry cultivation in Kerala. Among the different nutrient combinations, FYM (30 t ha^{-1}), N, P_2O_5, K_2O @ 75:20:100 kg ha^{-1} (T_8) was found suitable for better nutrient recommendation for strawberry. Though closer spacing of 20 cm x 20 cm recorded maximum yield but wider spacing would enhance the quality of fruits. Grow bag is found the best suitable growing system with growing medium Soil: Cocopeat: Vermicompost at 1:1:1 ratio, for home gardening of strawberry.