NUTRIENT MANAGEMENT IN STRAWBERRY (*Fragaria x ananassa* Duch.)

by

Arjun Mohan P.
(2015-12-005)

THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Horticulture
(FRUIT SCIENCE)

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF FRUIT SCIENCE
COLLEGE OF HORTICULTURE
VELLANIKKARA
THRISSUR – 680656
KERALA, INDIA
2017

DECLARATION

I, hereby declare that this thesis entitled **"Nutrient management in strawberry (*Fragaria x ananassa* Duch.)"** 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: 23-12-2017

ARJUN MOHAN P.

(2015-12-005)

CERTIFICATE

Certified that this thesis entitled **"Nutrient management for strawberry (*Fragaria x ananassa* Duch.)"** is a record of research work done independently by **Mr. Arjun Mohan P. (2015-12-005)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

Vellanikkara

Date: 23/12/2017

Dr. K. Ajith Kumar
(Chairperson, Advisory committee)
Professor (Horticulture)
Department of Fruit Science
College of Horticulture
Kerala Agricultural University
Vellanikkara, Thrissur

CERTIFICATE

We, the undersigned members of advisory committee of **Mr. Arjun Mohan P. (2015-12-005)** a candidate for the degree of **Master of Science in Horticulture** with major in **Fruit Science**, agree that the thesis entitled **"Nutrient management for strawberry (*Fragaria x ananassa* Duch.)"** may be submitted by **Mr. Arjun Mohan P (2015-12-005)**, in partial fulfilment of the requirement for the degree.

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

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

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

23/12/17
Dr. P. Sureshkumar
(Member, Advisory Committee)
Professor and Head
RTL
Vellanikkara

23/12/17
EXTERNAL EXAMINER
Dr. J. RAJANGAM

ACKNOWLEDGEMENT

First and foremost, I bow my head before the ***Almighty God*** *for all the blessing showered upon me to complete the thesis work successfully.*

With immense pleasure I avail this opportunity to express my deep sense of gratitude and indebtedness to my major advisor ***Dr. K. Ajith Kumar****, Professor, Department of Fruit Science and chairperson of my advisory committee for his inspiring guidance, practical suggestions, extreme patience, painstaking scrutiny of the manuscript, friendly approach, kind advice and timely help at various stages of my work and thesis preparation. He has been a support to me during each step of this venture. I really consider myself being greatest fortunate in having his guidance for my research work and will be remembered forever.*

I would like to express my extreme indebtedness and obligation to ***Dr. A. Suma****, Professor and Head, Department of Fruit Science and member of my advisory committee for her meticulous help, unwavering encouragement, timely support and critical examination of the manuscript that has helped a lot for the improvement and preparation of the thesis.*

Words are inadequate to express my sincere gratitude to ***Dr. P. Sureshkumar****, Professor and Head, RTL, Vellanikkara and member of my advisory committee for his valuable suggestions, criticisms, critical scrutiny and well timed support throughout the course of study.*

I express my heartiest gratitude to ***Dr. P. Rajendran,*** *Associate Director of Research, Regional Agricultural Research Station, Ambalavayal, Wayanad and member of my advisory committee for his overwhelming help, valuable guidance and creative suggestions throughout the period of my study.*

I wish to extend my heartfelt thanks to my beloved teachers ***Dr. Jyothi Bhaskar, Dr. P. K. Sudhadevi, Dr. C.K Geetha, Dr. N. Parameswaran, Dr.T. Radha, Dr. K. Lila Mathew, Dr. Mini Shankar, Dr Sreelatha U.*** *of Department of Fruit Science and Department of Floriculture and Landscaping and* ***Dr. S. Krishnan****, Professor and Head, Department of Agricultural Statistics for their encouragement, valuable help, and friendly suggestions rendered during the course of study.*

I am thankful to Uthaman sir, Santhosh chettan, Preman chettan, Varghese chettan, Pushpa chechi, Abitha chechi, Rajani chechi and all other non- teaching staff of the Department of Fruit Science and Department of Floricultue and Landscaping for their *sincere help and valuable cooperation during investigation period.*

With pleasure I express my heartfelt gratitude to my classmates (Umesh, Shilpa and Deepa), seniors (Anu Kurian, Aslam Muhammad, Sameer Muhammad, Sanjay Chavaradar, Andrew.L. Myrthong and Jyolsana Mohan) and juniors whose constant support and encouragement could never be forgotten.

I would like to express my deep sense of gratitude to ***all the staff and non- teaching staff of Regional Agricultural Research Station, Ambalavayal*** *for their friendliness, caring, meticulous and rendlous support in completing my thesis works.*

I wish to express my sincere thanks to our librarian ***Dr. A. T. Francis*** *and other staffs of the college and university library for their patience, guidance, consideration and immense help rendered to me.*

I wish to extend my pleasure to mention about ***Aravind chettan, Computer Centre*** *for his friendliness and support throughout the study.*

I wish to express my thanks to Kerala Agricultural University for the financial attention offered during the study period.

My heartfelt gratitude to my dear friends Akhil Thomas, Mahesh Mohan, Vishnu K S, Vivek S, Nikhil Narayanan, Ashok Madala, Noushad A.K, Debashish Sahoo, Sunayana Suja, Suvarna Shyam, Dhanalakshmi V.N and Geethumol for their help and encouragement.

On my personal ground, I cannot forget the fondness, constant support and encouragement showered by my loving family. I convey my affection and heartfelt gratitude to them who supported me a lot in my long journey of research.

It would be impossible to list out all those who have helped me in one way or another, for the completion of my work. I once again express my heartfelt thanks to all those who helped me in completing my work.

Arjun Mohan P.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

14	Monthly mean light intensity (lux) during the cropping period	80-81
15	Monthly mean rainfall (mm) during the cropping period	80-81

LIST OF PLATES

LIST OF APPENDICES

Introduction

1. INTRODUCTION

Strawberry is an important table fruit of millions of people throughout the world. The common cultivated strawberry (*Fragaria x ananassa* Duch.) is a widely grown hybrid plant resulting from the breeding between two American species, *Fragaria chiloensis* of western North and South America and *Fragaria virginiana* of eastern North America. It can be grown in wide climatic conditions, ranging from temperate to tropical climate. Botanically, the strawberry is an aggregate accessory fruit derived from the receptacle. This fruit is widely appreciated for its characteristic aroma, bright red color, juicy texture and sweetness.

The United States is the world's largest producer of strawberries with a production of 13 lakh tonnes followed by Turkey, Spain, Egypt, Korea, Mexico, and Poland (FAO, 2014). In India, it is generally cultivated in Nainital and Dehradun in Uttarkhand, Mahabaleshwar in Maharashtra, Kashmir Valley, Bangalore and Kalimpong in West Bengal. In recent years, strawberry is being cultivated successfully in plains of Maharashtra around Pune, Nashik and Sangali towns.

According to Agriculture ministry estimates, the production of the fruit in India is 8 million tonnes in 2014. Satara district in Maharashtra is famous for the country's 80 per cent strawberry production. The fruit is grown mainly at Mahabaleshwar, Wai and Panchagani areas. The Panchgani-Mahabaleshwar belt contributes around 85 per cent of the total production in the country. The rest comes from Himachal Pradesh and Jammu and Kashmir. In Kerala, strawberry cultivation is confined mainly to Wayanad and Idukki districts as a part of the initiatives taken up by Kerala State Horticulture Mission (SHM-K). As many as 35 progressive farmers have started cultivating strawberries on a commercial basis on 50 ha of land with financial assistance from the SHM in Wayanad. Munnar is now emerging as a strawberry hub where the SHM-K has embarked on a project to provide critical support facilities for procurement, marketing and value-addition of the crop.

Strawberry is one of the most sensitive plants and its nutrient management is a key factor to ensure high yields and fruit quality. Furthermore, an adequate management of nutrient elements is crucial to guarantee food safety and food quality. The plant is a surface feeder and very sensitive to nutrients and soil moisture.

Nitrogen is referred to as the balance wheel of strawberry nutrition as an excess or deficiency of nitrogen is detrimental to the plant. Nitrogen has not only a pivotal role on plant growth and development, but also on fruit quality parameters such as fruit firmness, size, health and correction of fruit disorders, chemical components, and shipping qualities. Phosphorous is considered as the best fertilizer to increase fruit size, yield and to produce firm berries. Phosphorous has a more evident effect on fruit quality parameters and on the activation of defense mechanisms than on yield and productivity. The deficiency of potassium causes reduction in growth, yield and fruit size and has an important effect on fruit quality and stress responses. Sulfur affects strawberry fruit quality and may act as an important priming factor in response to environmental cues such as osmotic stress impaired by salinity and artificial dehydration and pathogen attack. Calcium plays a crucial role in fruit firmness and cell wall structure. Furthermore, Ca affects plant and fruit growth, and mediates responses to salinity. Magnesium also plays a substantial part in phosphorus transport in the plant; it assists in phosphate metabolism, plant respiration, protein synthesis, and activation of several enzyme systems.

The Kerala State Horticultural Mission has drawn up a pilot project to cultivate strawberry in 750 acres in Kerala. In order to achieve the best performance of strawberry plants, an adequate management of nutrient elements is crucial to guarantee not only plant growth and development, but also fruit production and responses to environmental cues. In Kerala, cultivation of strawberry started momentum and there is a need to develop efficient production techniques by devising a precise package of practices for this crop with special reference to nutrient management. Therefore, there is a need to develop optimum nutrient doses for ensuring higher productivity with optimal input use efficiency for strawberry in high ranges of Kerala.

Review of literature

2. REVIEW OF LITERATURE

In this chapter, relevant literature based on the objectives of the study are reviewed and presented in the order of varietal performance, vegetative growth, yield, fruit quality and flowering based on nutrition. The influence of climatological factors and pest and disease incidences are also reviewed.

2.1 Performance of strawberry genotypes/ varieties

Beniwal *et al.* (1989) compared different strawberry cultivars under Hisar conditions. They reported that plant height ranged from 9.60 cm in Fairfax to 13.00 cm in Elista, while Blackmore had the highest number of leaves (13.90). The maximum number of runners per plant was obtained in Elista (4.70) and minimum in Torrey (3.20).

Baumann *et al.* (1993) evaluated behavior of vegetative growth, flowering and yield components of day neutral and short day strawberry varieties, on raised beds in British Columbia. They concluded that cultivar Shuswap was a prolific producer of runners (8), with maximum leaf size (63.00 cm2) whereas, cultivars Sumas, Red Crest and Pajaro had less number of runners. Among the day neutral strawberry varieties, Irvine and Ozark Beauty had highest number of runner count (10) followed by Fern (8). The leaf size was maximum in Tristar (57.00 cm2) followed by Fern (55.00 cm2). The maximum number of flowers per plant was produced in *cv.* Ozark Beauty (54) followed by Fern (45) and Hecker (44). Among the short day strawberry cultivars, Pajaro exhibited the highest number of flowers per plant (9) in the first year whereas, in second year it was highest in the *cv.* Sumas (26) and in Pajaro (16).

Chandel and Badiyala (1996) screened different strawberry varieties in foot hills of Himachal Pradesh and reported that the cultivar Etna attained the maximum plant spread (19.8 cm) closely followed by Belrubi (19.2 cm) and chandler (17.5 cm).

Highest number of runners per plant was obtained by Belrubi (8.7), which was statistically at par with Torrey (8.4) but differed significantly from all other cultivars.

Mondal *et al.* (2001) studied the performance of strawberry cultivars under the conditions of West Bengal and found that among the cultivars, Pajaro recorded highest plant height of 22.00 cm, while Torrey exhibited the widest plant spread (46.00 cm). The *cv.* Dana recorded the highest leaf area (72.79 cm^2), while the maximum number of runners (12.75) and leaves per plant (49.30) was recorded in *cv.* Shasta. Whereas the *cv.* Fern took minimum number of days to flower under West Bengal conditions.

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

Ashrey and Singh (2004) studied the performance of some strawberry cultivars under semi-arid irrigated regions of Punjab and observed that the cultivar Gorella recorded maximum number of leaves per plant (6.33) and plant spread (14.16 cm) while *cv.* Seascape recorded minimum number of leaves per plant (3.33) and minimum plant spread was observed in *cv.* Dana (8.83 cm).

Das *et al.* (2007) conducted a study on varietal screening of strawberry grown on different mulching material under sub-humid, sub-tropical plateau conditions of Eastern India revealed that irrespective of mulches, the maximum average fruit weight was observed in cv. Douglas (6.58 g), which was statistically at par with Etna.

Bielinski *et al.* (2007) evaluated six different cultivars of strawberry in Florida. The experiment revealed that cultivar Winter Dawn had the best performance and recorded a yield of more than 80 t ha^{-1}.There were no differences in the total yields of Carmine, Albion, Festival, Camarosa and 00-51 which ranged between 60 and 70 t ha^{-1}.

Sharma and Thakur (2008) evaluated fifteen strawberry varieties for fruit yield characters in Himachal Pradesh. The results revealed that the *cv.* Chandler exhibited maximum fruit length (3.49 cm), fruit breadth (3.14 cm) and berry weight (9.62 g). The maximum yield of 1.18 kg / plot was registered in Chandler and Selva recorded 1.11 kg / plot.

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

Rao and Lal (2010) reported that among the 17 strawberry genotypes evaluated for their growth and yield characters under Garhwal agro-climatic conditions, Belrubi (16.8) and Gorella (15.10) have the maximum number of fruits per plant and *cv.* Chandler (190.70 g) had maximum yield per plant.

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

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

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

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

Sharma *et al.* (2014) reported that, cultivar Chandler exhibited maximum fruit length (3.49 cm), breadth (3.14 cm), berry weight (9.62 g) and yield (1.18 kg / plot) along with *cv.* Selva which was found to be promising in mid hills of Himachal Pradesh.

Rahman *et al.* (2014) reported that among the five promising strawberry genotypes *viz.*, Sweet Charlie, Festival, Camarosa, FA 008 and BARI strawberry-1, the genotype Sweet Charlie produced the maximum number of fruits (28.75) while FA 008 produced minimum fruits (19.25). Maximum number of leaves per plant was observed in genotype Festival (39.5) followed by Camarosa (37.58) and the lowest in FA 008 (30.67). Strawberry genotype Festival gave the highest yield per plant (421.79 g) which was on par with Sweet Charlie (415.20 g). Lowest yield was recorded in genotype FA008.

Kurian (2015) reported that strawberry cultivar Winter Dawn planted in the last week of September with black polyethene mulch in open field in highlands recorded maximum growth and yield characters when compared to plants grown in midlands of Kerala.

Kurian *et al.* (2015) evaluated strawberry cultivar Winter Dawn in open-field, greenhouse and fan and pad system in high ranges and mid lands of Kerala. The study indicated that in central mid lands, growing system had no significant influence on number of leaves, number of flowers, number of clusters and yield per plant whereas in high ranges, plants in open-field recorded maximum number of fruits and yield per plant.

2.2 Response of crops to different nutrients

2.2.1 Vegetative characters

Neuweiler (2001) reported that largely readily available N in the rooting zone controls the response of vegetative plant development to increasing N fertilization.

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

Rana and Chandel (2003) observed that maximum plant height (24.51 cm) was observed with *Azotobacter* inoculation combined with 100 N ha^{-1}. Maximum number of leaves (26.20) were observed with *Azotobacter* inoculation combined with 100 N ha^{-1}.

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

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

Santos and Chandler (2009) studied the strawberry varieties such as Festival and Winter Dawn to different nitrogen (N) rates and found linearly increased canopy diameters of both cultivars but there were no differences between the total marketable fruit weights of both cultivars.

Yadav *et al.* (2010) observed positive influence of inorganic fertilizers (80, 40, 40 kg ha^{-1} N, P_2O_5 and K_2O respectively) on plant height (16.65 cm) in strawberry.

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

Experiment was conducted to study the effect of different doses of nitrogen and potassium on the vegetative growth of strawberry *cv.* Confitura revealed that maximum plant height (27.25 cm) was recorded with nitrogen upto 150 kg ha^{-1} and potassium upto 150 kg ha^{-1} (Ahmad *et al.*, 2011).

Andriolo *et al.* (2011) tested five nutrient solutions at nitrogen concentrations (6.5, 8, 9.5, 11 and 12.5 mmol L^{-1}. Number of leaves, shoot and root dry mass and crown diameter decreased by effect of increasing N concentrations in the nutrient solution.

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

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

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

Different days of transplanting (30, 45, 60,75, 90 and 105 days) and application of integrated sources of nutrients *Azotobacter* (50%) + *Azospirillum* (50%) + NPK

(50%) + FYM significantly influenced vegetative growth of strawberry cv. Chandler (Lata *et al.*, 2013).

Pandit *et al.* (2013) observed that application of VAM @ 12 kg ha^{-1} showed a significant increase in plant height 22.17 cm (34.37 %) higher over the control in strawberry.

2.2.2 Yield

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

Kopanski and Kaweci (1994) reported that N application of 90 kg N ha^{-1} decreased fruit mean weight.

Singh *et al.* (2001) observed that urea at 30 g m^{-2} resulted in the highest number of fruits per plant, highest fruit weight and crop yield in strawberry *cv.* Chandler. Application of urea higher than 30 g m^{-2} reduced fruit number and yield.

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

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

Yadav *et al.* (2010) observed that the number of berries (22.27 $plant^{-1}$) and fruit yield (101.99 q ha^{-1}) were maximum in *Azotobacter* inoculated with 50 per cent N substitution by vermicompost and remaining 50 per cent through inorganic fertilizer in two equal splits applied at time of planting and before flowering stage.

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

Ebrahimi *et al.* (2012) reported that 300 ppm of K in nutrient solution increased vitamin C content, total soluble solids, fruit number, fruit weight, yield of plant, root weight, root dry weight and length of root

2.2.3 Fruit quality

Fruits from plots fertilized with N were a little firmer than fruits from plots receiving no extra N. In general, plants with low or moderate vegetative growth tend to have firmer fruits. (Darrow, 1934).

Ulrich *et al.* (1980) observed that fruit fails to develop full color in K deficient plants, is pulpy in texture, and insipid to taste. Flowers and fruits of P deficient plants tend to be smaller than normal, while fruit of susceptible cultivars occasionally develops albinism.

Nitrogen applied in spring resulted in larger fruits, especially in the latter part of the picking season (Shoemaker and Greve, 1930). Similar effect of fertilizer treatment on fruit yield was reported by Kongsrud (1988).

Kopanski and Kaweci (1994) reported that N application (90 kg N ha^{-1}) increased fruit dry weight and vitamin C content of strawberry *cv.* Dukat and Senga Sengana.

In a soilless closed system with a recycled nutrient solution, an excessive uptake of potassium reduced the fruit quality by lowering sugar content (Pivot and Gillioz, 2001).

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

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

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

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

Odongo *et al.* (2011) evaluated the effect of FYM and triple super phosphate on quality and profitability of strawberries. It was found that FYM (54 t ha^{-1}) + P (34 kg ha^{-1}) and FYM (36 t ha^{-1}) + P (17 kg ha^{-1}) were found best for large sized and sweetest, long- storing berries respectively.

Gupta and Tripathi (2012) reported that combined application of *Azotobacter* (7 kg ha^{-1}) + vermicompost (30 t ha^{-1}) in two seasons produced berries with maximum TSS (10.31 ^{0}B and 9.29 °B), total sugars (9.73% and 8.74 %), ascorbic acid (56.52

mg/100 g edible pulp and 54.53 mg/100 g edible pulp) with minimum titratable acidity (0.52 % and 0.47 %) contents in comparison to untreated plants.

Rodas *et al.* (2013) tested four nitrogen doses (100, 200, 300 and 400 kg ha^{-1}) and the effect of potassium (150, 300, 450 and 600 kg ha^{-1} K_2O) fertigation in strawberry crop under field conditions on chemical properties and fruit external color rates. In case of total soluble solids, seven degree brix or higher were achieved with the application of 200 and 400 kg ha^{-1} N. Fruit chemical properties and fruit external color rates were influenced by potassium fertigation. The highest TSS content and acidity were found in fruits of plants receiving 344.50 kg ha^{-1} K_2O.

2.2.4 Flowering

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

Azotobacter (6 kg ha^{-1}) + vermicompost (30 t ha^{-1}) significantly increased number of flowers per plant (67.48 and 64.51 respectively) during two seasons in strawberry *cv.* Chandler (Gupta and Tripathi, 2012).

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

2.3 Response of crop to climatological factors

Roberts and Kenworthy (1956) have reported ambient temperature range between 20 ^{0}C and 26 ^{0}C for proper growth of strawberry. Temperature below 15.6 ^{0}C inhibits pollen germination and pollen tube growth, resulting in mis-shapen fruits (Garren, 1980).

Exposure to high temperature ($\geq 35^0$C) results in reduced plant growth and lower yields (Hellman and Travis, 1988).

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

Strawberry is mainly grown in temperate climates because its optimum growth temperature ranges from 10 ^{0}C to 26 ^{0}C (Strik, 1985). Strawberry plants are highly sensitive to variation in environmental conditions. Factors such as water availability, day and night time temperatures, and day light intensities affect fruit size (Avidov, 1986).

Duration of dark period rather than the light period is the factor, which controls floral initiation in strawberry. After the induction of flowering, short day promotes flower initiation, but delays differentiation of flower organs in strawberry (Hartman, 1947; Durner and Poling, 1987).

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

Yanagi and Oda (1993) reported that stolon formation, petiole length, leaf area and yield increases with increasing photoperiod. Runner formation is clearly promoted by long photoperiod (>14 – 16 h) and high temperature (>17 – 20 °C), in short day cultivars of strawberry (Darrow 1936; Heide 1977; Durner *et al.*, 1987; Guttridge 1985; Le Mière *et al.*, 1996).

Wand and Camp (1999) studied the influence of four day/night temperature combinations (18/12, 25/12, 25/22, 30/22) on plant growth and fruit quality of strawberry *cv.* Earliglow and Kent. The optimum day/night temperatures for leaf and petiole growth were 25/12 °C, while for roots and fruits it was at 18/12 °C. For the growth of the whole plant, 25/12 °C was also the optimum temperature.

The influence of four day or night temperature combinations (18/12, 25/12, 25/22, 30/22) on plant growth and fruit quality of strawberry cultivars were studied. The optimum day/night temperatures for leaf and petiole growth was 25/12 ^{0}C, while for roots and fruits, it was at 18/12 ^{0}C. For the growth of whole plant, 25/12 ^{0}C was the optimum temperature. The pigment intensity (chroma value) of the leaves decreased as the day/night temperature increased. As the day/night temperature increased, malic acid content increased whereas citric acid content decreased (Shiow and Mary, 2000).

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

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

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

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

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

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

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

2.4 Response of crop to nutrient deficiency/toxicity

Yoshida *et al.* (2002) studied the effects of nutrient deficiency (N, P and K) on color development and anthocyanin accumulation in strawberry fruit. It was concluded that the anthocyanin synthesis in strawberry fruits may be reduced by N deficiency.

Nam *et al.* (2006) studied the different levels of nitrogen, phosphorus, potassium and calcium in fertilizer solutions on the severity of anthracnose on strawberry *cv.* Nyoho revealed that elevated nitrogen and potassium concentrations in the fertilizer solution increased disease severity in contrast to phosphorus and calcium.

2.5 Post-harvest studies

Shoemaker and Greve (1930) reported that a spring application of 280 kg ha^{-1} of ammonium sulphate (58.8 kg N) in the fruiting year had no effect upon shipping quality, even though the spring application resulted in slightly softer fruits.

Nitrogen, especially if applied in the spring, has a tendency to increase leaf number and area, thus making conditions more favorable for the growth of mold organisms in the field and subsequently in transit (Darrow, 1934).

Mukkun *et al.* (2001) reported that application of 225 kg ha^{-1} of N was effective in maintaining fruit quality of strawberry upto twenty one days storage compared to other nitrogen treatments (300, 450 and 600 kg ha^{-1} N).

Odongo *et al.* (2011) evaluated the effect of FYM and triple super phosphate on quality and profitability of strawberries. It was found that FYM (54 t ha^{-1}) + P (34 kg ha^{-1}) and FYM (36 t ha^{-1}) + P (17 kg ha^{-1}) were found best for large sized and sweetest, long- storing berries respectively.

Materials and methods

3. MATERIALS AND METHODS

The investigation envisages to standardise the nutrient requirement of strawberry (*Fragaria* x *ananassa* Duch.) under the agro-climatic conditions of Wayanad. The procedures adopted are discussed below.

3.1. Experimental site

The experiment was conducted over a period of one season from October 2016 to March 2017 at Regional Agriculture Research Station, Ambalavayal, Wayanad, Kerala.

3.1.1. Locations

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

3.1.2. Soil

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

Table 1. Soil characteristics of experimental field

Soil characters		Compositions
1.	Physical properties	
a)	Mechanical composition	
1.	Sand	64.5%
2.	Silt	12.5%
3.	Clay	23%

Soil characters	Compositions
b) Texture	Sandy clay loam
2. Chemical properties:	
Constituents	
Available Phosphorous (kg ha^{-1})	18
Available Potash (kg ha^{-1})	161.3
Organic carbon (%)	1.76
Electrical conductivity (mmhos cm^{-1})	0.03
pH	5.75
Calcium (mg kg^{-1})	186.4
Magnesium (mg kg^{-1})	89.7
Iron (mg kg^{-1})	57.48
Manganese (mg kg^{-1})	50.18
Copper (mg kg^{-1})	2.99
Boron (mg kg^{-1})	0.20

3.1.3. Climate

The climate at RARS, Ambalavayal, Wayanad was mild sub-tropical climate. The monthly mean weather data for the cropping peroid is given in Appendix 1.

3.1.4. Season

The experiment was conducted from October 2016 to March 2017.

3.1.5. Planting time

The time of planting was in the first week of October 2016.

3.2. Materials

3.2.1. Variety

Strawberry variety Winter Dawn was used for this experiment. It is a cross between seed parent FL 93-103 and pollen parent FL 95-316; both non-patented breeding selections from University of Florida. Fruits are medium to large in size with attractive colour and aroma. It is a low chilling variety suited to subtropical climatic condition. The tissue culture plants were collected from KF Bioplants Pvt. Ltd, Hadapsar, Pune.

3.2.2. Growing systems

The system of growing was open condition.

3.3. Methods

3.3.1. Design of the experiment

Design of the experiment was Fractional Factorial RBD with nine treatments and an absolute control. As comparison with a control treatment was a necessity, the same was co-opted with the fractional factorial setup with nine treatments, the total tally for the experiment being ten treatments. The ten treatments were laid out as RBD with three replications.

3.3.2. Treatments

Treatments consist of three different levels of nutrients (factors) in nine different combinations. Farm Yard Manure (FYM), Urea (46 % N), Single Super Phosphate (SSP – 16 % P_2O_5) and Muriate of Potash (MOP – 60 % K) were used as sources of nutrients.

Table 2. Levels of nutrients

	Factors (Manures / Fertilisers)	Levels of nutrients
1	FYM	10, 20, 30 t ha^{-1}
2	N	50, 75, 100 kg ha^{-1}
3	P_2O_5	20, 30, 40 kg ha^{-1}
4	K_2O	50, 75, 100 kg ha^{-1}

Table 3. Treatment combinations

Notations	Treatment combinations FYM (t ha^{-1}), N, P_2O_5& K_2O kg ha^{-1} (kg / ha requirement)	kg $plant^{-1}$	g $plant^{-1}$		
		FYM	Urea	SSP	MOP
T_1	10:50:20:50	0.22	2.47	2.84	1.9
T_2	10:75:30:75	0.22	3.7	4.2	2.8
T_3	10:100:40:100	0.22	4.9	5.6	3.7
T_4	20:50:30:100	0.45	2.47	4.2	3.7
T_5	20:75:40:50	0.45	3.7	5.6	1.8
T_6	20:100:20:75	0.45	4.9	2.84	2.8
T_7	30:50:40:75	0.68	2.47	5.6	2.8
T_8	30:75:20:100	0.68	3.7	2.84	3.7
T_9	30:100:30:50	0.68	4.9	4.2	1.8
T_{10}	Absolute control	0	0	0	0

3.3.3. Preparation of land

Land was raked thoroughly and was made free of weeds and stubbles. Land was leveled properly and beds of size 2.1 m × 1.6 m were taken in such a way that water can run in either direction in the furrows between the beds.

3.3.4. Fertilizer application

Full dose of FYM and SSP and half dose of Urea and MOP were applied at the time of bed preparation and the remaining half dose was applied 45 days after planting.

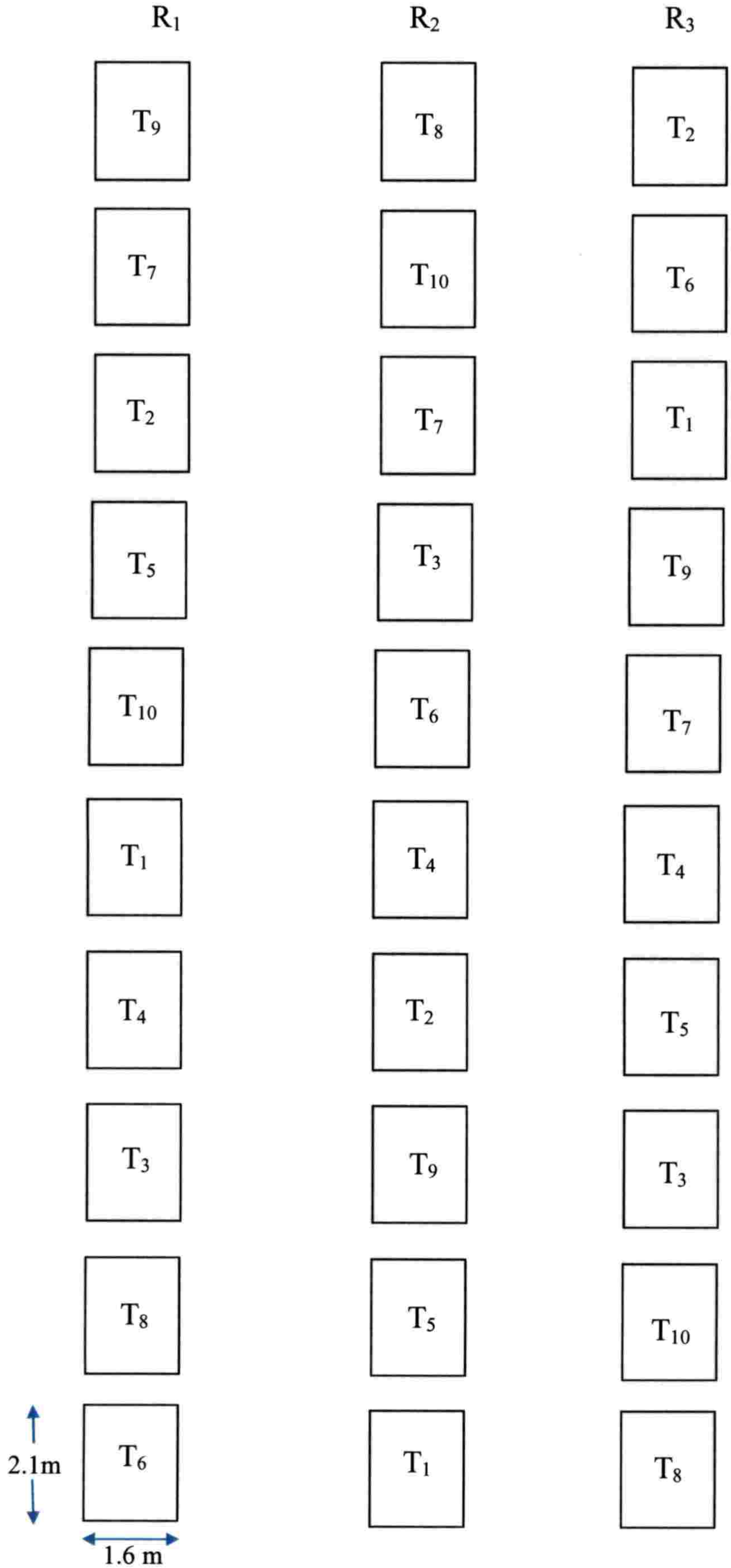


Fig. 1 Plan and layout of the experiment

3.3.5. Mulching

Black polythene cover was used as mulching material to avoid fruits touching the ground, conserve the soil moisture and to keep the plots free of weeds. The mulched beds were clipped with plastic coated metal clips.

3.3.6. Planting

Thirty number of beds / plots of size 2.1 m × 1.6 m were taken with a spacing of 50 cm between the beds and were covered with the plastic mulch. Double row hill system of planting was done with a spacing of 30 cm x 40 cm. Holes were made on the mulch depending on spacing.

Plots were randomly selected for planting. One month old tissue culture strawberry plants of twenty four numbers were planted in each bed / plot in holes by hand in late evening hours.

3.3.7. After cultivation

Weeding was done in the furrows as and when required. Irrigation was given especially during active vegetative growth and flowering. Plant protection chemicals consisting of Chlorpyriphos (Chlorinated Organophosphate - 2 mg/l) and Saaf (1 mg/l) were applied.

3.4. Observations

Observations were recorded from individual plots. The observations on various growth parameters were taken at monthly intervals. Five plants per treatment were randomly selected for recording various growth, flowering and yield attributes.

Plate 1. Experimental field

Layout of the experiment

Planting of tissue culture strawberry plants

Plate 2. Layout of the experiment and planting

Plate 3. Treatment plots

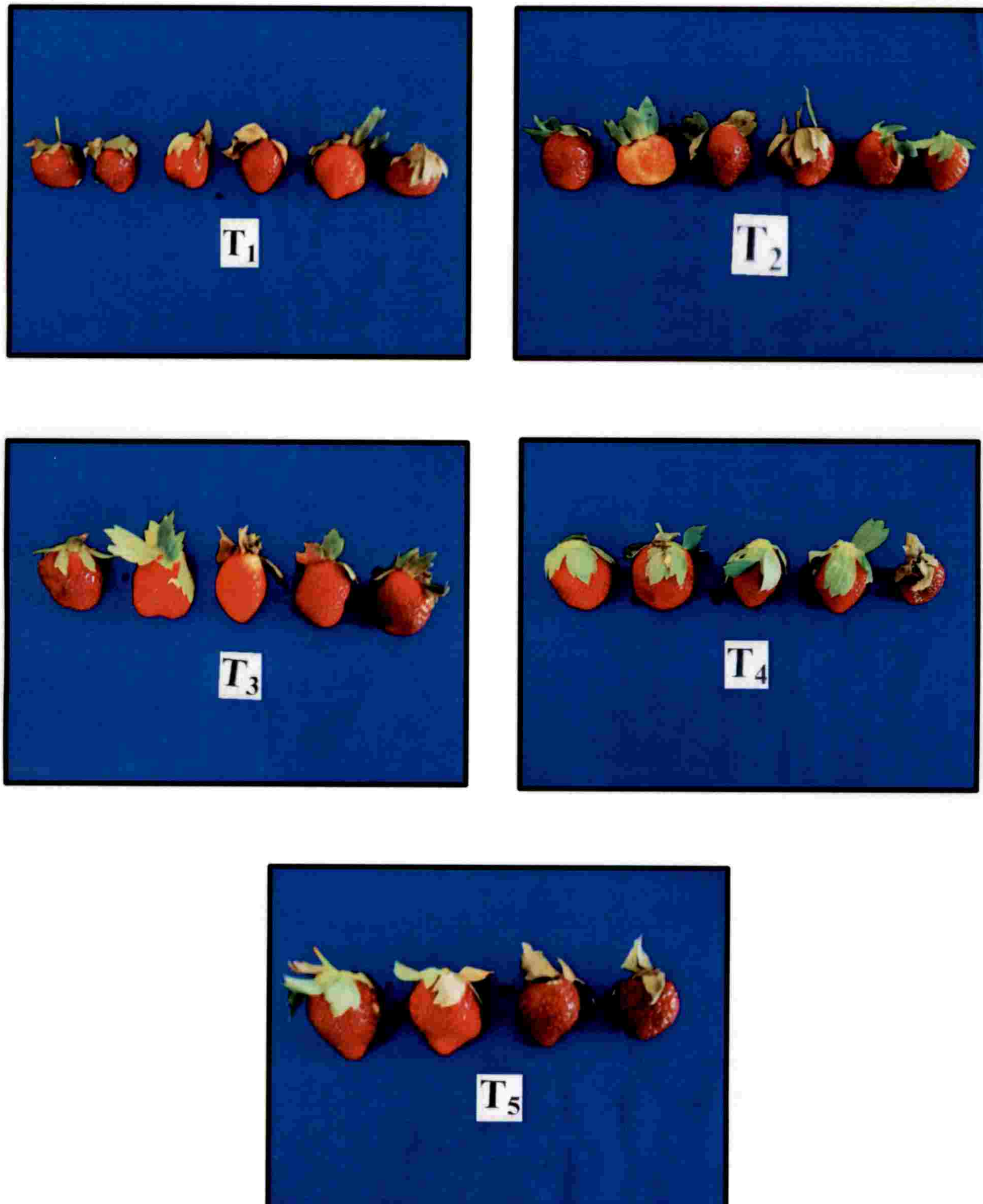


Plate 4. Strawberry fruits harvested from different treatments

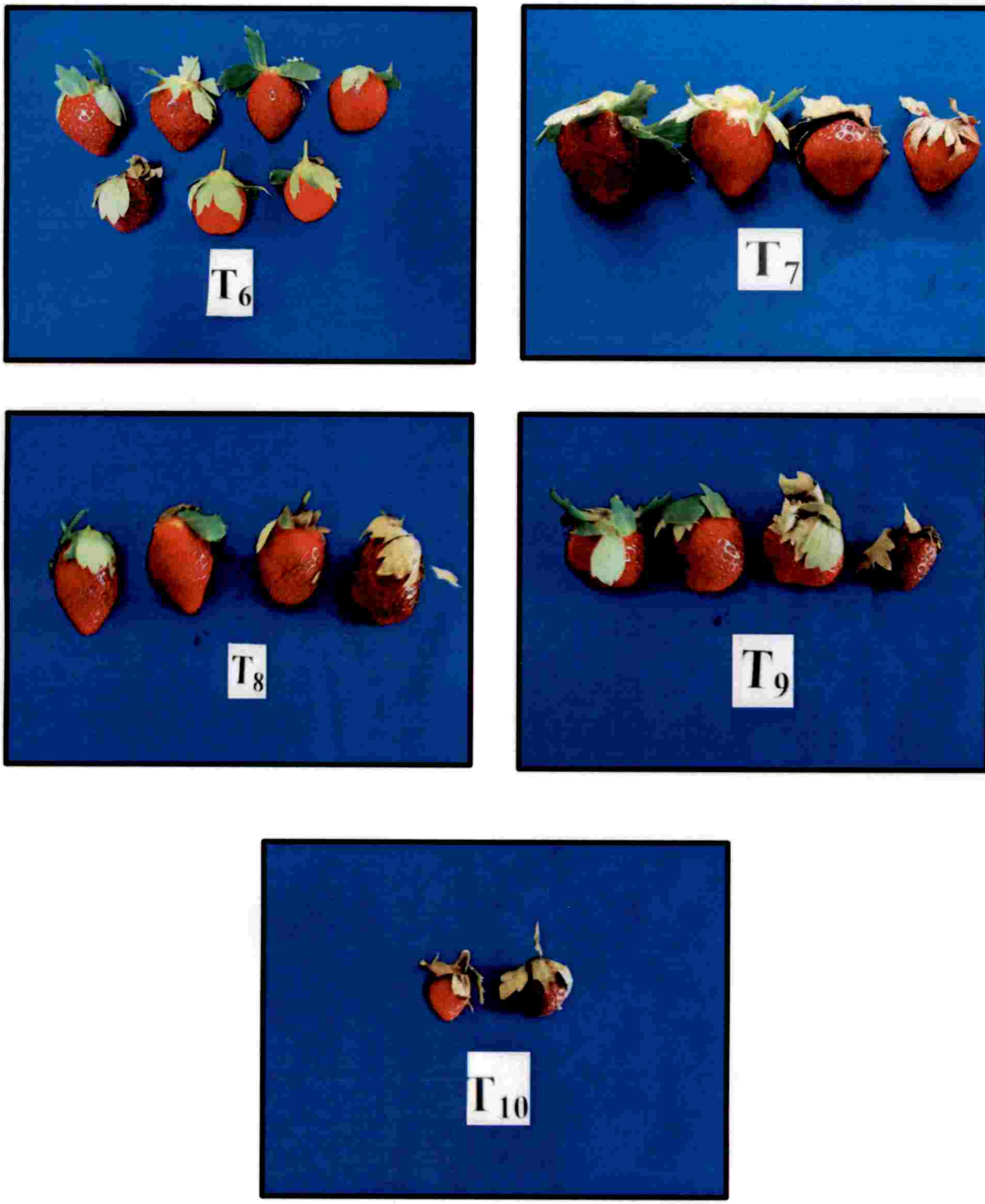


Plate 5. Strawberry fruits harvested from different treatments

Fruit borer

Hairy caterpillar

Plate 6. Pest infestation in strawberry

Leaf blight

Powdery mildew

Plate 7. Diseases of strawberry

3.4.1. Observations on vegetative/ growth attributes

The observations on vegetative/growth characters were noted from five sample plants selected randomly from each plot at monthly intervals for five months.

3.4.1.1. Plant height

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

3.4.1.2. Plant spread

Spread of the plant in East-West and North-South directions were measured and the average was recorded in centimeter (cm) up to five months after planting (MAP).

3.4.1.3. Number of leaves

Number of leaves produced per plant was recorded by counting fully opened leaves from each sample plants up to five months after planting (MAP).

3.4.2. Observations on flowering characters

The following flower characters were observed and recorded.

3.4.2.1. Days to first flowering

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

3.4.2.2. Number of flowers per plant

Number of flowers per plant was counted.

3.4.2.3. Number of clusters per plant

Number of clusters arising from each plant was counted.

3.4.3. Observations on yield characters

The following yield characters were observed and recorded.

3.4.3.1. Number of fruits per plant

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

3.4.3.2. Average fruit weight per plant

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

3.4.3.3. Days to first harvest

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

3.4.3.4. Days to final harvest

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

3.4.3.5. Yield per plant

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

3.4.4. Quality attributes

Total soluble solids (TSS), Acidity, TSS/Acidity and Total sugars were analysed as detailed.

3.4.4.1. Total soluble solids (TSS)

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

3.4.4.2. Acidity

Acidity was estimated as per the procedure described by Ranganna (1997). A representative sample of 5 g fruit pulp was macerated and digested with distilled water and made up to 100 ml. An aliquot of the filtrate was titrated against 0.1N sodium hydroxide using phenolphthalein as indicator. End point of titration was light pink colour of solution in the beaker. The titre value (TV) was noted and substituted in the equation to find the acidity.

3.4.4.3. TSS/acidity ratio

TSS/acidity ratio of the fruit was calculated.

3.4.4.4. Total sugars

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

3.4.4.5. Sensory evaluation

3.4.4.5.1. Selection of judges

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

3.4.4.5.2. Preparation of score card

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

3.4.4.5.3. Organoleptic evaluation

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

3.4.5. Post-harvest studies

The following post-harvest studies on shelf life was done and recorded.

3.4.5.1 Shelf life

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

3.5 Plant Analysis

Plants samples collected from each plot at harvest were analysed for N, P, K, Ca and Mg. Fully developed mid-shoot leaves were chopped and 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.

3.5.1 Total nitrogen

Total nitrogen was determined by Micro Kjeldhal method (Piper, 1942). In this method, all forms of nitrogen in the sample were converted into sulphate of ammonia by digestion with sulphuric and salicylic acid in the presence of sodium sulphate as the electrolyte and selenium as catalyst. The digest was made up to a known volume with distilled water. An aliquot of the resulting solution was distilled with excess of alkali and the distillate was collected in 4 per cent boric acid indicator mixture. The amount of ammonia evolved was determined by titration with standard sulphuric acid.

The analysis of other nutrients *viz.,* P, K, Ca and Mg was done after diacid digestion of the plant sample. In diacid digestion, the acid mixture was prepared by mixing the nitric and perchloric acid in 9: 4 ratio. The dried plant sample (0.5 g) was taken in a 50 ml conical flask and 20 ml of diacid was added for predigestion. After the predigestion, samples were heated on a hot plate for digestion until a clear solution was obtained. The digest was transferred to a 25 ml volumetric flask. The digestion flask was washed 2 to 3 times with double distilled water and volume was made upto 25 ml. Aliquots from this solution were taken for the analysis of the nutrient elements.

3.5.2 Total phosphorous

Five mg of the plant digest was pipetted out into a 50 ml volumetric flask. Barton's reagent 5 ml was added in to this, shaken well and the volume was made up. This was allowed to stand for 30 minutes for yellow color development. Then the intensity of the color was read at 420 nm in spectrophotometer (Piper, 1942). The absorbance value was plotted in the standard graph to obtain the concentration of P in the colored solution.

3.5.3 Total potassium

Five ml of the plant digest was pipetted out into a 25 ml volumetric flask and diluted to 25 ml with distilled water. The standards were aspirated followed by the sample to the flame and the meter reading was noted and K content was calculated by referring to the standard curve prepared (Piper, 1942).

3.5.4. Total Calcium and Magnesium

The content of Ca and Mg were determined by using an atomic absorption spectrophotometer (Piper, 1942).

3.6. Soil analysis

Soil samples were taken from the experimental area before and after the experiment. The composite samples from the experimental site prior to the experiment were analysed for mechanical and chemical composition. After the experiment, composite samples were collected from each plot, air dried, powdered and passed through a 2 mm sieve and analysed for pH, EC, organic carbon, available N, P, K, S, Ca and Mg as per the standard methodology given in Table 4.

Table 4. Soil analysis methodology

Parameter	Method	Reference
Soil pH	Soil water suspension of 1: 25 and read pH meter	Jackson, 1958
Electrical conductivity	Soil water suspension of 1: 25 and read electrical conductivity by meter	Jackson, 1958
Organic carbon	Walkley and Black method	Walkley and Black, 1934
Available Nitrogen	Alkaline permanganate method	Subbiah and Asija, 1956
Available phosphorous	Ascorbic acid reduced molybdophosphoric blue color method	Watanabe and Olsen, 1965
Available potassium	Neutral normal ammonium acetate using photometry	Jackson, 1958
Available sulphur	Extraction using 0.15 percent $CaCl_2$ turbidimetry method	Massoumi and Cornfield, 1963
Available Ca and Mg	Using atomic absorption spectrophotometer	Hesse, 1971

3.7. Observations on weather parameter

Daily observations on temperature (^0C), relative humidity (%) and rainfall (mms) were recorded.

3.8. Pest and diseases

The incidence of pest and diseases were observed and recorded.

52

3.9. Statistical analysis

The data pertaining to the growth parameters and floral characters were subjected to statistical analysis by applying the technique of analysis of variance (ANOVA) for Randomized Block Design (Panse and Sukhatme, 1985). It was desired to study the main effects of the major nutrients (factors) applied viz., organic carbon (FYM), N, P_2O_5 and K_2O at three levels as also the interaction effects under factor combinations on morphological, floral, yield and quality attributes under a fractional factorial experiment (Finney,1945). For a comparative evaluation, an absolute control was maintained. Since all possible factorial combinations led to unwieldy number of treatments, fractional factorial experiment was conducted as $1/3^2$ (3^4) experiment along with an absolute control.

Results

4. RESULTS

The results of the study pertaining to nutrient management for strawberry (*Fragaria x ananassa* Duch.) under the agro-climatic conditions of Wayanad are presented in this chapter. The influence of different treatments on the morphological, floral, yield and quality attributes of strawberry were studied. The main effects of the major nutrients applied i.e., organic carbon (FYM), N, P and K and the interaction effects under factor combinations were also noted. The results are presented under the following heads.

1. Vegetative growth attributes
2. Flowering attributes
3. Yield attributes
4. Quality attributes
5. Plant analysis
6. Soil analysis
7. Postharvest study
8. Pest and disease incidence

4.1 Vegetative/ growth attributes

Various observations on growth attributes *viz.*, plant height, plant spread and number of leaves per plant were recorded, analyzed and the results are presented in Tables 5a to 7c.

Table 5a. Effect of different combinations of FYM, nitrogen, phosphorous and potassium on plant height

Treatments	Plant height (cm)				
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP
T_1 (10:50:20:50)	7.63	14.47	15.80	15.93	16.56
T_2 (10:75:30:75)	7.20	17.33	17.53	17.96	18.20
T_3 (10:100:40:100)	8.30	16.00	17.33	17.80	18.16
T_4 (20:50:30:100)	6.40	15.53	16.20	16.40	16.81
T_5 (20:75:40:50)	6.96	16.86	17.13	17.40	17.60
T_6 (20:100:20:75)	7.06	17.10	15.83	16.63	16.96
T_7 (30:50:40:75)	7.30	15.60	15.83	16.56	16.83
T_8 (30:75:20:100)	6.83	17.66	17.86	18.24	18.50
T_9 (30:100:30:50)	6.30	15.53	14.63	16.66	16.86
T_{10} (Absolute control)	6.23	13.73	13.93	14.56	14.76
CD	NS	2.28	2.23	2.08	2.04

Table 5b. Effect of different levels of FYM, nitrogen, phosphorous and potassium on plant height.

Levels of nutrients	Plant height (cm)				
FYM	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP
10	7.71	15.93	16.9	17.23	17.64
20	6.81	16.5	16.38	16.82	17.12
30	6.81	16.26	15.71	17.15	17.39
CD	NS	NS	NS	NS	NS
Nitrogen (N)					
50	7.11	15.20	15.55	16.30	16.73
75	7.00	17.28	17.51	17.86	18.1
100	7.22	16.21	15.93	17.03	17.32
CD	NS	NS	NS	NS	NS
Phosphorous (P_2O_5)					
20	7.17	16.41	16.51	16.93	17.34
30	6.63	16.13	16.12	17.02	17.29
40	7.52	16.15	16.36	17.25	17.53
CD	NS	NS	NS	NS	NS
Potassium (K_2O)					
50	6.96	15.62	15.86	16.66	17.00
75	7.18	16.67	16.00	17.05	17.33
100	7.17	16.4	17.13	17.49	17.82
CD	NS	NS	NS	NS	NS

56

Table 5c. Effect of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions on plant height

Levels of nutrients	Plant height (cm)														
	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
N / FYM	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
10	22.9	21.6	24.9	43.4	52.0	48.0	47.4	52.6	52.0	47.8	53.9	53.4	49.7	54.6	54.4
20	19.2	20.9	21.2	46.6	50.6	51.3	48.6	51.4	47.5	49.2	52.2	49.9	50.4	52.8	50.9
30	21.9	20.5	18.9	46.8	53.0	46.6	47.5	53.6	43.9	49.7	54.7	50.0	50.5	55.5	50.6
CD	NS			NS			NS			NS			NS		
P / FYM	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
10	22.9	21.6	24.9	43.4	52.0	48.0	47.5	52.6	52.0	47.8	53.9	53.4	49.7	54.6	54.5
20	21.2	19.2	20.9	51.3	46.6	50.6	47.5	48.6	51.4	49.9	49.2	52.2	50.9	50.4	52.8
30	20.5	18.9	21.9	53.0	46.6	46.8	53.6	43.9	53.6	54.7	50.0	54.7	55.5	50.6	50.5
CD	NS			NS			NS			NS			NS		
K / FYM	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
10	22.9	21.6	24.9	43.4	52.0	48.0	47.4	52.6	52.0	47.8	53.9	53.4	49.7	54.6	54.5
20	20.9	21.2	19.2	50.6	51.3	46.6	51.4	47.5	48.6	52.2	49.9	49.2	52.8	50.9	50.4
30	18.9	21.9	20.5	46.6	46.8	53.0	43.9	47.5	53.6	50.0	49.9	54.7	50.6	50.5	55.5
CD	NS			NS			NS			NS			NS		
P / N	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
50	22.9	19.2	21.9	43.4	46.6	46.8	47.4	48.6	47.5	47.8	49.2	49.7	49.7	50.4	50.5
75	20.5	21.6	20.9	53.0	52.0	50.6	53.6	52.6	51.4	54.7	53.9	52.2	55.5	54.6	52.8
100	21.2	18.9	24.9	51.3	46.6	48.0	47.5	43.9	52.0	49.9	50.0	53.4	50.9	50.6	54.5
CD	NS			NS			NS			NS			NS		
K / N	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
50	22.9	21.9	19.2	43.4	46.8	46.6	47.4	47.5	48.6	47.8	49.7	49.2	49.7	50.5	50.4
75	20.9	21.6	20.5	50.6	52.0	53.0	51.4	52.6	53.6	52.2	53.9	54.7	52.8	54.6	55.5
100	18.9	21.2	24.9	46.6	51.3	48.0	43.9	47.5	52.0	50.0	49.9	53.4	50.6	50.9	54.5
CD	NS			NS			NS			NS			NS		
K / P	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
20	22.9	21.2	20.5	43.4	51.3	53.0	47.4	47.5	53.6	47.8	49.9	54.7	49.7	50.9	55.5
30	18.9	21.6	19.2	46.6	52.0	46.6	43.9	52.6	48.6	50.0	53.9	49.2	50.6	54.6	50.4
40	20.9	21.9	24.9	50.6	46.8	48.0	51.4	47.5	52.0	52.2	49.7	53.4	52.8	50.5	54.5
CD	NS			NS			NS			NS			NS		

4.1.1 Plant height

The effects of treatments on plant height at different stages of growth are presented in Tables 5a, 5b and 5c.

The results showed that plant height was significantly influenced by different treatments.

At 1 MAP, there was no significant effect on the plant height due to applications of different nutrient combinations. At 2 MAP, maximum plant height was noted in T_8 (17.66 cm) which was on par with T_2 (17.33 cm), T_6 (17.1 cm), T_5 (16.86 cm), T_3 (16 cm), T_7 (15.6 cm), T_4 and T_9 (15.53 cm). The lowest height of 13.73 cm was recorded by T_{10} which was on par with T_1 (14.47 cm). At 3 MAP, the same trend in plant height was observed as in the previous month. At 4 MAP, T_8 recorded the maximum plant height of 18.24 cm.The plant height recorded under T_2 (17.96 cm), T_3 (17.8 cm), T_5 (17.4 cm), T_9 (16.66 cm), T_6 (16.63 cm), T_7 (16.56 cm) and T_4 (16.4 cm) were on par with T_8. At 5 MAP also, T_8 recorded the maximum plant height of 18.50 cm which was on par with T_2 (18.2cm), T_3 (18.16 cm), T_5 (17.6 cm), T_6 (16.96 cm), T_9 (16.86 cm), T_7 (16.83 cm), T_4 (16.81 cm) and T_1 (16.56 cm). The lowest plant height was noted in T_{10} (14.76 cm). In general, all the treatments recorded superiority over the control.

Application of different levels of FYM, N, P and K did not influence the plant height significantly.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were non-significant on plant height at all stages of growth.

4.1.2 Plant spread

The effects of treatments on plant spread at different stages of growth are presented in Table 6a, 6b and 6c.

At 1 MAP, the highest plant spread was recorded in T_8 (24.3 cm) which was on par with T_9 (23.23 cm), T_6 (22.9 cm), T_3 (22.3 cm) and T_2 (22 cm). At 2 MAP, T_8 recorded the maximum plant spread of 25.4 cm. T_6 (25.26 cm), T_5 (25 cm), T_2 (24.8 cm), T_9 (24.56 cm), T_3 (24.4 cm) and T_1 (24.26 cm) were on par with T_8. The lowest was recorded by T_{10} (21.7 cm) and was on par with T_7 (22.1 cm) and T_4 (22.2 cm). At 3 MAP, the highest plant spread was recorded in T_8 (30.85 cm) which was on par with T_3 (30.71 cm), T_5 (29.45 cm), T_2 (29.04 cm), T_6 (28.8 cm), T_1 (28.63 cm), T_9 (28.21 cm) and T_7 (27.93 cm). T_{10} recorded the lowest plant spread of 23.9 cm and was on par with T_4 (26.5 cm).T_8 recorded significantly higher plant spread of 32.48 cm at 4 MAP. T_3 (32.45 cm), T_5 (31.26 cm), T_7 (30.35 cm), T_6 (30.2 cm), T_1 (30.08 cm) and T_2 (30 cm) were on par with T_8. Here also T_{10} recorded the lowest plant spread of 25.58 cm which was on par with T_9 (29.23 cm) and T_4 (29.5 cm). At 5 MAP also, T_8 was showing significantly higher plant spread of 33.1 cm which was on par with T_3 (32.98 cm), T_5 (31.88 cm), T_6 (31.13 cm), T_2 (31 cm), T_7 (30.93 cm) and T_1 (30.83 cm). It was followed by T_9 (30.18 cm) and T_4 (29.73 cm). T_{10} recorded the lowest plant spread of 25.9 cm.

Significant difference over an increased dosage of application of the nutrients was observed at 2 MAP at third level of FYM (30 t ha^{-1}). Among the different levels of N, second level of N (75 kg ha^{-1}) recorded the maximum plant spread which was on par with N at third level (100 kg ha^{-1}). Among the different levels of P, first level of P (20 kg ha^{-1}) produced the maximum plant spread which was on par with P at second level (30 kg ha^{-1}). The influence of K on plant spread was significant only at third level of K (100 kg ha^{-1}) which was on par with second (75 kg ha^{-1}) and first level (50 kg ha^{-1}).

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were noticeable only at 2 MAP. Among FYM x N interactions, third level of FYM (30 t ha^{-1}) and second level of N (75 kg ha^{-1}) recorded the highest plant spread.

Third level of FYM (30 t ha^{-1}) and first level of P (20 kg ha^{-1}) recorded maximum plant spread in case of FYM x P interactions which was on par with FYM at third level and P at second level.

In case of FYM x K interactions, maximum plant spread was noted in case of third level of FYM (30 t ha^{-1}) and third level of K (100 kg ha^{-1}) which was on par with third level of FYM (30 t ha^{-1}) and second level of K (75 kg ha^{-1}).

Second level of N (75 kg ha^{-1}) and first level of P (20 kg ha^{-1}) recorded significantly higher plant spread which was on par with N at second level (75 kg ha^{-1}) and P at second level (30 kg ha^{-1}) in case of N x P interactions.

In case of interaction effects between N and K, second level of N (75 kg ha^{-1}) and third level of K (100 kg ha^{-1}) recorded maximum plant spread which was on par with N at second level (75 kg ha^{-1}) and K at second level (75 kg ha^{-1}).

With respect to P x K interactions, first level of P (20 kg ha^{-1}) and third level of K (100 kg ha^{-1}) recorded the highest plant spread which was on par with P at first level (20 kg ha^{-1}) and K at second level (75 kg ha^{-1}).

Table 6a. Effect of different combinations of FYM, nitrogen, phosphorous and potassium on plant spread

Treatments	Plant spread (cm)				
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP
T_1 (10:50:20:50)	21.86	24.26	28.21	29.23	30.18
T_2 (10:75:30:75)	22.00	24.80	29.04	30.00	31.00
T_3 (10:100:40:100)	22.33	24.40	30.71	32.45	32.98
T_4 (20:50:30:100)	20.85	22.20	26.50	29.50	29.73
T_5 (20:75:40:50)	21.93	25.00	29.45	31.26	31.88
T_6 (20:100:20:75)	22.96	25.26	28.80	30.20	31.13
T_7 (30:50:40:75)	20.88	22.10	27.93	30.35	30.93
T_8 (30:75:20:100)	24.30	25.40	30.85	32.48	33.10
T_9 (30:100:30:50)	23.23	24.56	28.63	30.08	30.83
T_{10} (Absolute control)	19.85	21.70	23.90	25.58	25.90
CD	2.30	2.26	3.35	2.62	2.70

Table 6b. Effect of different levels of FYM, nitrogen, phosphorous and potassium on plant spread

Levels of nutrients	Plant spread (cm)				
FYM	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP
10	21.91	23.97	28.37	30.41	30.91
20	22.06	24.20	29.00	30.67	31.35
30	22.80	26.52	29.46	30.85	31.70
CD	NS	1.29	NS	NS	NS
Nitrogen (N)					
50	21.2	22.85	27.68	29.90	30.49
75	22.74	25.15	29.78	31.23	31.95
100	22.84	24.65	29.36	30.73	31.47
CD	NS	1.29	NS	NS	NS
Phosphorous (P_2O_5)					
20	23.04	24.84	29.54	31.36	31.97
30	22.02	23.96	29.36	31.00	31.64
40	21.71	23.46	27.91	29.57	30.30
CD	NS	1.29	NS	NS	NS
Potassium (K_2O)					
50	22.34	23.75	28.76	30.19	30.96
75	21.95	23.96	28.71	30.27	31.02
100	22.49	24.74	29.35	31.47	31.93
CD	NS	1.29	NS	NS	NS

Table 6c. Effect of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions on plant spread

Levels of nutrients	Plant spread (cm)														
	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
N / FYM	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
10	65.6	66.0	67.0	72.8	73.4	73.2	85.9	87.1	92.1	90.2	90.0	97.4	92.5	93.0	99.3
20	62.6	65.8	68.9	66.6	75.0	75.8	79.5	88.4	86.4	88.5	93.8	90.6	89.2	95.6	98.9
30	62.6	72.9	69.7	66.3	76.2	73.7	83.8	92.6	84.6	91.1	97.4	87.7	92.8	93.4	90.5
CD	NS			2.25			NS			NS			NS		
P / FYM	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
10	65.6	66.0	67.0	72.8	74.4	73.2	85.9	87.1	92.1	90.2	90.0	97.4	92.5	93.0	99.3
20	68.9	62.6	65.8	75.8	66.6	75.0	86.4	79.5	88.4	90.6	88.5	93.8	98.9	89.2	95.6
30	72.9	69.7	72.9	76.2	75.8	73.7	92.6	84.6	92.6	97.4	87.7	97.4	93.4	90.5	93.4
CD	NS			2.25			NS			NS			NS		
K / FYM	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
10	65.6	66.0	67.0	72.8	74.4	73.2	85.9	87.1	92.1	90.2	90.0	97.4	92.5	93.0	99.3
20	65.8	68.9	62.6	75.0	75.8	66.6	88.4	86.4	79.5	93.8	90.6	88.5	95.6	98.9	89.2
30	69.7	68.9	72.9	73.7	75.8	76.2	84.6	86.4	92.6	87.7	90.6	97.4	90.5	98.9	93.4
CD	NS			2.25			NS			NS			NS		
P / N	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
50	65.6	62.6	62.6	72.8	66.6	66.3	85.9	79.5	83.8	90.2	91.1	91.1	92.5	89.2	92.8
75	72.9	66.0	65.8	76.2	74.4	72.8	92.6	87.1	88.4	93.8	90.0	97.4	93.4	93.0	95.6
100	68.9	69.7	67.0	75.8	73.7	73.2	86.4	84.6	92.1	87.7	90.6	97.4	98.9	90.5	99.3
CD	NS			2.25			NS			NS			NS		
K / N	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
50	65.6	62.6	62.6	72.8	66.3	66.6	85.9	83.8	79.5	90.2	91.1	88.5	92.5	92.8	89.2
75	65.8	66.0	72.9	73.2	74.4	76.2	88.4	87.1	92.6	93.8	90.0	97.4	95.6	93.0	93.4
100	69.7	68.9	67.0	73.7	75.8	73.2	84.6	86.4	92.1	87.7	90.6	97.4	90.5	98.9	99.3
CD	NS			2.25			NS			NS			NS		
K / P	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
20	65.6	68.9	72.9	72.8	75.8	76.2	85.9	86.4	92.6	90.2	90.6	97.4	92.5	98.9	93.4
30	69.7	66.0	62.6	73.7	74.4	66.6	84.6	87.1	79.5	87.7	90.0	88.5	90.5	93.0	89.2
40	65.8	62.6	67.0	75.0	66.3	73.2	88.4	83.8	92.1	93.8	91.1	97.4	95.6	92.8	99.3
CD	NS			2.25			NS			NS			NS		

4.1.3 Number of leaves per plant

The effects of treatments on number of leaves per plant at different stages of growth is presented in Table 7a, 7b and 7c.

At 1 MAP, there was no significant effect on the plant height due to applications of different levels of nutrient combinations. At 2 MAP, T_8 (10.4) recorded maximum number of leaves. The number of leaves recorded under T_2 (10.33), T_5 (9.66), T_3 (9.33), T_6 (9), T_9 (8.66), T_1 (8.33) and T_4 (8.33) were on par with T_8. Lowest number of leaves were noted in T_{10} (7) and was on par with T_7 (7.33). At 3 MAP, the treatments were found to be non-significant. At 4 MAP, T_8 (18) showed significantly higher number of leaves which was on par with T_4 (17.66), T_9 (17.66), T_1 (17.33), T_7 (17.2), T_5 (17), T_6 (16.66) and T_3 (15.66). It was followed by T_2 (14) and T_{10} (10.66). At 5 MAP, T_8 (20) recorded the maximum number of leaves which was on par with T_9 (19.8), T_4 (19.66), T_6 (19.33), T_7 (19), T_1 (18.66), T_5 (18.33) and T_3 (17.92). It was followed by T_2 (16) and T_{10} (12.66).

Significant difference over an increased dosage of application of the nutrients was observed only at 5 MAP. Third level of FYM (30 t ha^{-1}) recorded the maximum number of leaves which was on par with FYM at second level (20 t ha^{-1}).

Among the different levels of N, second level of N (75 kg ha^{-1}) recorded the maximum number of leaves which was on par with N at third level (100 kg ha^{-1}). First level of P (20 kg ha^{-1}) produced the highest number of leaves which was on par with P at second level (30 kg ha^{-1}). K at third level (100 kg ha^{-1}) recorded maximum number of leaves which was on par with K at second (75 kg ha^{-1}) and first level (50 kg ha^{-1}).

63

Table 7a. Effect of different combinations of FYM, nitrogen, phosphorous and potassium on number of leaves per plant

Treatments	Number of leaves				
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP
T_1 (10:50:20:50)	5.00	8.33	12.3	17.33	18.66
T_2 (10:75:30:75)	6.00	10.33	13.00	15.40	16.00
T_3 (10:100:40:100)	5.33	9.33	12.66	15.66	17.92
T_4 (20:50:30:100)	5.00	8.33	13.66	17.66	19.66
T_5 (20:75:40:50)	5.00	9.66	12.66	17.00	18.33
T_6 (20:100:20:75)	5.33	9.00	13.00	16.66	19.33
T_7 (30:50:40:75)	5.00	7.33	12.70	17.20	19.00
T_8 (30:75:20:100)	5.00	10.40	14.33	18.00	20.00
T_9 (30:100:30:50)	4.66	8.66	13.33	17.66	19.82
T_{10} (Absolute control)	5.00	7.00	9.33	10.66	12.66
CD	NS	2.151	NS	2.437	2.34

Table 7b. Effect of different levels of FYM, nitrogen, phosphorous and potassium on number of leaves per plant

Levels of nutrients	Number of leaves				
FYM	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP
10	4.88	8.80	13.21	16.6	17.63
20	5.11	9.00	12.77	16.55	18.77
30	5.44	9.33	12.99	17.22	19.11
CD	NS	NS	NS	NS	1.39
Nitrogen (N)					
50	5.00	8.00	12.65	16.33	17.78
75	5.33	10.13	13.33	17.33	19.22
100	5.1	9.00	13.00	16.77	18.66
CD	NS	NS	NS	NS	1.39
Phosphorous (P_2O_5)					
20	5.20	9.24	13.22	17.53	19.55
30	5.10	9.11	13.00	17.44	19.44
40	5.10	8.70	12.76	15.55	17.00
CD	NS	NS	NS	NS	1.39
Potassium (K_2O)					
50	4.80	8.24	12.55	16.00	18.11
75	5.10	8.88	12.65	17.11	18.51
100	5.40	9.35	13.77	17.33	18.88
CD	NS	NS	NS	NS	1.39

Table 7c. Effect of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions on number of leaves per plant

Levels of nutrients	Number of leaves per plant														
	1 MAP			2 MAP			3 MAP			4 MAP			5 MAP		
FYM \ N	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
10	15	18	16	25	31	28	37	39	43	52	51	47	56	48	54
20	15	15	16	25	29	27	41	38	38	53	51	54	59	55	58
30	15	15	14	22	31	26	36	39	40	42	50	53	57	60	59
CD	NS			NS			NS			NS			2.42		
FYM \ P	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
10	15	18	16	25	31	28	37	39	43	52	51	47	56	48	54
20	16	15	15	29	27	25	38	41	38	54	53	51	58	59	55
30	15	14	15	26	22	31	39	40	39	50	53	50	60	59	56
CD	NS			NS			NS			NS			2.42		
FYM \ K	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
10	15	18	16	25	31	28	37	39	43	52	51	47	54	48	54
20	15	16	15	29	27	25	38	38	41	51	54	53	55	58	59
30	14	15	15	26	22	31	40	15	39	53	15	50	56	59	60
CD	NS			NS			NS			NS			2.42		
N \ P	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
50	15	15	15	25	25	22	37	41	36	52	53	42	56	59	57
75	15	18	15	31	31	29	39	39	38	50	51	51	60	48	55
100	16	14	16	27	26	28	38	40	43	54	53	47	58	59	54
CD	NS			NS			NS			NS			2.42		
N \ K	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
50	15	15	15	25	22	25	37	36	41	52	42	53	56	57	59
75	15	18	15	29	31	31	38	39	39	51	51	50	55	48	60
100	14	16	16	26	27	28	40	38	43	53	54	47	59	58	54
CD	NS			NS			NS			NS			2.42		
P \ K	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
20	15	16	15	25	27	31	37	38	39	52	54	50	56	58	60
30	14	18	15	26	31	25	40	39	41	53	51	53	59	48	59
40	15	15	16	29	22	28	38	36	43	51	42	47	55	57	54
CD	NS			NS			NS			NS			2.42		

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were significant only at 5 MAP. Among FYM x N interactions, significantly higher number of leaves were recorded at third level of FYM (30 t ha^{-1}) and second level of N (75 kg ha^{-1}) which was on par with FYM at third level (30 t ha^{-1}) and N at third level (100 kg ha^{-1}).

Among FYM x P interactions, significantly higher number of leaves were recorded at third level of FYM (30 t ha^{-1}) and first level of P (20 kg ha^{-1}) which was on par with FYM at third level (30 t ha^{-1}) and P at second level (30 kg ha^{-1}).

Third level of FYM (30 t ha^{-1}) and third level of K (100 kg ha^{-1}) recorded significantly higher number of leaves among FYM x K interactions which was on par with FYM at third level (30 t ha^{-1}) and K at second level (75 kg ha^{-1}).

Second level of N (75 kg ha^{-1}) and first level of P (20 kg ha^{-1}) recorded maximum number of leaves with respect to N x P interactions.

As regards N x K interactions, second level of N (75 kg ha^{-1}) and third level of K (100 kg ha^{-1}) recorded maximum number of leaves which as on par with N at first level (50 kg ha^{-1}) and K at third level (100 kg ha^{-1}).

In case of P x K interactions, significantly higher number of leaves were recorded at first level of P (20 kg ha^{-1}) and third level of K (100 kg ha^{-1}) which was on par with P at first level (20 kg ha^{-1}) and K at second level (75 kg ha^{-1}).

42 Flowering attributes

Various observations on flowering attributes *viz.,* days to first flowering, number of flowers per plant and number of clusters per plant of strawberry growing under different nutrient combinations were recorded, analyzed and the results are presented in Tables 8a to 8c.

4.2.1 Days to first flowering

The effect of treatment combinations on number of days to first flowering are presented in Table 8a.

Application of treatments had no significant effect on days to first flowering.

Application of graded doses of FYM, N, P and K did not influence the number of days to first flowering.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were non-significant with respect to number of days to first flowering.

4.2.2 Number of flowers per plant

The effect of treatment combinations on the number of flowers per plant are presented in Table 8a.

Maximum number of flowers were recorded by T_7 (12.31) which was on par with T_8 (11.6), T_9 (11.56), T_6 (11.47), T_2 (10.63), T_1 (10.43), T_5 (9.73) and T_3 (8.61). T_{10} recorded the lowest number of flowers per plant which was on par with T_4 (7.96).

Application of graded doses of FYM, N, P_2O_5 and K_2O did not influence the number of flowers per plant significantly.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were non-significant on number of flowers per plant.

4.2.3 Number of clusters per plant

The effect of treatment combinations on the number of clusters per plant are presented in Table 8a. Highest number of clusters were recorded in T_7 (6.73) which was on par with T_8 (6.7), T_9 (6.53), T_2 (5.73), T_6 (5.73), T_5 (5.4), T_1 (4.93) and T_3 (4.6).

Table 8a. Effect of different combinations of FYM, nitrogen, phosphorous and potassium on days to first flowering, number of flowers per plant and number of clusters per plant

Treatments	Days to first flowering	Number of flowers per plant	Number of clusters per plant
T_1 (10:50:20:50)	51.00	10.43	4.93
T_2 (10:75:30:75)	54.00	10.63	5.73
T_3 (10:100:40:100)	55.00	8.61	4.66
T_4 (20:50:30:100)	54.00	7.96	4.03
T_5 (20:75:40:50)	51.33	9.73	5.40
T_6 (20:100:20:75)	53.66	11.47	5.73
T_7 (30:50:40:75)	53.66	12.31	6.73
T_8 (30:75:20:100)	47.33	11.60	6.70
T_9 (30:100:30:50)	49.33	11.56	6.53
T_{10} (Absolute control)	53.66	5.13	2.33
CD	NS	3.96	2.43

Table 8b. Effect of different levels of FYM, nitrogen, phosphorous and potassium on days to first flowering, number of flowers per plant and number of clusters per plant

Levels of nutrients	Days to first flowering	Number of flowers per plant	Number of clusters per plant
FYM			
10	53.3	9.89	5.11
20	53.0	9.72	5.05
30	50.1	11.82	6.65
CD	NS	NS	NS
Nitrogen (N)			
50	52.8	10.00	5.22
75	50.8	10.64	5.88
100	52.6	10.80	5.71
CD	NS	NS	NS
Phosphorous (P_2O_5)			
20	50.66	11.15	5.73
30	52.44	10.30	5.50
40	53.33	9.98	5.58
CD	NS	NS	NS
Potassium (K_2O)			
50	50.55	10.88	5.68
75	53.70	11.23	6.05
100	52.10	9.38	5.07
CD	NS	NS	NS

68

Table 8c. Effect of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions on days to first flowering, number of flowers per plant and number of clusters per plant

Levels of nutrients	Days to first flowering			Number of flowers per plant			Number of clusters per plant		
N / FYM	50	75	100	50	75	100	50	75	100
10	153.0	162.0	165.0	31.3	31.9	25.8	14.8	17.2	14.0
20	162.0	154.0	161.0	23.9	29.2	34.4	12.1	16.2	17.2
30	161.0	142.0	148.0	36.9	34.8	34.7	20.2	20.1	19.6
CD	NS			NS			NS		
P / FYM	20	30	40	20	30	40	20	30	40
10	153.0	162.0	165.0	31.3	31.9	25.8	14.8	17.2	14.0
20	161.0	162.0	154.0	34.4	23.9	29.2	17.2	12.1	16.2
30	142.0	148.0	142.0	34.8	34.7	34.8	20.1	19.6	20.1
CD	NS			NS			NS		
K / FYM	50	75	100	50	75	100	50	75	100
10	153.0	162.0	165.0	31.3	31.9	25.8	14.8	17.2	14.0
20	154.0	161.0	162.0	29.2	34.4	23.9	16.2	17.2	12.1
30	148.0	161.0	142.0	34.7	34.4	34.8	19.6	17.2	20.1
CD	NS			NS			NS		
P / N	20	30	40	20	30	40	20	30	40
50	153.0	162.0	161.0	31.3	23.9	36.9	14.8	12.1	20.2
75	142.0	162.0	154.0	34.8	31.9	29.2	20.1	17.2	16.2
100	161.0	148.0	165.0	34.4	34.7	25.8	17.2	19.6	14.0
CD	NS			NS			NS		
K / N	50	75	100	50	75	100	50	75	100
50	153.0	161.0	162.0	31.3	36.9	23.9	14.8	20.2	12.1
75	154.0	162.0	142.0	29.2	31.9	34.8	16.2	17.2	20.1
100	148.0	161.0	165.0	34.7	34.4	25.8	19.6	17.2	14.0
CD	NS			NS			NS		
K / P	50	75	100	50	75	100	50	75	100
20	153.0	161.0	142.0	31.3	34.4	34.8	14.8	17.2	20.1
30	148.0	162.0	162.0	34.7	31.9	23.9	19.6	17.2	12.1
40	154.0	161.0	165.0	29.2	36.9	25.8	16.2	20.2	14.0
CD	NS			NS			NS		

The lowest number of clusters were recorded in T10 (2.33) which was on par with T4 (4.03).

Application of different levels of FYM, N, P_2O_5 and K_2O were found to be non-significant on number of clusters per plant.

FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were also non-significant on number of clusters per plant.

4.3 Yield attributes

Various observations on yield attributes *viz.,* number of fruits per plant, average fruit weight per plant, days to first harvest and days to final harvest of strawberry grown under different nutrient combinations were recorded, analysed and the results are presented in Tables 9a, 9b and 9c.

4.3.1 Number of fruits per plant

The influence of different combinations of FYM, N, P and K were significant on number of fruits per plant (Table 9a).

The maximum number of fruits were noted in T_7 (21.4) which was on par with T_8 (20.66). It was followed by T_9 (17.53) which was on par with T_4 (15.53), T_6 (15.33), T_3 (15.26), T_2 (15.06), T_5 (14.66) and T_1 (14.2). The lowest number of fruits were recorded in T_{10} (10.33).

Application of different levels of FYM, N, P and K were found to be significant on number of fruits per plant (Table 8b)

Table 9a. Effect of different combinations of FYM, N, P and K on number of fruits per plant, average fruit weight per plant, yield per plant, days to first harvest and days to final harvest

Treatments	Number of fruits per plant	Average fruit weight per plant (g)	Yield per plant (g)	Days to first harvest	Days to final harvest
T_1 (10:50:20:50)	14.20	10.82	165.03	65.00	132.00
T_2 (10:75:30:75)	15.06	12.45	204.13	63.30	124.00
T_3 (10:100:40:100)	15.26	12.63	195.53	63.00	129.00
T_4 (20:50:30:100)	15.53	11.17	218.26	64.33	129.00
T_5 (20:75:40:50)	14.66	12.83	215.13	65.33	129.66
T_6 (20:100:20:75)	15.33	13.88	206.70	62.00	134.66
T_7 (30:50:40:75)	21.40	14.60	297.60	61.60	137.60
T_8 (30:75:20:100)	20.66	13.30	264.36	60.00	134.00
T_9 (30:100:30:50)	17.53	12.80	228.21	61.00	132.66
T_{10} (Absolute control)	10.33	9.32	158.46	65.00	115.00
CD	3.44	2.14	24.9	2.80	NS

Table 9b. Effect of different levels of FYM, N, P and K on number of fruits per plant, average fruit weight per plant, yield per plant, days to first harvest and days to final harvest

Levels of nutrients	Number of fruits per plant	Average fruit weight per plant (g)	Yield per plant (g)	Days to first harvest	Days to final harvest
FYM					
10	14.84	11.97	188.20	63.77	131.4
20	15.17	12.63	213.38	63.88	131.1
30	19.86	15.59	263.39	60.88	131.6
CD	1.91	1.44	14.47	1.70	NS
Nitrogen (N)					
50	17.04	13.12	227.87	63.66	132.8
75	16.80	12.86	226.96	62.88	129.2
100	15.04	11.21	210.17	61.00	132.1
CD	1.91	1.44	14.47	1.70	NS
Phosphorous (P_2O_5)					
20	16.73	12.16	212.05	62.33	135.4
30	16.04	12.67	216.87	62.88	127.3
40	18.81	14.31	236.08	63.33	131.4
CD	1.91	1.44	14.47	1.70	NS
Potassium (K_2O)					
50	15.33	10.87	202.79	63.77	132.1
75	17.26	13.65	236.16	62.44	130.2
100	17.15	12.37	226.05	61.33	131.8
CD	1.91	1.44	14.47	1.70	NS

71

Table 9c. Effect of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions on number of fruits per plant, average fruit weight per plant, yield per plant, days to first harvest and days to final harvest

Levels of nutrients	Number of fruits per plant			Average fruit weight per plant (g)			Yield per plant (g)			Days to first harvest			Days to final harvest		
N / FYM	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
10	42.6	45.2	45.8	32.5	37.4	37.9	495.1	612.4	586.6	195	190	189	396	372	387
20	46.6	43.9	45.9	33.5	38.5	41.6	654.8	645.4	620.1	193	196	186	387	389	404
30	64.2	61.9	52.6	43.8	39.9	38.4	892.8	793.1	684.6	185	180	183	413	402	398
CD	3.63			2.1			25.1			2.9			NS		
P / FYM	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
10	42.6	45.2	45.8	32.5	37.4	37.9	495.1	612.4	586.6	195	190	189	396	372	387
20	45.9	46.6	43.9	41.6	33.5	38.5	620.1	654.8	645.4	186	193	196	404	387	389
30	52.6	61.9	64.2	39.9	38.4	43.8	793.0	684.6	892.8	180	182	183	402	398	402
CD	3.63			2.1			25.1			2.9			NS		
K / FYM	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
10	42.6	45.2	45.8	32.5	37.4	37.9	495.1	612.4	586.6	195	190	189	396	372	387
20	43.9	45.9	46.6	38.5	41.6	33.5	645.4	620.1	654.8	196	186	193	389	404	387
30	52.6	64.2	61.9	38.4	43.8	39.9	684.6	892.8	793.1	183	186	180	398	404	402
CD	3.63			2.1			25.1			2.9			NS		
P / N	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
50	42.6	46.6	64.2	32.5	33.5	43.8	495.1	654.8	892.8	195	193	185	396	387	413
75	61.9	45.2	43.9	39.9	37.4	38.5	793.1	612.4	645.4	180	190	196	402	372	389
100	45.9	52.6	45.7	41.6	38.4	37.9	620.1	684.6	586.6	186	183	189	404	398	387
CD	3.63			2.1			25.1			2.9			NS		
K / N	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
50	42.6	64.2	46.6	32.5	43.8	33.5	495.1	892.8	654.8	195	185	193	396	413	387
75	43.9	45.2	61.9	38.5	37.4	39.9	645.4	612.4	793.1	196	190	180	389	372	402
100	52.6	45.9	45.8	38.4	41.6	37.9	684.6	620.1	586.6	183	186	189	398	404	387
CD	3.63			2.1			25.1			2.9			NS		
K / P	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
20	42.6	45.9	61.9	32.5	41.6	39.9	495.1	620.1	793.1	195	186	180	396	404	402
30	52.5	45.1	46.5	38.4	37.4	33.5	684.6	612.4	654.8	183	190	193	398	372	387
40	43.9	64.2	45.8	38.5	43.8	37.9	645.4	892.8	586.6	196	185	189	389	413	387
CD	3.63			2.1			25.1			2.9			NS		

It was noted that FYM at third level (30 t ha^{-1}) recorded significantly higher number of fruits per plant. N at first level (50 kg ha^{-1}) recorded maximum number of fruits per plant which was on par with N at second level. P at third level (40 kg ha^{-1}) produced significantly higher number of fruits per plant. K at second level (75 kg ha^{-1}) recorded maximum number of fruits per plant which was on par with third level of K (100 kg ha^{-1}).

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were significant on number of fruits per plant. Third level of FYM (30 t ha^{-1}) and first level of N (50 kg ha^{-1}) recorded maximum number of fruits per plant which was on par with third level of FYM (30 t ha^{-1}) and second level of N (75 kg ha^{-1}).

Third level of FYM (30 t ha^{-1}) and third level of P (40 kg ha^{-1}) produced the highest number of fruits per plant which was on par with third level of FYM (30 t ha^{-1}) and second level of P (30 kg ha^{-1}).

FYM x K interactions, third level of FYM (30 t ha^{-1}) and second level of K (75 kg ha^{-1}) were noted to produce maximum number of fruits which was on par with third level of FYM (30 t ha^{-1}) and third level of K (100 kg ha^{-1}).

In case of N x P interactions, first level of N (50 kg ha^{-1}) and third level of P (40 kg ha^{-1}) recorded significantly higher number of fruits per plant.

First level of N (50 kg ha^{-1}) and second level of K (75 kg ha^{-1}) recorded the highest number of fruits with respect to N x K interactions,

In case P x K interactions, third level of P (40 kg ha^{-1}) and second level of K (75 kg ha^{-1}) was noted to produce significantly higher number of fruits per plant.

4.3.2 Average fruit weight per plant

Application of different combinations of FYM, N, P and K were significant on average fruit weight per plant. Among different combinations of nutrients, T_7 recorded the maximum fruit weight of 14.6 g which was on par with T_6 (13.88 g), T_8 (13.3 g), T_5 (12.83 g), T_9 (12.8 g) and T_3 (12.63 g). It was followed by T_2 (12.45 g) which was on par with T_4 (11.17 g) and T_1 (10.82 g). The lowest average fruit weight was noted in T_{10} (9.32 g).

Among the different levels of FYM, third level of FYM (30 t ha^{-1}) recorded significantly higher average fruit weight per plant. N at first level (50 kg ha^{-1}) produced maximum average fruit weight which was on par with N at second level (75 kg ha^{-1}). P at third level (40 kg ha^{-1}) recorded significantly higher average fruit weight per plant. Second level of K (75 kg ha^{-1}) produced maximum average fruit weight per plant which was on par with third level of K (100 kg ha^{-1}).

FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were significant on average fruit weight per plant. Third level of FYM (30 t ha^{-1}) and first level of N (50 kg ha^{-1}) produced significantly higher average fruit weight.

As regards FYM x P interactions, third level of FYM (30 t ha^{-1}) and third level of P (40 kg ha^{-1}) recorded significantly higher average fruit weight.

FYM at third level (30 t ha^{-1}) and K at second level (75 kg ha^{-1}) recorded the maximum average fruit weight in case of FYM x K interactions.

In case of N x P interactions, first level of N (50 kg ha^{-1}) and third level of P (40 kg ha^{-1}) produced significantly higher average fruit weight.

First level of N (50 kg ha^{-1}) and second level of K (75 kg ha^{-1}) was found to have maximum average fruit weight with respect to N x K interactions.

74

In the case of P x K interaction, third level of P (40 kg ha^{-1}) and second level of K (75 kg ha^{-1}) recorded the highest average fruit weight per plant.

4.3.3 Yield per plant

Application of different combinations of FYM, N, P and K were significant on yield per plant (Table 9a). The maximum yield was noted in T_7 (297.6 g) which was on par with T_8 (264.36 g). It was followed by T_9 (228.21 g) which was on par with T_4 (218.26 g), T_5 (215.13 g), T_6 (206.7 g) and T_2 (204.13 g). It was followed by T_3 (195.53 g). The lowest yield was recorded by T_{10} (158.46 g) which was on par with T_1 (165.03 g).

Application of graded doses of FYM, N, P and K significantly influenced yield per plant (Table 9b). FYM at third level (30 t ha^{-1}) recorded significantly higher yield per plant. N at first level (50 kg ha^{-1}) produced maximum yield which was on par with N at second level (75 kg ha^{-1}). P at third level (40 kg ha^{-1}) produced significantly higher yield per plant. K at second level (75 kg ha^{-1}) produced maximum yield which was on par with K at third level (100 kg ha^{-1}).

FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were significant on yield per plant (Table 8c). Third level of FYM (30 t ha^{-1}) and first level of N (50 kg ha^{-1}) produced significantly higher yield.

With respect to FYM x P interactions, FYM at third level (30 t ha^{-1}) and P at third level (40 kg ha^{-1}) recorded significantly higher yield per plant in case of FYM x P interactions.

In case of FYM x K interactions, third level of FYM (30 t ha^{-1}) and second level of K (75 kg ha^{-1}) were found to produce significantly higher yield.

First level of N (50 kg ha^{-1}) and third level of P (40 kg ha^{-1}) produced maximum yield in case of N x P interactions.

As regards N x K interactions, N at first level (50 kg ha^{-1}) and K at second level (75 kg ha^{-1}) recorded significantly higher yield.

In case of P x K interactions, third level of P (40 kg ha^{-1}) and second level of K (75kg ha^{-1}) recorded the maximum yield.

4.3.4 Days to first harvest

The influence of different combinations of FYM, N, P and K were significant on days to first harvest (Table 8a). The lowest days to first harvest was recorded in T_8 (60) which was on par with T_9 (61), T_7 (61.6) and T_6 (62). The maximum days to first harvest was recorded in T_5 (65.33) which was on par with T_1 (65), T_{10} (65), T_4 (64.33), T_2 (63.3) and T_3 (63).

Different levels of FYM, N, P and K were found to be significant. Third level of FYM (30 t ha^{-1}) recorded minimum days to first harvest. Third level of N (100 kg ha^{-1}) also recorded minimum days to first harvest. P at first level (20 kg ha^{-1}) recorded lower days to first harvest which was on par with P at second level (30 kg ha^{-1}). Third level of K (100 kg ha^{-1}) recorded minimum days to first harvest which was on par with K at second level (75 kg ha^{-1}).

FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were having significant effect on days to first harvest (Table 9c).

In case of FYM x N interactions, FYM at third level (30 t ha^{-1}) and N at second level (75 kg ha^{-1}) recorded minimum days to first harvest.

FYM at third level (30 t ha^{-1}) and P at first level (20 kg ha^{-1}) recorded minimum days to first harvest which was on par with FYM at third level (30 t ha^{-1}) and P at second level (30 kg ha^{-1}) with respect to FYM x P interactions.

76

As regards FYM x K interactions, FYM at third level (30 t ha^{-1}) and K at third level (100 kg ha^{-1}) recorded minimum days to first harvest.

Second level of N (75 kg ha^{-1}) and first level of P (20 kg ha^{-1}) recorded significantly lower number of days to first harvest in case of N x P interactions.

In case of N x K interactions, second level of N (75 kg ha^{-1}) and third level of K (100 kg ha^{-1}) recorded minimum days to first harvest.

Among P x K interactions, plants receiving the first level of P (20 kg ha^{-1}) and third level of K (100 kg ha^{-1}) registered significantly lower days to first harvest.

4.3.5 Days to final harvest

The effect of different treatments on days to final harvest was not significant (Table 9a).

Different levels of nutrients had no effect on days to final harvest.

FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions also had no effect on days to final harvest.

4.4 Quality attributes

Various observations on quality characters *viz.,* total soluble solids (TSS), acidity, TSS/acidity ratio, total sugars and shelf life of strawberry plants grown under different nutrient combinations were recorded, analyzed and the results are presented in Table 10a, 10b and 10c.

4.4.1 Total soluble solids (TSS)

There was no significant effect on TSS content of the fruits due to the application of different treatments.

Application of different levels of nutrients had no effect on TSS content of the fruits.

FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were not having significant effect on TSS content of the fruits.

4.4.2 Acidity

Application of different treatments had no effect on acidity of the fruits.

Application of different levels of nutrients had no significant effect on acidity of the fruits.

Influence of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were found to be non-significant on acidity.

4.4.3 TSS/acidity ratio

Application of different treatments had no effect on TSS/acidity ratio of the fruits.

Application of different levels of nutrients had no effect on TSS/acidity ratio of the fruits.

Effect of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions on TSS / acidity ratio of the fruits was non-significant.

78

Table 10a. Effect of different combinations of FYM, nitrogen, phosphorous and potassium on total soluble solids (TSS), acidity, TSS / acidity ratio and total sugars

Treatments	TSS (° Brix)	Acidity (%)	TSS / Acidity ratio	Total sugars (%)
T_1 (10:50:20:50)	6.8	0.76	8.95	4.23
T_2 (10:75:30:75)	7.60	1.04	7.31	3.75
T_3 (10:100:40:100)	8.13	0.83	10.0	5.20
T_4 (20:50:30:100)	7.70	0.75	10.27	4.27
T_5 (20:75:40:50)	6.57	0.84	7.74	4.63
T_6 (20:100:20:75)	7.90	0.70	11.29	4.47
T_7 (30:50:40:75)	8.33	0.62	13.39	5.24
T_8 (30:75:20:100)	8.66	0.67	12.84	5.50
T_9 (30:100:30:50)	8.30	0.72	11.25	5.67
T_{10} (Absolute control)	6.20	0.69	8.98	3.74
CD	NS	NS	NS	1.01

Table 10b. Effect of different levels of farm yard manure, nitrogen, phosphorous and potassium on total soluble solids (TSS), acidity, TSS / acidity ratio and total sugars

FYM	TSS (° Brix)	Acidity (%)	TSS / Acidity ratio	Total sugars (%)
10	7.51	0.84	8.75	4.40
20	7.39	0.76	9.76	4.45
30	8.43	0.67	12.49	5.50
CD	NS	NS	NS	1.03
Nitrogen (N)				
50	7.61	0.71	10.87	4.56
75	7.67	0.85	9.29	4.62
100	8.11	0.75	10.84	5.71
CD	NS	NS	NS	1.03
Phosphorous (P_2O_5)				
20	7.78	0.77	11.02	4.56
30	7.61	0.78	9.61	5.92
40	7.67	0.75	10.37	4.75
CD	NS	NS	NS	1.03
Potassium (K_2O)				
50	7.22	0.77	9.31	6.00
75	7.94	0.78	10.6	4.84
100	8.16	0.75	11.03	4.47
CD	NS	NS	NS	1.03

Table 10c. Effect of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions on total soluble solids (TSS), acidity, TSS / acidity ratio and total sugars

Levels of nutrients	TSS (° Brix)			Acidity (%)			TSS / Acidity ratio			Total sugars (%)		
N / FYM	50	75	100	50	75	100	50	75	100	50	75	100
10	20.4	22.8	24.4	2.3	3.1	2.5	26.9	21.9	30.0	12.7	11.2	15.6
20	23.1	19.7	23.7	2.3	2.5	2.1	30.8	23.2	33.9	12.8	13.9	13.4
30	25.0	26.0	24.9	1.9	2.0	2.2	40.2	38.5	33.8	15.7	16.5	17.1
CD	NS			NS			NS			1.1		
P / FYM	20	30	40	20	30	40	20	30	40	20	30	40
10	20.4	22.8	24.4	2.3	3.1	2.5	26.9	21.9	30.0	12.7	11.6	15.6
20	23.7	23.1	19.7	2.1	2.3	2.5	33.9	30.8	23.2	13.4	12.8	13.9
30	26.0	24.9	26.0	2.0	2.2	2.0	38.5	33.8	38.5	15.7	17.1	16.5
CD	NS			NS			NS			1.1		
K / FYM	50	75	100	50	75	100	50	75	100	50	75	100
10	20.4	22.8	24.4	2.3	3.1	2.5	26.9	21.9	30.0	12.7	11.2	15.6
20	19.7	23.7	23.1	2.5	2.1	2.3	23.2	33.9	30.8	13.9	13.4	12.8
30	24.9	23.7	26.0	2.2	2.1	2.0	33.8	33.9	38.5	17.1	16.5	13.4
CD	NS			NS			NS			1.1		
P / N	20	30	40	20	30	40	20	30	40	20	30	40
50	20.4	23.1	25.0	2.3	2.3	1.9	26.9	30.8	40.2	12.7	12.8	15.7
75	26.0	22.8	19.7	2.0	3.1	2.5	38.5	21.9	23.2	16.5	11.2	13.9
100	23.7	24.9	24.4	2.1	2.2	2.5	33.9	33.8	30.0	13.4	17.1	15.6
CD	NS			NS			NS			1.1		
K / N	50	75	100	50	75	100	50	75	100	50	75	100
50	20.4	25.0	23.1	2.3	1.9	2.3	26.9	40.2	30.8	12.7	15.7	12.8
75	19.7	22.8	26.0	2.5	3.1	2.0	23.2	21.9	38.5	13.9	11.2	16.5
100	24.9	23.7	24.4	2.2	2.1	2.5	33.8	33.9	30.0	17.1	13.4	15.6
CD	NS			NS			NS			1.1		
K / P	50	75	100	50	75	100	50	75	100	50	75	100
20	20.4	23.7	26.0	2.3	2.1	2.0	26.9	33.9	38.5	12.7	13.4	16.5
30	24.9	22.8	23.1	2.2	3.1	2.3	33.8	21.9	30.8	17.1	11.2	12.8
40	19.7	25.0	24.4	2.5	1.9	2.5	23.2	40.2	30.0	13.9	15.7	15.6
CD	NS			NS			NS			1.1		

4.4.4 Total sugars

Among the treatments, T_9 (5.67 %) recorded the maximum content of total sugars which was on par with T_8 (5.50 %), T_7 (5.24 %) and T_3 (5.2 %). It was followed by T_5 (4.63 %) which was on par with T_6 (4.47 %), T_4 (4.27 %), T_1 (4.23 %), T_2 (3.75 %) and T_{10} (3.74 %).

Among different levels of nutrients, third level of FYM (30 t ha^{-1}), third level of N (100 kg ha^{-1}), second level of P (30 kg ha^{-1}), and first level of K (50 kg ha^{-1}) registered significantly higher total sugar content in the fruit.

FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions had significant effect on total sugar content of the fruit.

As regards FYM x N interactions, third level of FYM (30 t ha^{-1}) and third level of N (100 kg ha^{-1}) recorded maximum content of total sugars which was on par with third level of FYM and second level of N.

Interactions between FYM at third level (30 t ha^{-1}) and P at second level (30 kg ha^{-1}) recorded significantly higher content of total sugars which was on par with FYM at third level and P at third level.

In case of FYM x K interactions, third level of FYM (30 t ha^{-1}) and first level of K (50 kg ha^{-1}) recorded the highest total sugar which was on par with third level of FYM (30 t ha^{-1}) and second level of K (75 kg ha^{-1}).

With respect to N x P interactions, third level of N (100 kg ha^{-1}) and second level of P (30 kg ha^{-1}) recorded significantly higher content of total sugars.

Third level of N (100 kg ha^{-1}) and first level of K (50 kg ha^{-1}) recorded maximum content of total sugars in case of N x K interactions.

In case of P x K interactions, second level of P (30 kg ha^{-1}) and first level of K (50 kg ha^{-1}) recorded significantly higher total sugar content.

4.4.5 Sensory evaluation

Data corresponding to the sensory evaluation of strawberry fruits grown under different nutrient combinations are presented in Table 11.

In strawberry, colour, taste, flavor and texture contribute to the fruit quality. Hence for quality assessment, sensory evaluation was carried out on a nine point hedonic scale using score card for eight attributes namely appearance, color, texture, flavor, odor, taste, after taste and overall acceptability. Sensory evaluation was conducted on the same day of harvest. Among the nine treatments, the highest score for appearance was recorded by T_8 and the lowest was recorded by T_2. The highest score for color was recorded by T_7 and the lowest by T_{10}. For flavor, T_7 recorded the maximum score and minimum was recorded by T_{10}. In case of taste, highest score was recorded by T_7 and the minimum score by T_2. For texture, T_4 recorded the highest score and the lowest was recorded by T_{10}. T_1 recorded highest score in terms of after-taste and T_8 recorded the minimum. Finally in case of overall acceptability, T_7 was found to have the highest score and T_{10} recorded the lowest.

4.5 Plant analysis

The effect of treatments on the plant N, P, K, Ca and Mg are presented in Table 12a, 12b and 12c.

4.5.1 Nitrogen

Application of different treatments was not significant on plant N content.

The effect of different levels of nutrients had no significant effect plant N content.

Table 11. Sensory evaluation of strawberry fruits from different treatments

Treatments	Appearance	Color	Flavour	Odour	Taste	Texture	After taste	Overall Acceptability	Total score
T_1	6.57 (6.14)	7.57 (6.04)	6.57 (5.36)	7.29 (5.93)	5.43 (4.14)	6.00 (4.79)	5.57 (4.21)	6.52 (5.10)	51.52
T_2	5.57 (3.93)	5.71 (4.00)	5.71 (4.43)	5.71 (4.29)	5.71 (4.71)	6.14 (5.21)	5.86 (4.72)	5.63 (4.14)	46.06
T_3	6.14 (5.00)	5.86 (4.20)	5.14 (3.86)	5.57 (4.50)	6.14 (5.36)	5.57 (3.79)	5.71 (4.29)	5.82 (4.43)	45.96
T_4	6.24 (5.86)	5.94 (4.79)	6.04 (5.00)	6.04 (4.83)	6.01 (5.00)	6.23 (5.36)	6.40 (5.66)	6.46 (4.93)	49.37
T_5	5.91 (4.50)	6.53 (5.50)	5.86 (4.43)	5.70 (4.21)	6.26 (5.21)	5.80 (4.43)	5.87 (4.71)	6.26 (5.07)	48.19
T_6	7.09 (6.71)	6.64 (5.62)	6.31 (4.91)	6.07 (6.14)	6.26 (5.29)	6.41 (5.57)	6.50 (5.43)	6.61 (4.83)	51.90
T_7	6.57 (6.57)	7.14 (6.79)	6.07 (4.61)	6.29 (5.42)	7.21 (6.61)	6.43 (5.61)	6.36 (5.24)	7.14 (6.36)	53.21
T_8	6.20 (5.43)	6.57 (5.00)	6.54 (5.14)	6.71 (5.43)	7.37 (6.75)	6.36 (5.54)	6.36 (5.43)	6.76 (5.50)	52.87
T_9	7.21 (6.50)	6.79 (5.71)	6.36 (5.04)	6.46 (5.74)	6.46 (5.26)	6.83 (5.66)	6.27 (5.36)	6.23 (4.93)	52.60
T_{10}	5.14 (2.79)	5.45 (3.57)	5.93 (4.21)	5.36 (3.29)	4.71 (3.29)	5.57 (5.28)	5.36 (3.86)	5.42 (2.71)	42.84
Kendal's W	0.28	0.25	0.12	0.27	0.27	0.18	0.18	0.42	

Table 12a. Effect of different combinations of FYM, nitrogen, phosphorous and potassium on nitrogen, phosphorous, potassium, calcium and magnesium content of plants

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T_1 (10:50:20:50)	0.31	0.34	1.70	1.21	0.34
T_2 (10:75:30:75)	1.27	0.35	2.11	1.28	0.35
T_3 (10:100:40:100)	1.30	0.44	2.08	1.06	0.34
T_4 (20:50:30:100)	1.28	0.41	2.40	1.16	0.32
T_5 (20:75:40:50)	1.09	0.38	1.93	1.18	0.34
T_6 (20:100:20:75)	1.61	0.38	2.14	1.20	0.32
T_7 (30:50:40:75)	1.26	0.40	2.55	1.20	0.33
T_8 (30:75:20:100)	1.29	0.45	3.28	1.16	0.36
T_9 (30:100:30:50)	1.30	0.49	1.72	1.37	0.37
T_{10}(Absolute control)	0.29	0.24	1.67	0.92	0.27
CD	NS	NS	NS	NS	0.05

Table 12b. Effect of different levels of FYM, nitrogen, phosphorous and potassium on nitrogen, phosphorous, potassium, calcium and magnesium content of plants

Levels of nutrients	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
FYM					
10	0.96	0.37	1.96	1.18	0.35
20	1.32	0.39	2.15	1.18	0.36
30	1.29	0.45	2.51	1.24	0.39
CD	NS	NS	NS	NS	0.03
Nitrogen (N)					
50	0.95	0.38	2.21	1.19	0.35
75	1.22	0.39	2.44	1.20	0.38
100	1.40	0.43	1.98	1.21	0.38
CD	NS	NS	NS	NS	0.03
Phosphorous (P_2O_5)					
20	1.07	0.39	2.37	1.19	0.37
30	1.28	0.41	2.07	1.27	0.39
40	1.22	0.40	2.18	1.14	0.38
CD	NS	NS	NS	NS	0.03
Potassium (K_2O)					
50	0.90	0.40	1.78	1.25	0.39
75	1.38	0.37	2.26	1.22	0.36
100	1.29	0.43	2.58	1.12	0.35
CD	NS	NS	NS	NS	0.03

Table 12c. Effect of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions on nitrogen, phosphorous, potassium, calcium and magnesium content of plants

Levels of nutrients	N (%)			P (%)			K (%)			Ca (%)			Mg (%)		
N / FYM	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
10	0.9	3.8	3.9	1.0	1.1	1.3	5.1	6.3	6.2	3.6	3.8	3.2	1.1	0.9	0.9
20	3.8	3.3	4.8	1.2	1.1	1.1	7.2	5.8	6.4	3.5	3.5	3.6	1.1	1.1	1.1
30	3.8	3.9	3.9	1.2	1.4	1.5	7.7	9.8	5.2	3.6	3.5	4.1	1.2	1.0	1.4
CD	NS			NS			NS			NS			0.05		
P / FYM	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
10	0.9	3.8	3.9	1.0	1.1	1.3	5.1	6.3	6.2	3.6	3.8	3.2	1.1	0.9	0.9
20	4.8	3.8	3.3	1.1	1.2	1.1	6.4	7.2	5.8	3.6	3.5	3.5	1.1	1.1	1.1
30	3.9	3.9	3.9	1.4	1.5	1.4	9.8	5.2	9.8	3.5	4.1	3.5	1.0	1.4	1.0
CD	NS			NS			NS			NS			0.05		
K / FYM	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
10	0.9	3.8	3.9	1.0	1.1	1.3	5.1	6.3	6.2	3.6	3.8	3.2	1.1	0.9	0.9
20	3.3	4.8	3.8	1.1	1.1	1.2	5.8	6.4	7.2	3.5	3.6	3.5	1.1	1.1	1.1
30	3.9	4.8	3.9	1.5	1.1	1.4	5.2	6.4	9.8	4.1	3.6	3.5	1.4	1.1	1.0
CD	NS			NS			NS			NS			0.05		
P / N	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
50	0.9	3.8	3.8	1.0	1.2	1.2	5.1	7.2	7.7	3.6	3.5	3.6	1.1	1.1	1.2
75	3.9	3.8	3.3	1.4	1.1	1.1	9.8	6.3	5.8	3.5	3.8	3.5	1.0	0.9	1.1
100	4.8	3.9	3.9	1.1	1.5	1.3	6.4	5.2	6.2	3.6	4.1	3.2	1.1	1.4	0.9
CD	NS			NS			NS			NS			0.05		
K / N	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
50	0.9	3.8	3.8	1.0	1.2	1.2	5.1	7.7	7.2	3.6	3.6	3.5	1.1	1.2	1.1
75	3.3	3.8	3.9	1.1	1.1	1.4	5.8	6.3	9.8	3.5	3.8	3.5	1.1	0.9	1.0
100	3.9	4.8	3.9	1.5	1.1	1.3	5.2	6.4	6.2	4.1	3.6	3.2	1.4	1.1	0.9
CD	NS			NS			NS			NS			0.05		
K / P	50	75	100	50	75	100	50	75	100	50	75	100	50	75	100
20	0.9	4.8	3.9	1.0	1.1	1.4	5.1	6.4	9.8	3.6	3.6	3.5	1.1	1.1	1.0
30	3.9	3.8	3.8	1.5	1.1	1.2	5.2	6.3	7.2	4.1	3.8	3.5	1.4	0.9	1.1
40	3.3	3.8	3.9	1.1	1.2	1.3	5.8	7.7	6.2	3.5	3.6	3.2	1.1	1.2	0.9
CD	NS			NS			NS			NS			0.05		

FYM x N, FYM x P, FYM x K, N x P, N x K and P x K had no effect on plant N content.

4.5.2 Phosphorous

Application of different treatments had no significant effect on plant P content.

The influence of different levels of nutrients had no effect on plant P content.

Effect of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were not having any significant effect on plant P content.

4.5.3 Potassium

Application of different treatments had no effect on plant K content.

Application of different levels of nutrients had no effect on on plant K content.

FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions also had no significant influence on plant K content.

4.5.4 Calcium

Application of different treatments had no significant effect on plant Ca content.

Application of different levels of nutrients had no significant effect on plant Ca content.

FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions also had no influence on plant Ca content.

4.5.5 Magnesium

Application of different treatments had significant effect on plant Mg content.

T_9 recorded higher plant Mg content of 0.37 percent which was on par with T_7 (0.33 %), T_1 (0.34 %), T_4 (0.32 %), T_5 (0.34 %), T_6 (0.32 %), T_8 (0.36%), T_3 (0.34 %) and T_2 (0.35 %). The lowest was noted in T_{10} (0.27 %).

Among different levels of nutrients, significantly higher content of Mg was recorded under the third level of FYM (30 t ha^{-1}), third level of N (100 kg ha^{-1}), second level of P (30 kg ha^{-1}), and first level of K (50 kg ha^{-1}).

FYM at third level (30 t ha^{-1}) and N at third level (100 kg ha^{-1}) recorded significantly higher content of Mg.

Third level of FYM (30 t ha^{-1}) and second level of P (30 kg ha^{-1}) recorded maximum content of Mg.

As regards FYM x K interactions, third level of FYM (30 t ha^{-1}) + first level of K (50 kg ha^{-1}) were noted to have highest level of plant Mg content.

In case of N x P, third level of N (100 kg ha^{-1}) and second level of P (30 kg ha^{-1}) recorded maximum Mg content.

With respect to N x K interactions, third level of N (100 kg ha^{-1}) and first level of K (50 kg ha^{-1}) recorded the highest plant Mg content.

P at second level (30 kg ha^{-1}) K at first level (50 kg ha^{-1}) were found to have the highest plant Mg content in case of P x K interactions.

4.6 Soil analysis

The important physical and chemical properties of soil before and after the experiment are presented in tables 13a and 13b respectively.

4.6.1 Soil pH

Soil samples were collected from the site before planting of the crop and recorded a pH of 5.75. After the final harvest, T_8 recorded the highest pH of 5.69 which was followed by T_2 (5.64), T_5 (5.61), T_3 (5.46), T_1 (5.40), T_6 (5.39), T_4 (5.32), T_{10} (5.18), T_7 (5.14) and T_9 (5.06).

4.6.2 Soil EC

Before planting, the EC recorded was 0.03 dSm^{-1} and after the final harvest, the highest EC was noted for T_5 (0.05 dSm^{-1}) which was followed by T_2 (0.04 dSm^{-1}), T_3 (0.04 dSm^{-1}), T_8 (0.04 dSm^{-1}), T_9 (0.04 dSm^{-1}), T_1 (0.03 dSm^{-1}), T_{10} (0.03 dSm^{-1}), T_4 (0.02 dSm^{-1}), T_6 (0.02 dSm^{-1}) and T_7 (0.02 dSm^{-1}).

4.6.3 Organic carbon

Before planting, the organic carbon content of the soil before planting was 1. 76 per cent. After the final harvest, the highest organic carbon content was recorded in T_8 (0.76 %), followed by T_9 (0.73 %), T_7 (0. 68 %), T_6 (0.55 %), T_3 (0.54%), T_2 (0.50 %), T_1 (0.48 %), T_5 (0.48 %) and T_4 (0.36 %).

Table 13a. Physio – chemical properties of soil at the experiment site before planting

Parameters	Content in the soil
Mechanical composition	
Sand	64.5 %
Silt	12.5 %
Clay	23 %
Soil pH	5.75
Soil EC (dSm^{-1})	0.03
Organic carbon (%)	1.76
Available P content (kg/ha)	18
Available K content (kg/ha)	161.3
Available Ca content (mg/kg)	186.4
Available Mg content (mg/kg)	89.7
Available S content (mg/kg)	1.65

Table 13b. Physio – chemical properties of soil at the experiment site after the experiment

Treatments	pH	EC (dSm^{-1})	Organic carbon (%)	Available P (kg/ha)	Available K (kg/ha)	Available Ca (mg/kg)	Available Mg (mg/kg)	Available S (mg/kg)
T_1 (10:50:20:50)	5.40	0.03	0.48	19.56	179.20	109.80	91.93	3.53
T_2 (10:75:30:75)	5.64	0.04	0.50	17.53	251.93	142.06	74.20	2.14
T_3 (10:100:40:100)	5.46	0.04	0.54	20.06	240.16	182.10	81.73	3.26
T_4 (20:50:30:100)	5.32	0.02	0.36	19.13	252.63	184.80	92.83	3.51
T_5 (20:75:40:50)	5.61	0.05	0.48	19.00	215.83	151.53	91.76	2.75
T_6 (20:100:20:75)	5.39	0.02	0.55	20.70	232.73	140.23	87.40	3.71
T_7 (30:50:40:75)	5.14	0.02	0.68	20.03	262.16	133.03	74.30	2.29
T_8 (30:75:20:100)	5.69	0.04	0.76	20.60	340.5	137.96	87.76	2.86
T_9 (30:100:30:50)	5.06	0.04	0.73	20.23	186.70	123.46	93.20	3.25
T_{10} (Absolute control)	5.18	0.03	0.35	15.76	140.20	138.16	79.90	3.70

4.6.4 Available Phosphorous

Available phosphorous content of 18 kg ha^{-1} was recorded before planting. After final harvest, T_5 recorded the highest available P content of 20.7 kg ha^{-1} which was followed by T_8 (20.6 kg ha^{-1}), T_9 (20.23 kg ha^{-1}), T_3 (20.06 kg ha^{-1}), T_7 (20.03 kg ha^{-1}), T_1 (19.56 kg ha^{-1}), T_4 (19.13 kg ha^{-1}), T_6 (19 kg ha^{-1}), T_2 (17.53 kg ha^{-1}) and T_{10} (15.76 kg ha^{-1}).

4.6.5 Available Potassium

Before planting, the available potassium content of the soil was 161.6 kg ha^{-1}. After the final harvest, the highest available K content recorded was in T_8 (340 kg ha^{-1}), which was followed by T_7 (262.2 kg ha^{-1}), T_4 (252.63 kg ha^{-1}), T_2 (251.9 kg ha^{-1}), T_3 (240.2 kg ha^{-1}), T_6 (232.7 kg ha^{-1}), T_5 (215.8 kg ha^{-1}), T_9 (186.7 kg ha^{-1}), T_1 (179.2 kg ha^{-1}) and T_{10} (140.2 kg ha^{-1}).

4.6.6 Available Calcium

The available calcium content of the soil before planting was 186.4 mg kg^{-1}. After the final harvest, the highest available Ca content was noted in T_4 (184.8 mg kg^{-1}), T_3 (182.1 mg kg^{-1}), T_5 (151.53 mg kg^{-1}), T_2 (142.1 mg kg^{-1}), T_6 (140.23 mg kg^{-1}), T_{10} (138.16 mg kg^{-1}), T_8 (137.96 mg kg^{-1}), T_7 (133 mg kg^{-1}) and T_9 (123.5 mg kg^{-1}).

4.6.7 Available Magnesium

The available magnesium content of the soil before planting was noted to be 89.7 mg kg^{-1}. After the final harvest, the highest Mg content was recorded in T_9 (93.2 mg kg^{-1}), T_4 (92.8 mg kg^{-1}), T_1 (91.9 mg kg^{-1}), T_5 (91.7 mg kg^{-1}), T_8 (87.7 mg kg^{-1}), T_6 (87.4 mg kg^{-1}), T_3 (81.7 mg kg^{-1}), T_{10} (79.9 mg kg^{-1}), T_7 (74.3 mg kg^{-1}) and T_2 (74.2 mg kg^{-1}).

4.6.8 Available Sulphur

The available sulphur content of 1.65 mg kg^{-1} was recorded before planting. After the final harvest, T_6 recorded the highest S content of 3.71 mg kg^{-1} which was followed by T_{10} (3.70 mg kg^{-1}), T_1 (3.53 mg kg^{-1}), T_4 (3.51 mg kg^{-1}), T_3 (3.26 mg kg^{-1}), T_9 (3.25 mg kg^{-1}), T_8 (2.86 mg kg^{-1}), T_5 (2.75 mg kg^{-1}), T_7 (2.29 mg kg^{-1}) and T_2 (2.14 mg kg^{-1}).

4.7 Post harvest study

4.7.1 Shelf life in days

The effect of treatments on shelf life of strawberry fruits are presented in table 14.

There was no significant effect on shelf life of strawberry fruits due to the application of treatments. Mean shelf life of three days was observed when the fruits were stored in ambient temperature after harvest of the fruit at 75 per cent ripened stage.

4.8 Pest and disease incidence

During the entire period of study, no severe incidence of pests and diseases were noted. Pests such as hairy caterpillar and fruit borer were noticed. As disease, and leaf blight and powdery mildew were also noticed.

Table 14. Shelf life of strawberry from different treatments

Treatments	Shelf life (days)
T_1 (10:50:20:50)	2
T_2 (10:75:30:75)	2
T_3 (10:100:40:100)	3
T_4 (20:50:30:100)	2
T_5 (20:75:40:50)	3
T_6 (20:100:20:75)	3
T_7 (30:50:40:75)	2
T_8 (30:75:20:100)	3
T_9 (30:100:30:50)	3
T_{10} (Absolute control)	2
CD	NS

Discussion

5. DISCUSSION

An experiment entitled 'Nutrient management in strawberry (*Fragaria x ananassa* Duch.)' was conducted to study the effect of major nutrients applied viz., organic carbon (FYM), N, P_2O_5 and K_2O on the growth and yield characters of strawberry under the agro-climatic conditions of Wayanad. The results of the experiment are discussed under eight heads namely, vegetative growth attributes, flowering attributes, yield attributes, quality attributes, plant analysis, soil analysis, pest and disease incidences and benefit cost ratio.

5.1 Vegetative growth attributes

5.1.1 Plant height

All the treatments were on par and superior over the control (T_{10}) in case of plant height. This may be due to better uptake of nutrients like nitrogen available from organic manure and inorganic fertilizer applied which has a major role in increasing cell division and improving plant growth. FYM and inorganic fertilisers recorded the highest cation exchange capacity and soil organic carbon. The interaction effect of both organic and inorganic fertilizers increase the available NPK status, microbial biomass and dehydrogenase activity and hence increasing the height and spread of the plant. Khalid *et al.* (2010) reported positive influence on plant height of strawberry upon increased application of organic manure.

It was noted that application of graded doses of FYM, N, P and K did not influence plant height significantly.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were non- significant on plant height at all stages of growth.

Fig 2. Plant height (cm) of strawberry plants under different treatment combinations

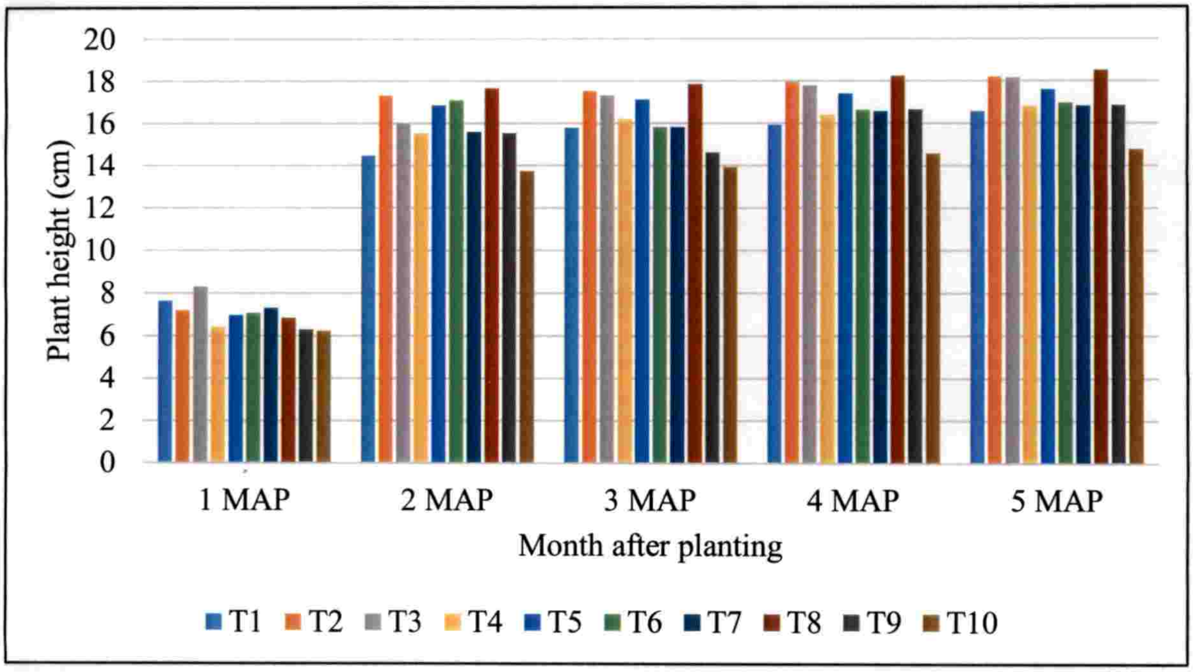


Fig 3. Plant spread (cm) of strawberry plants under different treatment combinations

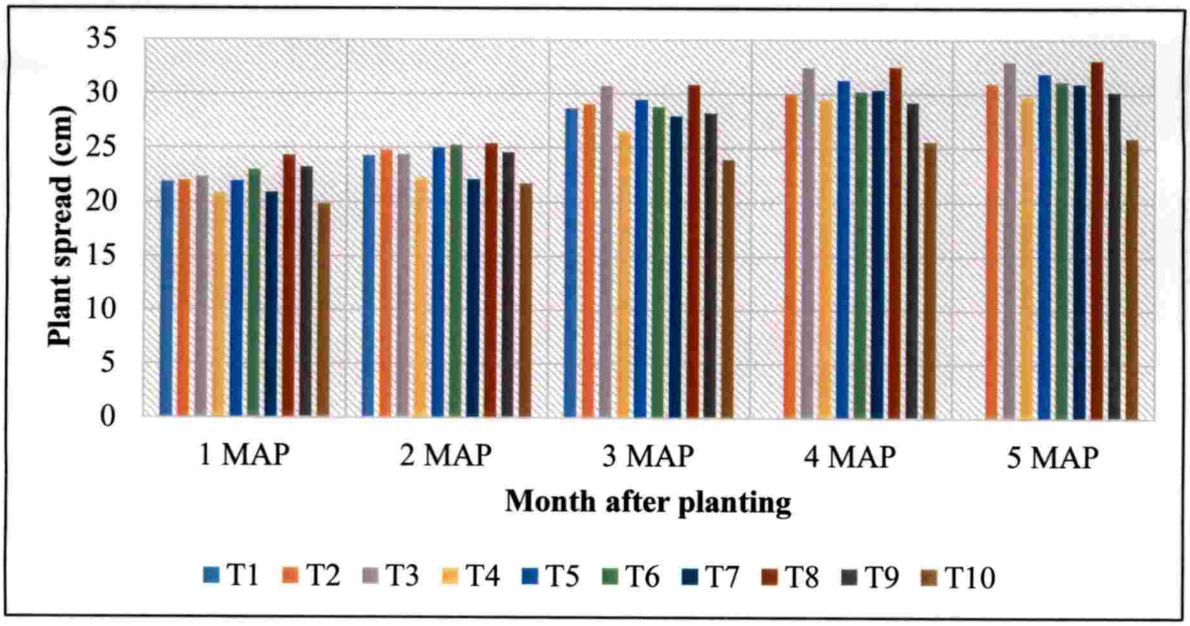


Fig 4. No. of leaves of strawberry plants under different treatment combinations

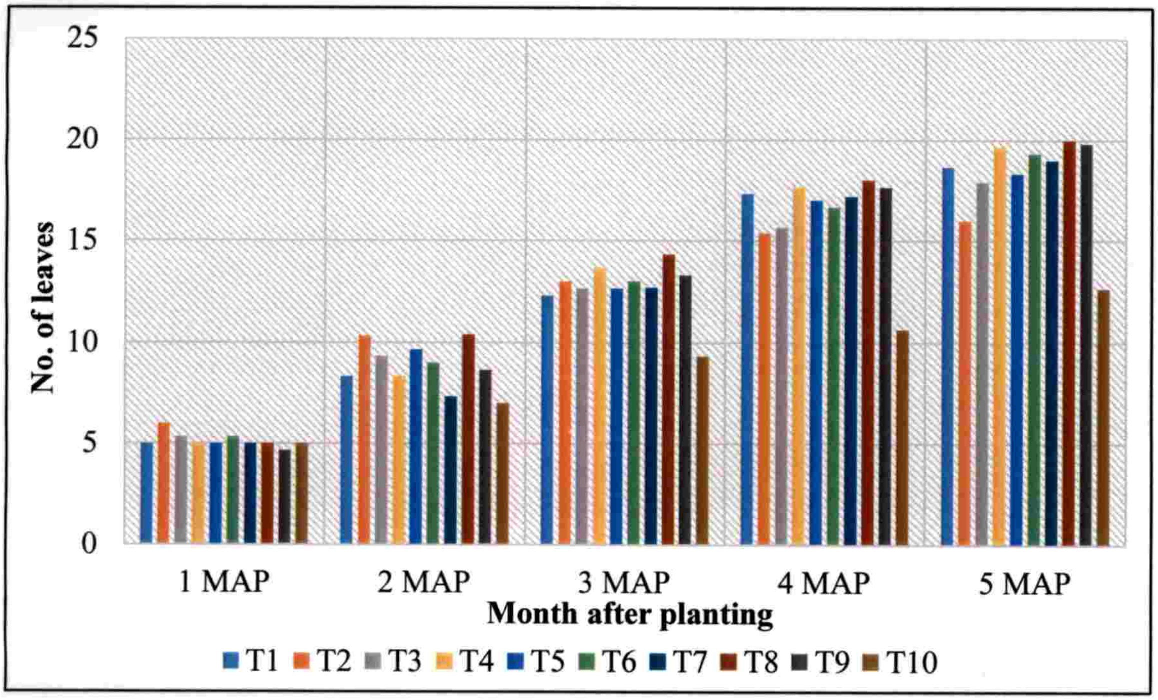
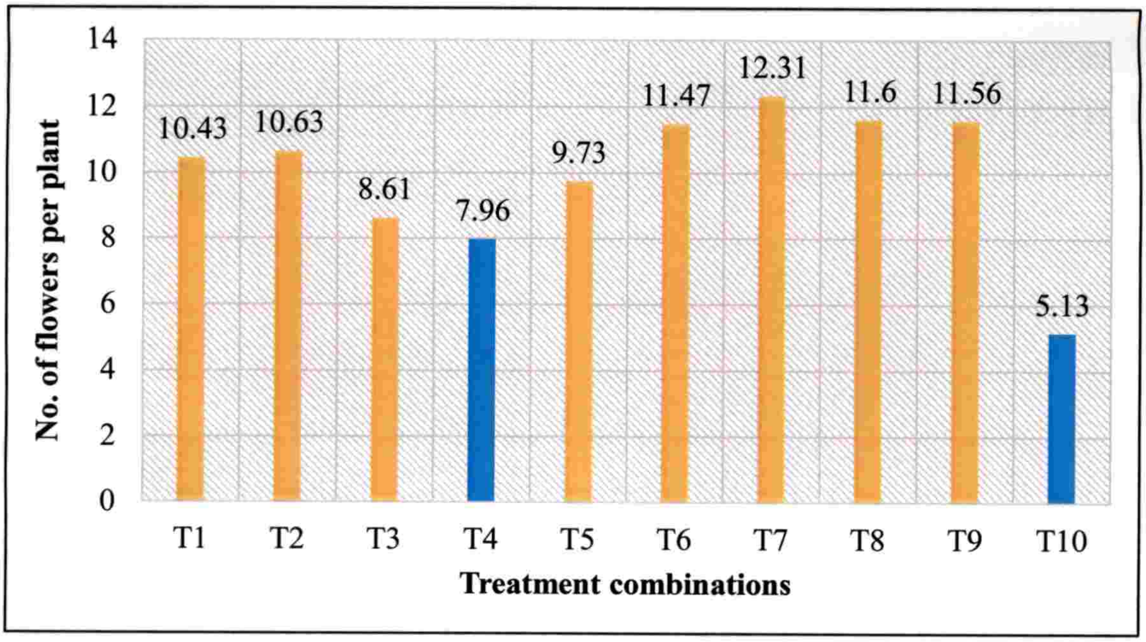


Fig 5. No. of flowers per strawberry plant under different treatment combinations



5.1.2 Plant spread

In case of plant spread, T_2, T_3, T_5, T_6, T_7, T_8 and T_9 were on par and superior over the control while T_1 and T_4 were on par with each other but differs with other treatments. This may be due to the positive influence of incremental doses of organic carbon (FYM) and N applied. Improved vegetative characters were noticed in all treatments over the control as organic amendments improve vegetative growth characters in strawberry by increasing soil enzyme activity and improving soil aeration (Bhattacharrya *et al.*, 2003).

The effect of different levels of FYM, N, P_2O_5 and K_2O was significant only at 2 MAP.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were significant only at 2 MAP.

5.1.3 Number of leaves per plant

All the treatments except T_2 were on par and superior over the control with respect to number of leaves per plant. The total number of leaves produced per plant was significantly influenced by application of incremental doses of FYM and nitrogen. Being a key element of plant growth, effect of organic carbon and nitrogen on vegetative growth is reflected on the number of leaves produced by the plant. This is in accordance with the findings of Ahmad *et al.*, (2011) in strawberry.

The effect of different levels of FYM, N, P and K was significant only at 5 MAP.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were significant only at 5 MAP.

5.2 Flowering attributes

5.2.1 Days to first flowering

The days to first flowering ranged from 47 to 55 days and was not significantly influenced by the application of different treatments. In strawberry, earliness may be due to the optimum supply of plant nutrients in the right amount during the entire crop period in the form of organic and inorganic fertilisers which induces vegetative growth and photosynthesis and ultimately earliness in flowering.

Application of graded doses of FYM, N, P and K did not influence days to first flowering.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were non- significant on days to first flowering.

5.2.2 Number of flowers per plant

With respect to number of flowers per plant, T_1, T_2, T_3, T_5, T_6, T_7, T_8 and T_9 were on par and superior over the control while T_4 was on par with the control (T_{10}). Addition of organic manure might have influenced the formation of more number of flowers in plots receiving treatments other than the control. This is in accordance with the findings of Ali *et al.* (2003) in strawberry.

It was noted that application of graded doses of FYM, N, P and K did not influence number of flowers per plant.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were non- significant on number of flowers per plant.

Fig 6. No. of clusters per plant of strawberry plants under different treatment combinations

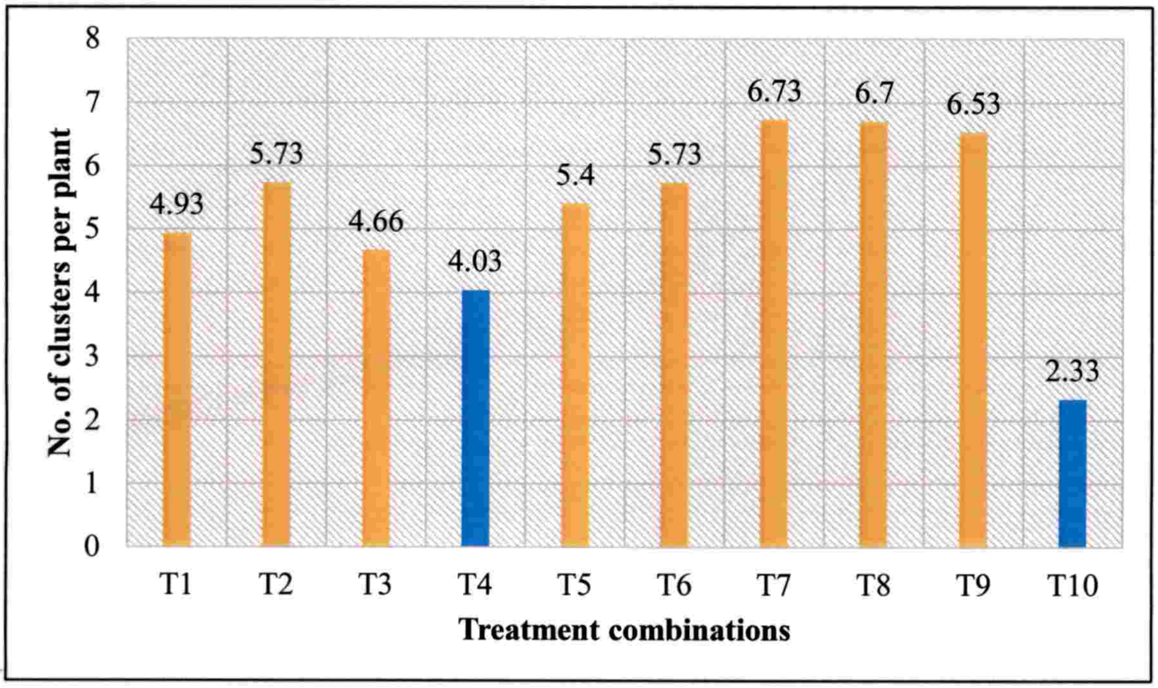
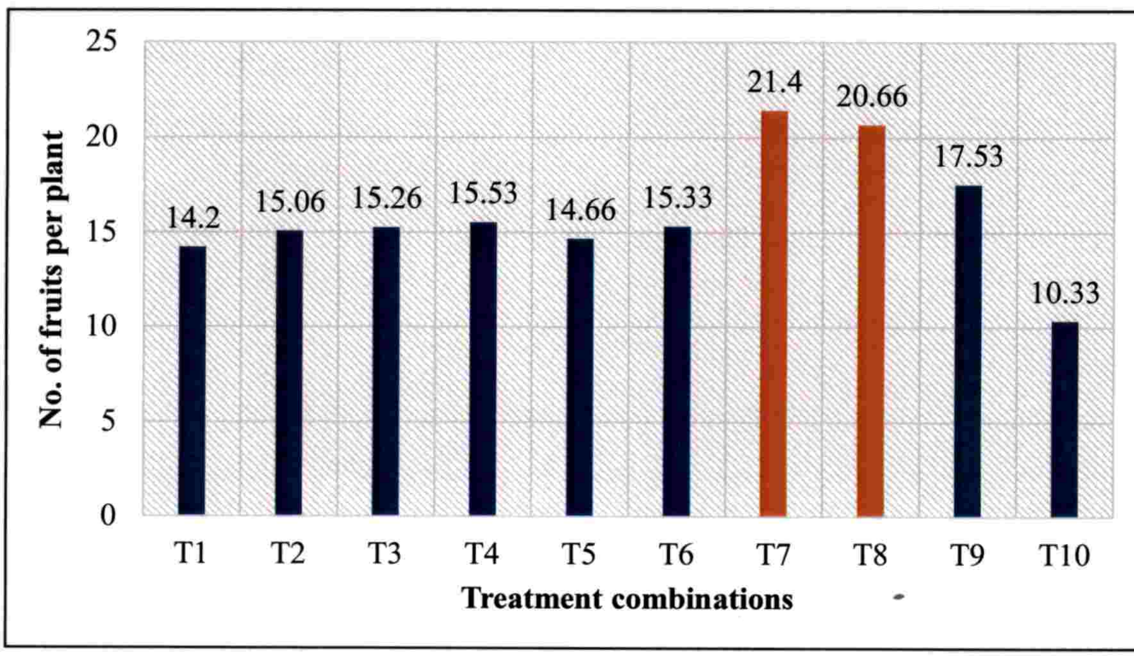


Fig 7. No. of fruits per plant of strawberry plants under different treatment combinations



5.2.3 Number of clusters per plant

In case of number of clusters also, T_1, T_2, T_3, T_5, T_6, T_7, T_8 and T_9 were on par and superior over the control while T_4 was on par with the control (T_{10}). This may be due to production of more number of flowers in plants receiving treatments other than the control. This is in accordance with the findings of Ali *et al.* (2003) in strawberry.

It was noted that application of graded doses of FYM, N, P and K did not influence number of clusters per plant.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were non- significant on number of clusters per plant.

5.3. Yield attributes

5.3.1 Number of fruits per plant

With respect to number of fruits per plant, the effect of T_7 (FYM 30 t ha^{-1} + NPK 50:40:75 kg ha^{-1}) and T_8 (FYM 30 t ha^{-1} + NPK 75:20:100 kg ha^{-1}) were on par and superior over other treatments including T_1, T_2, T_3, T_4, T_5, T_6 and T_9 which were on par and superior over the control. This may be due to the increased photosynthetic ability of the plant resulting from improved vegetative growth due to application of organic manure. The findings are in agreement with those of Ali *et al.* (2003) and Odongo *et al.* (2008) who found significant increase in fruit set and yield with application of farm yard manure.

The effect of different levels of FYM, N, P_2O_5 and K_2O was found to be significant.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were significant on number of fruits per plant.

99

Fig 8. Yield per plant (g) of strawberry plants under different treatment combinations

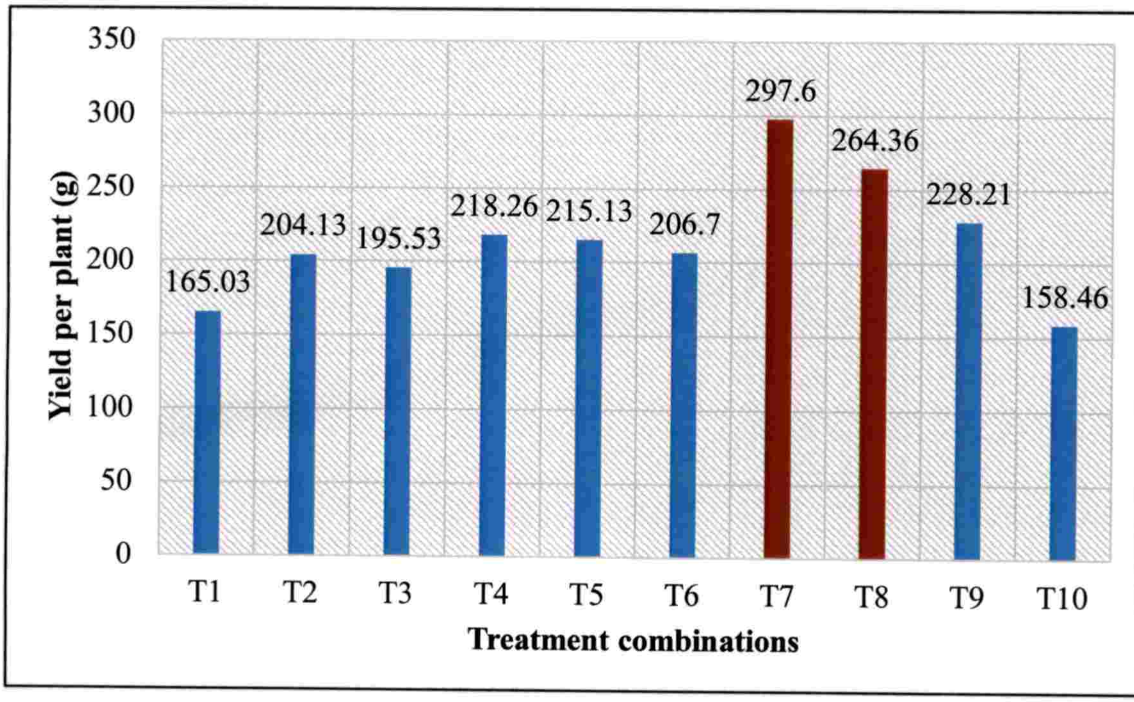
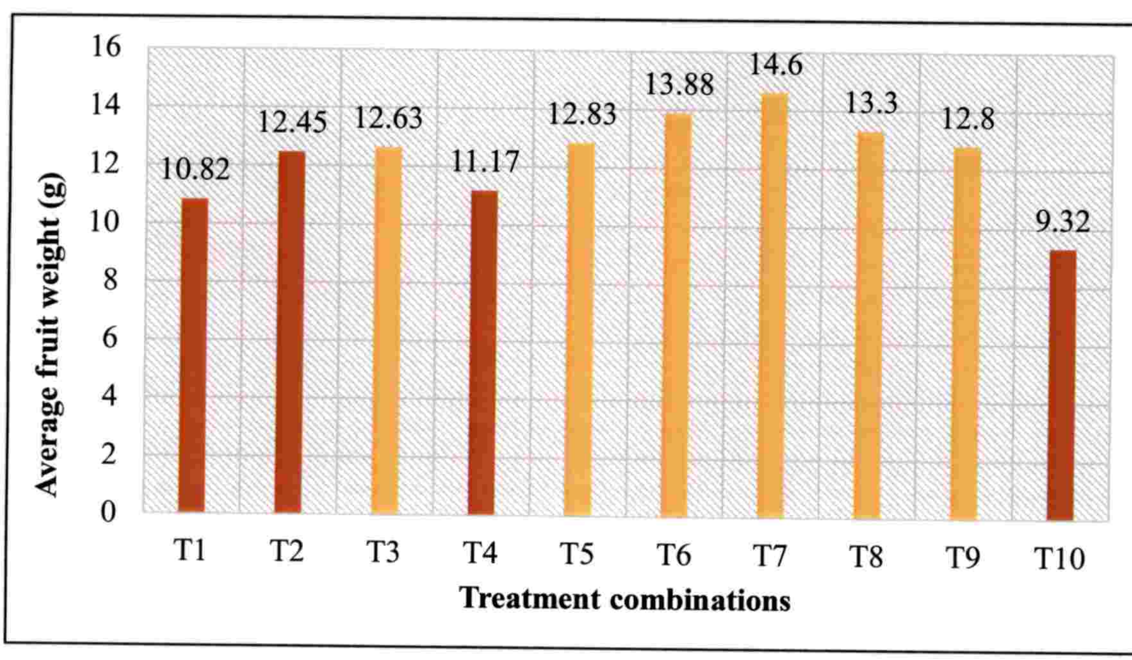


Fig 9. Average fruit weight (g) of strawberry plants under different treatment combinations



5.3.2 Yield per plant

In case of yield per plant, the effect of T_7 (FYM 30 t ha^{-1} + NPK 50:40:75 kg ha^{-1}) and T_8 (FYM 30 t ha^{-1} + NPK 75:20:100 kg ha^{-1}) were on par and superior over other treatments including T_1, T_2, T_3, T_4, T_5, T_6 and T_9 which were on par and superior over the control. This may be due to the increased photosynthetic ability of the plant resulting from improved vegetative growth due to application of organic manure. The findings are in agreement with those of Ali *et al.* (2003) and Odongo *et al.* (2008) who found significant increase in fruit set and yield with application of farm yard manure. Singh *et al.* (2015) obtained similar results on application of 75 percentage nitrogen along with organic manure. Formation of more metabolites by increased number leaves and high rate of photosynthesis was reported in strawberry by Hossan *et al.* (2013).

The effect of different levels of FYM, N, P_2O_5 and K_2O was found to be significant.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were significant on yield per plant.

5.3.3 Average fruit weight per plant

Average fruit weight recorded under T_3, T_5, T_6, T_7, T_8, and T_9 were on par and was followed by T_2 on par with T_4 and T_1. This may be due to production of fruits with improved size and volume along with improved vegetative growth characters.

The effect of different levels of FYM, N, P_2O_5 and K_2O was found to be significant.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were significant on average fruit weight per plant.

Fig 10. Days to first harvest of strawberry plants under different treatment combinations

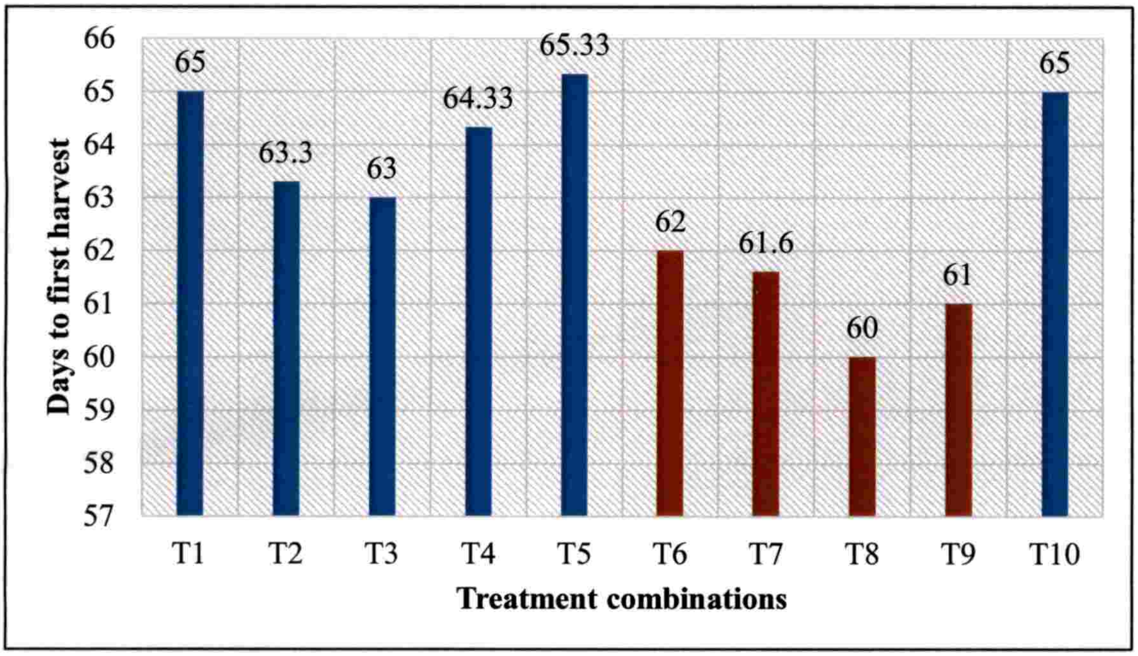
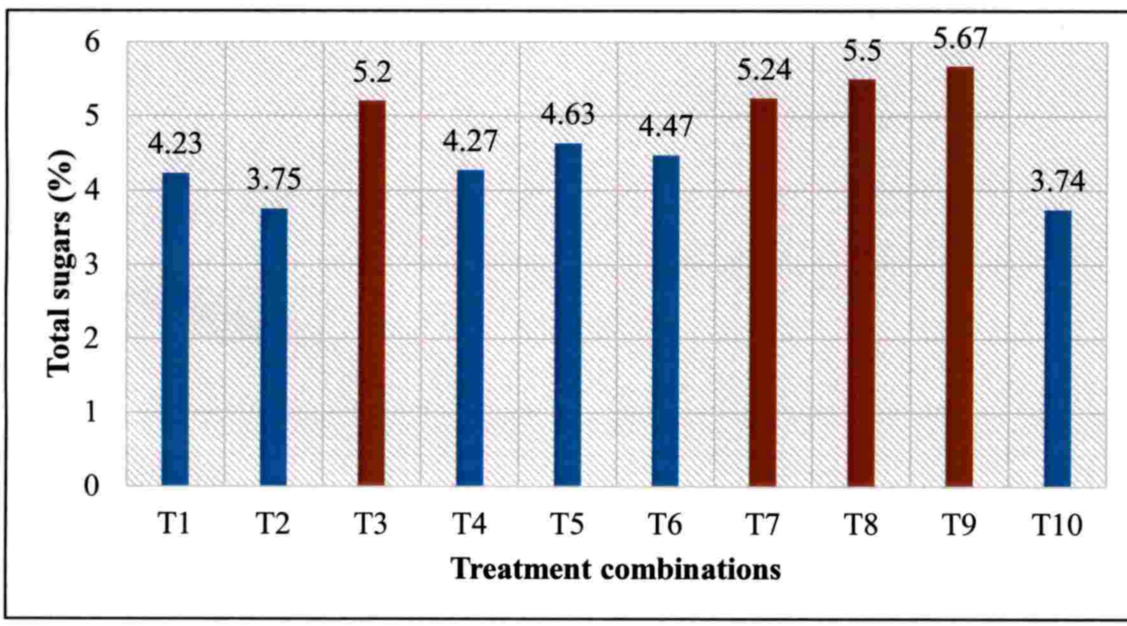


Fig 11. Total sugars (%) of strawberry fruits under different treatment combinations



5.3.4 Days to first harvest

Days to first harvest was minimum in T_6, T_7, T_8 and T_9 which were on par while all other treatments were on par with the control (T_{10}). This may be due to the effect of higher doses of organic manure. Similar results were reported by Uddin *et al.* (2016).

The effect of different levels of FYM, N, P_2O_5 and K_2O was found to be significant on days to first harvest.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were significant on days to first harvest.

5.3.5. Days to final harvest

The days to final harvest ranged from 115 to 137 days and were not significant among the treatments. Application of graded doses of FYM, N, P and K did not influence days to final harvest.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were non- significant on days to final harvest.

5.4 Quality attributes

5.4.1 Total Soluble Solids (TSS)

The total soluble solids ranged from 6.2 ^{o} Brix to 8.6 ^{o} Brix and was not significant among the treatments. Application of graded doses of FYM, N, P and K did not influence total soluble solids.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were non- significant on total soluble solids.

5.4.2 Acidity (%)

The acidity of fruits ranged from 0.62 to 1.04 % and was not significant among the treatments.

Application of graded doses of FYM, N, P and K did not influence acidity of fruits.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were non- significant on acidity of fruits.

5.4.3 TSS/acidity ratio

The TSS/acidity ratio of fruits ranged from 7.31 to 13.39 and was not significant among the treatments.

Application of graded doses of FYM, N, P and K did not influence TSS/acidity ratio

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were non- significant on TSS/acidity ratio.

5.4.4 Total sugars

In case of total sugars, T_3, T_7, T_8 and T_9 were on par which was followed by T_5 on par with T_1, T_2, T_4, T_6 and T_{10}. This may be due to higher levels nitrogen applied and is in accordance with the findings of Odongo *et al.* (2011).

The effect of different levels of FYM, N, P_2O_5 and K_2O was found to be significant.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were significant on total sugar content. Organic and inorganic fertilisers influence quick metabolic transformations of starch and pectin into soluble compounds and rapid translocation of sugars from leaves to the developing fruits in strawberry.

4.4.5 Sensory evaluation

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

The highest score for appearance was recorded by T_8. The highest score for color, flavor and taste was recorded by T_7. For texture, T_4 recorded the highest score. T_1 was noted to have the highest score in terms of after-taste. Finally in case of overall acceptability, T_7 was found to have the highest score. T_7 can be considered as the best for sensory characters.

5.5 Plant analysis

5.5.1 Nitrogen

The plant N content was not significantly influenced by various treatments. Application of graded doses of FYM, N, P and K did not influence N content.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were non- significant on N content.

5.5.2 Phosphorous

The plant P content was not significantly influenced by the application of various treatments. Application of graded doses of FYM, N, P and K did not influence P content.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were non- significant on P content.

5.5.3 Potassium

The plant K content was not significantly influenced by the application of various treatments. Application of graded doses of FYM, N, P and K did not influence plant K content.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were non- significant on plant K content.

5.5.4 Calcium

The plant Ca content was not significantly influenced by the application of various treatments. Application of graded doses of FYM, N, P and K did not influence plant Ca content.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were non- significant on plant Ca content.

5.5.5 Magnesium

Plant Mg content was found to be on par in all treatments and superior over the control. This may be due to effect of the organic and inorganic fertilizers influencing the soil rhizosphere and availability of micro-nutrients.

The effect of different levels of FYM, N, P and K was found to be significant.

Effects of FYM x N, FYM x P, FYM x K, N x P, N x K and P x K interactions were also significant.

5.6 Soil analysis

5.6.1 Soil pH

Initially, a pH of 5.75 was recorded for the soil sample collected from the site before planting of the crop. After the final harvest, T_8 recorded the highest pH of 5.69, which is lower than the initial pH before planting. The reduction may be due to the addition of organic carbon in the form of FYM at higher levels (30 t ha^{-1}).

5.6.2 Soil EC

Before planting, the EC recorded was 0.03 dSm^{-1} for the soil sample collected from the site. After the final harvest, the highest EC was noted for T_5 (0.05 dSm^{-1}). A slight increase was noted than the initial soil EC which may be attributed to the application of N, P and K fertilizers influencing the ionic concentration in the soil.

5.6.3 Organic carbon

The initial organic carbon content of the soil before planting was 1. 76 percent. After the final harvest, the highest organic carbon content was recorded in T_8 (0.76 %). It was noted that the organic carbon content of the soil was reduced after planting which might be due to the influence of seasonal characters like high temperature and low rainfall.

5.6.4 Available P content

The initial available P content of soil was 18 kg ha^{-1}. After final harvest, T_5 recorded the highest available P content of 20.7 kg ha^{-1} which may be due to the application of higher level of phosphorous (40 kg ha^{-1}).

5.6.5 Available K content

Before planting, the available K content of the soil was 161.6 kg $ha^{-1.}$ After the final harvest, the highest available K content was recorded in T_8 (340 kg ha^{-1}) which may be attributed to the application of higher level of potassium (100 kg ha^{-1}).

5.6.6 Available Ca content

The available Ca content of the soil before planting was 186.4 mg kg^{-1}. After the final harvest, the highest available Ca content was noted in T_4 (184.8 mg kg^{-1}) as application of N and P fertilizers might have improved the Ca absorption by the plants from the soil.

5.6.7 Available Mg content

The available Mg content of the soil before planting was noted to be 89.7 mg kg^{-1}. After the final harvest, the highest Mg content was recorded in T_9 (93.2 mg kg^{-1}) which may be attributed to higher level of organic manure applied.

5.6.8 Available S content

The available S content of the soil before planting was recorded to be 1.65 mg $kg^{-1.}$ After the final harvest, T_6 recorded the highest S content of 3.71 mg kg^{-1}.The increase in available S content may be due to the increase in the content of organic carbon, N, P and K levels.

5.7 Post harvest study

5.7.1 Shelf life

The shelf life of strawberry fruits ranged from 2 to 3 days and was found to be non-significant with respect to the application of different treatment combinations.

The storage temperature and relative humidity was found to play an important role in determining the shelf life than the nutrients applied.

5.8 Pest and disease incidence

During the entire period of study, there was no severe incidence of pests and diseases. Mild incidence of pests (hairy caterpillar and fruit borer) and diseases (leaf blight and powdery mildew) were observed. Pest and diseases were controlled by adopting suitable control measures.

5.9 Benefit cost ratio

Benefit cost ratio is an important and ultimate factor which decides the optimum levels of input to be used for maximization of production and returns of any crop. The different inputs and operations in strawberry cultivation were identified and the costs and benefits were worked out. The analysis revealed that T_7 was having a benefit cost ratio of 3.06 followed by T_8 (2.72). The maximum benefit cost ratio obtained for T_7 was due to higher returns compared to cost of cultivation. The least benefit cost ratio in control (T_{10}) was due to lower returns compared to cost of cultivation of strawberry.

Fig 12. Monthly mean temperatures (^{0}C) during the cropping period

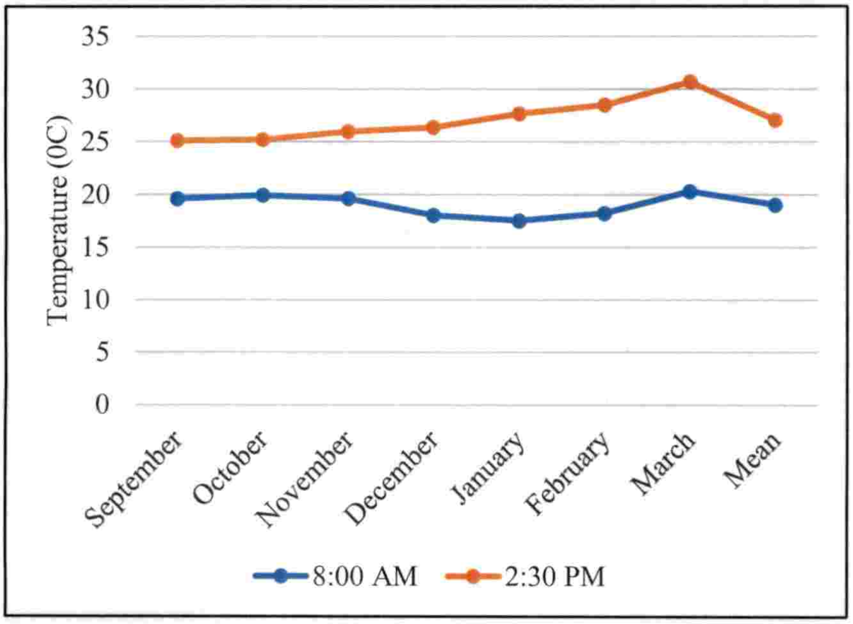


Fig 13. Monthly mean relative humidity (%) during the cropping period

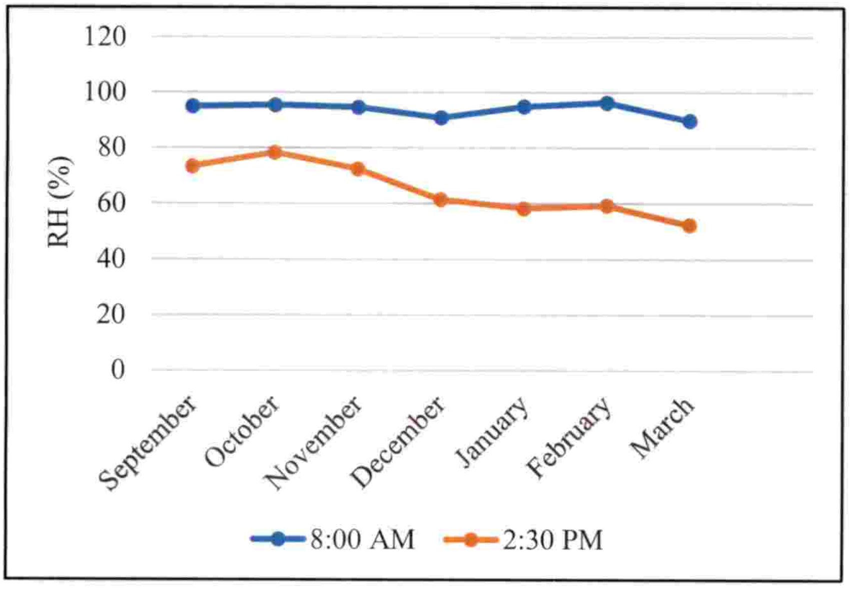


Fig 14. Monthly mean light intensity (lux) during the cropping period

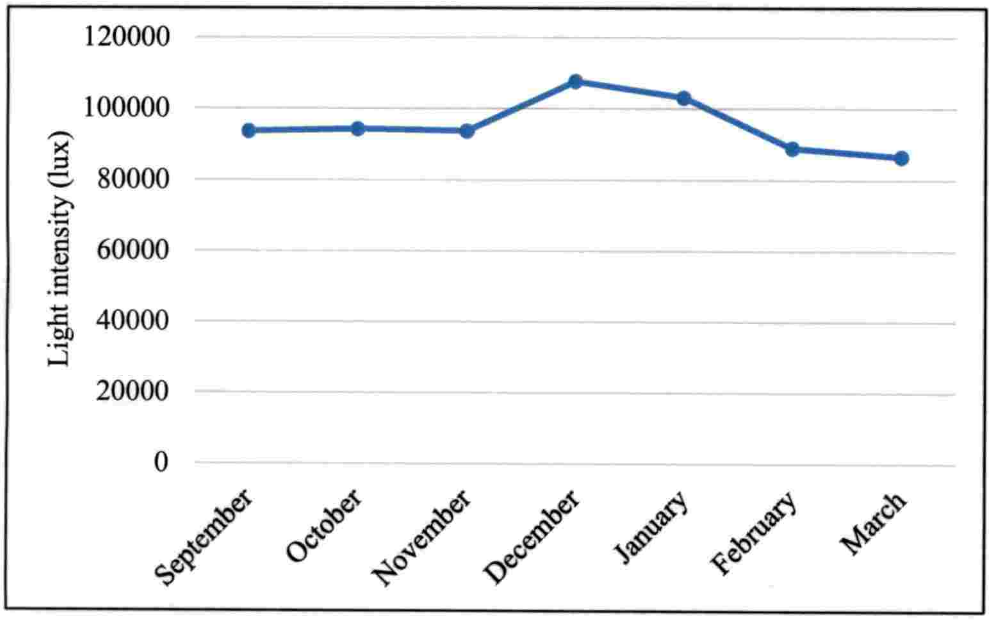
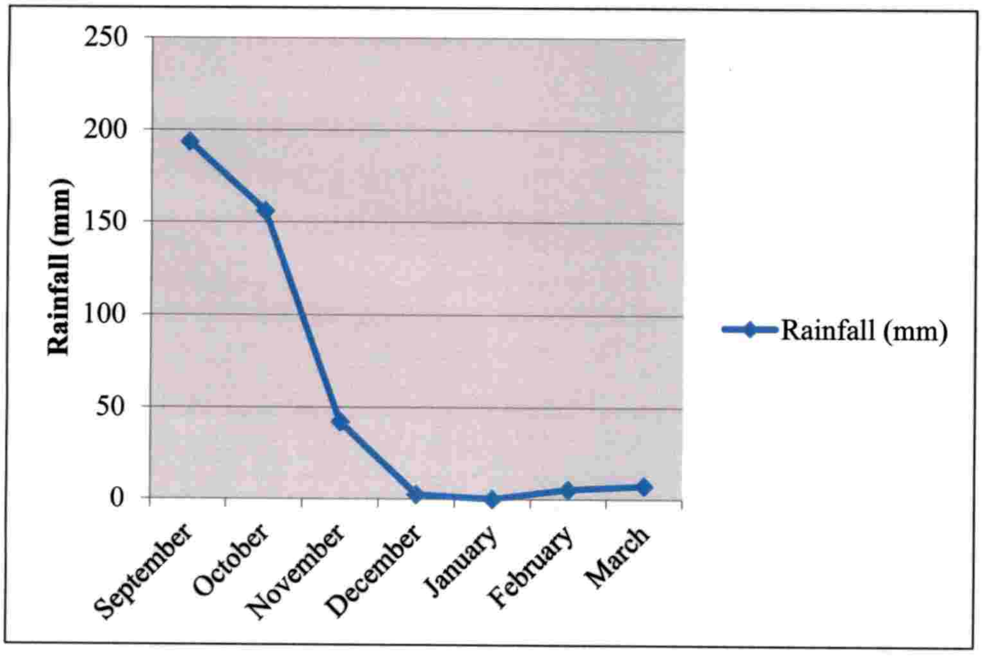


Fig 15. Monthly mean rainfall (mm) during the cropping period



Summary

6. SUMMARY

The present investigation "Nutrient management in strawberry (*Fragaria x ananassa* Duch.) was conducted to find out a suitable recommendation of major nutrients (N, P_2O_5 and K_2O) for the optimum growth and yield of strawberry grown in Wayanad district. The study was undertaken at Regional Agricultural Research Station, Ambalavayal, Wayanad during the year 2016-17. One month old tissue culture plants of variety Winter Dawn was used for the study. Time of planting was first week of October. The experiment was laid in Fractional factorial RBD with nine treatments and a control replicated thrice. Treatments comprised of different levels of FYM, N, P_2O_5 and K_2O in diverse combinations. Basal dose of full dose of FYM, P_2O_5 and half dose of N and K_2O were applied at the time of planting and the remaining dose of N and K_2O were given 45 DAP. The effect of major nutrients on growth, flowering, yield, quality, plant analysis, soil analysis, post -harvest life and pest and disease incidence were studied in detail and important findings are summarised below.

Application of treatments significantly influenced the plant height. Effect of N, P_2O_5 and K_2O was significant throughout the growth period except one month after planting. All the treatments were on par and superior over the control (T_{10}) in case of plant height. The effect of different levels of nutrients and interactions between various factors were found to be non-significant at all stages of growth.

Plant spread was found to be significantly influenced by the application of treatments. It was noted that T_2, T_3, T_5, T_6, T_7, T_8 and T_9 were on par and superior over the control while T_1 and T_4 were on par with each other but differs with other treatments. The effect of different levels of nutrients and interactions between various factors were significant only at 2 MAP.

The number of leaves per plant were significantly affected by the levels of FYM, N, P_2O_5 and K_2O only at second, fourth and fifth months after planting. All the treatments except T_2 were on par and superior over the control with respect to number of leaves per plant. Different levels of nutrients and the interactions between various factors were significant only at 5 MAP.

The days to first flowering was not significantly influenced by the application of different combinations and levels of nutrients.

The number of flowers and clusters per plant were significantly influenced by different combinations of nutrients. It was noted that $T_1, T_2, T_3, T_5, T_6, T_7, T_8$ and T_9 were on par and superior over the control while T_4 was on par with the control (T_{10}). The effect of different levels of nutrients and interactions between various factors were found to be non-significant at all stages of growth.

Days to first harvest was minimum in T_6, T_7, T_8 and T_9, which were on par while all other treatments were on par with the control (T_{10}).

Application of treatments influenced the number of fruits produced per plant. Application of FYM 30 t ha^{-1} + NPK 50:40:75 kg ha^{-1} (T_7) and FYM 30 t ha^{-1} + NPK 75:20:100 kg ha^{-1} (T_8) were on par and superior over other treatments including T_1, T_2, T_3, T_4, T_5, T_6 and T_9 which were on par and superior over the control. The effect of different levels of nutrients and interactions between various factors were found to be significant.

In case of yield per plant also, application of FYM 30 t ha^{-1} + NPK 50:40:75 kg ha^{-1} (T_7) and FYM 30 t ha^{-1} + NPK 75:20:100 kg ha^{-1} (T_8) were on par and superior over other treatments including T_1, T_2, T_3, T_4, T_5, T_6 and T_9 which were on par and superior over the control. The effect of different levels of nutrients and interactions between various factors were found to be significant.

Average fruit weight recorded under T_3, T_5, T_6, T_7, T_8, and T_9 were on par which was followed by T_2 on par with T_4 and T_1. The effect of different levels of nutrients and interactions between various factors were found to be significant.

Days to first harvest was minimum in T_6, T_7, T_8 and T_9, which were on par while all other treatments were on par with the control (T_{10}).

Days taken for final harvest was not found to be influenced significantly by the application of treatments.

Biochemical characters including TSS, Acidity and TSS/acidity ratio were not significantly influenced by the application of major nutrients whereas in the case of total sugars, T_3, T_7, T_8 and T_9 were having the highest content and were on par which was followed by T_5 on par with T_1, T_2, T_4, T_6 and T_{10}. The effect of different levels of nutrients and interactions between various factors were found to be significant in case of total sugars.

N, P, K and Ca content in the plant were not significantly affected by any treatment combination while Mg content was found to on par in all treatments and superior over the control.

Soil analysis after the harvest of the crop revealed that the values for soil EC, available P, K, Mg and S were found to be elevated while soil pH, organic carbon and available Ca content were found to be at lower levels than the initial values before planting.

The overall sensory score was highest in T_7 followed by T_8. Application of different treatments had no significant effect on the shelf life of strawberry fruits.

During the entire period of study, there was not much severe incidence of pests and diseases.

It was concluded that among different nutrient combinations evaluated, T_7 (FYM 30 t ha^{-1} + NPK 50:40:75 kg ha^{-1}) with a BC ratio of 3.06 can be recommended for further optimization and refinement

Reference

7. REFERENCES

Ahmad, M.F. 2009. Effect of planting density on growth and yield of strawberry. *Indian J. Hortic.* **66**(1): 132-134.

Ahmad, M.F., Khan, I.A., and Wani, N. 2011. Nutritional studies on strawberry under polyhouse. *Indian J. Hortic.* **68**(1): 39-43.

Ali, Y.M., Iqbal, S.Z., Shah, A., and Ahmed, M.J. 2003. Effect of different combinations of nitrogen, phosphorous and farm yard manure on yield and quality of strawberry. *Sarhad J. Agric.* **19**: 185-188.

Andriolo, J.L., Erpen, L., Cardoso, F.L., Cocco, C., Casagrande, G.S., and Jänisch, D.I. 2011. Nitrogen levels in the cultivation of strawberries in soilless culture. *Hortic. Bra.* **29**: 516-519.

Ankita, S. and Chandel, J.S. 2014. Studies on the comparative performance of strawberry cultivars under mid-hill conditions of north-western Himalayas. *Indian J. Hortic.* **71**(3): 330-334.

Ashok, K., Avasthe, R.K., Ramesh, K., Pandey, B., Borah, T.R., Denzongpa, R., and Rahman, H. 2011. Influence of growth conditions on yield, quality and diseases of strawberry (*Fragaria x ananassa* Duch.) var Ofra and Chandler under mid hills of Sikkim Himalaya. *Sci. Hortic.* **130**: 43- 48.

Ashrey, R. and Singh, R. 2004. Evaluation of strawberry varieties under semi-arid irrigated regions of Punjab. *Indian J. Hortic.* **61**(2): 122-124.

Avidov, A.H. 1986. Strawberry. In: Monselise, S.P. (ed.), *Fruit set and development.* CRC Press, Boca Raton, pp. 419-448.

Baumann, T.E., Eaton, G.W., and Spaner, D. 1993. Yield component of day neutral and short day strawberry varieties on raised beds in British Columbia. *Hortic. Sci.* **28**(9): 891-894.

Beniwal, L.S., Daulta, B.S., and Bisla, S.S. 1989. Evaluation of different strawberry (*Fragaria* × *ananassa*) cultivars under Hisar conditions. *Haryana J. Hortic. Sci.* **18**(1-2): 34-39.

Bhattacharyya, P., Chakrabarti, K., and Chakraborty, A. 2003. Effect of MSW compost on microbiological and biochemical soil quality indicators. *Compost Sci. Util.* **11** (3): 220–227.

Bielinski, M., Santos., Craig, K., Chandler., Stephen, M., Olson., and Teresa, W. 2007. *Strawberry Cultivar Evaluations in Florida: 2006-07 Season*. Institute of food and agricultural sciences, 53p.

Chandel, J.S. and Badiyala, S.D. 1996. Performance of some strawberry cultivars in foot hills of Himachal Pradesh. *Annals Agri. Res.* **17**(4): 375- 378.

Darrow, G.M. 1934. Interrelation of temperature and photoperiodism in the production of fruit buds and runners in the strawberry. *Proc. Am. Soc. Hortic. Sci.* **34**: 360-363.

Das, B., Vishal, N., Jana, R.R., Dey, P., Pramanick, K.K., and Kishore, D.K. 2007. Performance of strawberry cultivars grown on different mulching materials under sub-humid, sub-tropical conditions of Eastern India. *Indian J. Hortic.* **64**: 136-143.

Durner, E.F. and Poling, E.B. 1987. Flower bud induction, initiation, differentiation and development in the 'Earliglow' strawberry. *Sci. Hortic.* **31**: 61-69.

Ebrahimi, R., Souri, M.K., Ebrahimi, F., and Ahmadizadeh, M. 2012. Growth and yield of strawberries under different potassium concentrations of hydroponic system in three substrates. *World Appl. Sci. J.* **16**:1380-1386.

Emdad, A., Hossain, M.I., Kabirand, K., and Jahan, M.S. 2013. Correlation and path analysis in six strawberry (*Fragaria x ananassa* Duch.) genotypes**.** *The Agricst.* **11**(2): 74-78.

FAO [Food and Agricultural Organisation of the United Nations]. 2014. *FAOSTAT, 2014* [On-line]. Available: http:// faostat. fao.org.

Garren, R. 1980. Causes of misshaped strawberries. In: Childers, N. F. (ed.), *The strawberry.* Horticultural Publications, Gainsville, Florida, pp. 326-335.

Gupta, A.K. and Tripathi, V.K. 2012. Efficacy of Azotobacter and vermicompost alone and in combination on vegetative growth, flowering and yield of strawberry (*Fragaria x ananassa* Duch.) cv. Chandler. *Prog. Hortic.* **44**(2): 256-261.

Guttridge, G.C. 1985. Flower induction in strawberry (*Fragaria x ananassa* Duch). In: Halvey, A. H. (ed.), *CRC Handbook of Flowering*. CRC Press, Boca Raton, Florida, pp. 16-33.

Hartmann, H.T. 1947. Some effects of temperature and photoperiod on flower formation and runner production in the strawberry. *Plant Physiol.* **22**: 407-420.

Heide, O. M. 1977. Photoperiod and temperature interactions in growth and flowering of strawberry. *Physiologia plantarum*. 40: 21-26.

Heide, O.M. and Sonsteby, A. 2007. Interactions of temperature and photoperiod in the control of flowering of latitudinal and altitudinal populations of wild strawberry (*Fragaria vesca*). *Plant Physiol.* **130**: 280-289.

Hellman, E.W. and Travis, J.D. 1988. Growth inhibition of strawberry at high temperatures. *Adv. Strawberry Prod.* **7**: 36-38.

Hossan, M. J., Islam, M. S., Ashan, M. K., Mehraj, H., and Jamaluddin, A. F. M. 2013. Growth and yield performance of strawberry germplasm at Sher-E- Bangla Agriculture University. *J. Expt. Biosci.* **4**(1): 89-92.

Iqbal, U., Wali, V.K., Ravi, K., and Mahital, J. 2009. Effect of FYM, Urea and *Azotobacter* on growth, yield and quality of strawberry cv. Chandler. *Notulae Botanicae Horti Agrobotanici, Cluj-Napoca.* **37**(1): 139-143.

Jackson, M.L. 1958. *Soil Chemical Analysis* (Indian Reprint, 1976). Prentice Hall of India, New Delhi, 478p.

Jellinek, G. 1985. *Sensory Evaluation of food: Theory and Practice*. Ellis Horwood., Chichester, England, 429p.

Jonkers, H. 1965. Flower formation, dormancy and the early forcing of strawberries. Msc Thesis, Mededelingen van de Landbouwhoge School, Wageningen, Netherlands.

Khalid, S., Qureshi, K.M., Hafiz, I.A., Khan, K.S., and Qureshi, U.S. 2013. Effect of organic amendments on vegetative growth, fruit and yield quality of strawberry. *Pakistan J. Agric.* **26**(2): 104-112.

Kongsrud, K.L. 1988. Nitrogeng jødsling til jordbærsorten "Bounty". *Norsk Landbruksforskning.* **2**: 265-271.

Konsin, M., Voipio, I., and Palonen, P. 2001. Influence of photoperiod and duration of short day treatment on vegetative growth and flowering of strawberry. *J. Hortic. Sci. and Biotechnol.* **76**(1): 77-82.

Kopanski, K. and Kawecki, Z. 1994. Nitrogen fertilization and growth and cropping of strawberries in the conditions of Zlawy. *Acta Acad. Agric. Technicae Olstenensis Agric.* **58**: 135-142.

Kumar, A., Avasthe, R.K., Ramesh, K., Pandley, B., Borah, T.R., Denzongpa, R. and Rahman, H. 2011. Influence of growth conditions on yield, quality and diseases of strawberry (*Fragaria x ananassa* Duch.) var. Ofra and Chandler under mid hills of Sikkim Himalaya. *Sci. Hortic.* **130**: 43-48.

Kurian, A. 2015. Performance of strawberry (*Fragaria x ananassa* Duch.) in different growing conditions. M.Sc. (Hort) thesis, Kerala Agricultural University, Thrissur, 107p.

Kurian, A., Ajithkumar, K., Sankar, M., and Vijayaraghavan, R. 2015. Effect of different growing conditions on yield and quality of strawberry. *Int. J. Trop. Agric.* **33**(2): 796-800.

Lata, R., Dwivedi, D.H., Ram, R.B., and Meena, M.L. 2013. Influence of microbial, organic and inorganic sources of nutrients on growth parameters of strawberry. *Hort. Flora. Res. Spectrum* **2**(2): 135-138.

Le Mière, P., Hadley, P., Darby, J., and Battey, N. 1996. The effect of temperature and photoperiod on the rate of flower initiation and onset of dormancy in the strawberry (*Fragaria x ananassa* Duch.). *J. Hort. Sci. Biotech.* **71**: 361-371.

Lieten, P. 2002. The effect of humidity on the performance of greenhouse grown strawberry. *Acta Hort.* **567**(2): 479-482.

Manakasem, Y. and Goodwin, P.B. 2001. Responses of day neutral and June bearing strawberries to temperature and day length. *J. Hortic. Sci. Biotechnol.* **76**: 629-635.

Massoumi, A. and Cornfield, A.H. 1963. A rapid method for determining sulphur in water extracts of soils. *Analyst* **88**:321.

Mondal, K.K., Bhattacharya, B. and Ghosh, S.K. 2001. Introduction of some promising cultivars of strawberry to study their performance under Terai agroclimatic regions of West Bengal. *Environ. and Ecol.* **19**(2): 275- 278.

Michel, J.V., Anita S., and Svein O.G. 2006. Interactions of photoperiod, temperature, duration of short – day treatment and plant age on flowering of *Fragaria x ananassa Duch*. cv. Korona. *Scientia Hort.* **107**: 164-170.

Mishra, A.N. and Tripathi, V.K. 2011. Effect of biofertilizers on vegetative growth, flowering, yield and quality of strawberry cv. chandler. In: *Proceeding of the International Symposium on Minor Fruits and Medicinal Plants for Health and Ecological Security (ISMF & MP)*. 19- 22 December, West Bengal, India, pp. 211-215.

Mukkun, L., Singh, Z., and Phillips, D. 2001. Nitrogen nutrition affects fruit firmness, quality and shelf life of strawberry. *Acta Hortic*. **553**: 69-71.

Nam, M.H., Jeong, S.K., Lee, Y.S., Choi, J.M., and Kim, H.G. 2006. Effects of nitrogen, phosphorus, potassium and calcium nutrition on strawberry anthracnose. *Plant Pathol*. **55**: 246-249.

Neuweiler, N. 2001. Ground cover and nitrogen management in strawberry cultivation under Swiss humid climate conditions. Dissertation ETH No.14221. http://ecollection. library.ethz.ch/eserv/eth:24407/eth-24407-01.pdf.

Odongo, T., Isutsa, D.K., and Aguyoh, J.N. 2008. Effects of integrated nutrient sources on growth and yield of strawberry grown under tropical high altitude conditions. *Afr. J. Hort. Sci*. **1**: 53-69.

Odongo, T., Isutsa, D.K., and Aguyoh, J.N. 2011. Response of strawberry quality and profitability to farmyard manure and triple super phosphate under tropical high altitude conditions. *Jomo Kenyatta Univ. Agric. Technol.* **13**: 7-21.

Pandit, B.A., Aamir, H., Gousia, H., Shazia, H., and Ahmad, M.F. 2013. Response of bio-fertilizers on vegetative growth and yield of strawberry under sub-tropical conditions of U.P. *Prog. Hortic.* **45**(1): 58-62.

Panse, V. G. and Sukhatme, D. V. 1985. *Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research, New Delhi, 36pp.

Piper, C. S. 1942. Soil and Plant Analysis. Inter Science Publishers, New York, 368p.

Pivot, D. and Gillioz, J.M. 2001. Mineral disorders of strawberry grown in a soilless closed system: Influence of the climate. *Revue suisse de viticulture, arboriculture, hort. (Switzerland)*. **21**(4): 31-40.

Pradeepkumar, T., Babu, D.S., and Aipe, K.C. 2002. Performance of strawberry varieties in Wayanad district of Kerala. *J. Trop. Agric.* **40**: 51-52.

Rahman, M.M., Hossain, M.M., and Moniruzzaman, M. 2014. Effect of planting time and genotypes growth, yield and quality of strawberry (*Fragaria x ananassa* Duch.). *Sci. Hortic.* **167**: 56-62.

Ram, A. and Gaur, G.S. 2003. Studies on the vegetative growth, yield and quality of strawberry (*Fragaria x ananassa* Duch.) as influenced by different levels of nitrogen. *Sci. Hortic.* **8**: 71-74.

Rana, R.K. and Chandel, J.S. 2003. Effect of biofertilizers and nitrogen on growth, yield and fruit quality of strawberry. *Prog. Hortic.* **35**(1): 25-30.

Ranganna, S. 1997. *Handbook of Analysis and quality control for fruits and vegetable products* (2^{nd} Ed.). Tata McGrow Hill Publishing Company Ltd, New Delhi, pp. 12-16.

Rao, V.K. and Lal, B. 2010. Evaluation of promising strawberry genotypes under Garhwal Himalayan conditions. *Indian J. Hortic.* **67**(4): 470-474.

Roberts, A.N. and Kenworthy, A.L. 1956. Growth and composition of strawberry plant in relation to root temperature and intensity of nutrition. *Proc. of the Am. Soc. for Hortic. Sci.* **58**: 157-160.

Rodas, C.L., Pereira da Silva, I., Toledo-Coelho, V.A., Guimarães-Ferreira, D.M., and de Souza, R.J. 2013. Chemical properties and rates of external color of strawberry fruits grown using nitrogen and potassium fertigation. *IDESIA (Chile).* **31**:53-58.

Santos, B.M. and Chandler, C.K. 2009. Influence of nitrogen fertilization rates on the performance of strawberry cultivars. *Int. J. Fruit Sci.* **9**(2): 126-135.

Shoemaker, J.S. and Greve, E.W. 1930. Relation of nitrogen fertilizer to the firmness and composition of strawberries. *Int. J. Fruit Sci.* **13**(3): 145-156.

Sharma, G. and Thakur, M.S. 2008. Evaluation of different strawberry cultivars for yield and quality characters in Himachal Pradesh. *Agri. Sci. Digest.* **28**(3): 213-215.

Sharma, G., Yadav, A. and Gara, S. 2014. Evaluation of different strawberry cultivars for yield and quality characters. *Agric. Sustain. Dev.* **2**(1): 59-61.

Shiow, Y. W. and Mary, J. C. 2000. Temperatures after bloom affect plant growth and fruit quality of strawberry. *Scientia Horticulturae* **85**: 183-199.

Singh, A. K., Pitam, C., and Gupta, M.J. 2001. Effect of urea doses on growth and fruit yield of strawberry (*Fragaria x ananassa* Duch.) cultivated under greenhouse condition. *Prog. Hortic.* **33**(2): 194-198.

Singh, A., Syndor, A., Deka, B.C., Singh, R.K., and Patel, R.K. 2015. The effect of microclimate and nutrients inside low tunnels on off-season production of strawberry (*Frageria x ananassa* Duch.) *Sci. Hortic.* **114**: 36- 41.

Stolle, G. 1955. The effect of manuring on yield, fruit number and average single fruit weight per plant, their variability and relationships in forcing strawberries. *Arch. Gartenb.* **12**(3): 373-384.

Strik, B.C. 1985. Flower bud initiation in strawberry cultivars. *Fruit Var*. J. (39): 5-9.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for estimation of available nitrogen in soils. *Current Sci.* **25**: 259–260.

Timo, H. 2009. Regulation of strawberry growth and development. Available: [online] http://ethesis.helsinki.fi [20 Mar. 2009].

Uddin, H., Chowhan, S., Ahmed, S., and Hasan, M. 2016. Evaluation of nutritive value and shelf life of strawberry genotypes. *Asian J. Med. Biol. Res.* **2**(1): 19-26.

Ulrich, A., Mostafa, M.A.E., and Allen, W.W. 1980. Strawberry deficiency symptoms: A visual and plant analysis guide to fertilization. *Agr. Expt. Sta. Univ. Calif.* Bull. 30-31.

Umar, I., Wali, V.K., Kher, R., and Akash, S. 2008. Impact of integrated nutrient management on strawberry yield and soil nutrient status. *Appl. Biol. Res.* **10** (3): 22-25.

Walkley, A. and Black, I.A. 1934. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.* **37**: 29-37.

Wand, G.M and Camp, D. F. 1999. *Responses of strawberry varieties and species to the duration of the daily light period*. United states Department of Agriculture, Washington, D. C. Tech. Bull. No (573): 32p.

Westwood, M.N. 1993. *Temperate Zone Pomology, Physiology and Culture*. W. H. Freeman and Co., San Francisco, pp 523.

Yadav, S.K., Khokhar, U.U., and Yadav, R.P. 2010. Integrated nutrient management for strawberry. *Indian J. Hortic.* **67**(4): 445-449.

Yanagi, Y.T. and Oda, Y. 1993. Effects of photoperiod and chilling on floral formation on intermediate types between June and everbearing strawberries. *Acta Hortic.* **348**: 339-346.

Yoshida, Y., Goto, T., Hirai, M., and Masuda, M. 2002. Anthocyanin accumulation in strawberry fruits as affected by nitrogen nutrition. *Acta Hortic.* **567**:357-360.

Yusuf, A., Massood, I., Shah, S.Z.A., and Ahmed, M.J. 2003. Effect of different combinations of nitrogen, phosphorous and farm yard manure on yield and quality of strawberry. *Sarhad J. Agric.* **19**(2): 185-188.

Appendices

Appendix-I

WEATHER DATA

Period from October 2016 to March 2017

a) Monthly mean temperature (^0C)

Month	8.00 am	2.30 pm
September	19.58	25.09
October	19.90	25.18
November	19.60	25.95
December	18.01	26.35
January	17.51	27.63
February	18.21	28.45
March	20.28	30.66
Mean	**19.01**	**27.04**

b) Monthly mean relative humidity (%)

Month	8.00 am	2.30 pm
September	94.80	73.24
October	95.32	78.16
November	94.50	72.26
December	90.71	61.39
January	94.77	58.19
February	96.23	59.19
March	89.68	52.23
Mean	**93.72**	**64.95**

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

Month	Light intensity (lux)	Rainfall (mm)
September	93500.30	193.4
October	94158.06	156
November	93603.23	42.2
December	107597.42	2.4
January	103014.19	0
February	88817.42	5.2
March	86400.32	7.2
Mean	**95298.70**	**58.05**

Appendix –II

Benefit Cost ratio of growing one hectare strawberry for six months under different treatments

Treatment	Total cost (Rs)	Total returns (Rs)	B/C ratio
T_1	1590808	2750489	1.72
T_2	1593218	3402153	2.13
T_3	1595295	3258820	2.04
T_4	1605892	3637652	2.26
T_5	1606087	3585486	2.23
T_6	1604544	3444986	2.14
T_7	1618892	4959980	3.06
T_8	1617469	4405982	2.72
T_9	1617544	3803485	2.35
T_{10}	1573490	2640989	1.67

Appendix- III

Score card for organoleptic evaluation

Name of the judge:

Date:

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

9 point Hedonic scale

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

Signature

List of symbols and abbreviations

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

NUTRIENT MANAGEMENT IN STRAWBERRY (*Fragaria x ananassa* Duch.)

by

ARJUN MOHAN P.
(2015-12-005)

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Horticulture
(FRUIT SCIENCE)

Faculty of Agriculture
Kerala Agricultural University

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

ABSTRACT

The experiment entitled "Nutrient management in strawberry (*Fragaria* x *ananassa* Duch.)" was undertaken at Regional Agricultural Research Station, Ambalavayal, Wayanad during the year 2016-17. Performance of strawberry variety Winter Dawn was evaluated under nine treatments and a control in the open field *viz*., FYM 10 t ha^{-1} + NPK 50:20:50 kg ha^{-1} (T_1); FYM 10 t ha^{-1} + NPK 75:30:75 kg ha^{-1} (T_2); FYM 10 t ha^{-1} + NPK 100:40:100 kg ha^{-1} (T_3); FYM 20 t ha^{-1} + NPK 50:30:100 kg ha^{-1} (T_4); FYM 20 t ha^{-1} + NPK 75:40:50 kg ha^{-1} (T_5); FYM 20 t ha^{-1} + NPK 100:20:75 kg ha^{-1} (T_6); FYM 30 t ha^{-1} + NPK 50:40:75 kg ha^{-1} (T_7); FYM 30 t ha^{-1} + NPK 75:20:100 kg ha^{-1} (T_8); FYM 30 t ha^{-1} + NPK 100:30:50 kg ha^{-1} (T_9) and an absolute control (T_{10}), without any nutrient application.

All the treatments were on par and superior over the control (T_{10}) in case of plant height. In case of plant spread, T_2, T_3, T_5, T_6, T_7, T_8 and T_9 were on par and superior over the control while T_1 and T_4 were on par with each other but differs with other treatments. All the treatments except T_2 were on par and superior over the control with respect to number of leaves per plant.

Application of treatments had no significant effect on days to first flowering. In case of number of flowers and clusters per plant, T_1, T_2, T_3, T_5, T_6, T_7, T_8 and T_9 were on par and superior over the control while T_4 was on par with the control (T_{10}).

Days to first harvest was minimum in T_6, T_7, T_8 and T_9 which were on par while all other treatments were on par with the control (T_{10}).In case of number of fruits and yield per plant, T_7 (FYM 30 t ha^{-1} + NPK 50:40:75 kg ha^{-1}) and T_8 (FYM 30 t ha^{-1} + NPK 75:20:100 kg ha^{-1}) were on par and superior over other treatments including T_1, T_2, T_3, T_4, T_5, T_6 and T_9 which were on par and superior over the control. Average fruit weight recorded under T_3, T_5, T_6, T_7, T_8 and T_9 were on par which was followed by T_2

on par with T_4 and T_1. Days to final harvest was not found to be influenced by the application of different treatments.

Biochemical characters of fruits *viz.,*TSS, acidity and TSS/acidity ratio were not having any significant effect due to the application of treatments. In case of total sugars, T_3, T_7, T_8 and T_9 were having the highest content and were on par which was followed by T_5 on par with T_1, T_2, T_4, T_6 and T_{10}. The overall sensory score was highest in T_7 followed by T_8. Application of different treatments had no significant effect on the shelf life of strawberry fruits.

N, P, K and Ca content in the plant were not significantly affected by any treatment while Mg content was found to be on par in all treatments and superior over the control.

Soil analysis after the harvest of the crop revealed that the values for soil EC, available P, K, Mg and S were found to be elevated while soil pH, organic carbon and available Ca content were found to be at lower levels than the initial values before planting.

It was concluded that among different nutrient combinations evaluated, T_7 (FYM 30 t ha^{-1} + NPK 50:40:75 kg ha^{-1}) with a BC ratio of 3.06 can be recommended for further optimization and refinement.