INFLUENCE OF ORGANIC MANURES ON GROWTH, YIELD AND QUALITY OF STRAWBERRY (*Fragaria* × *ananassa* Duch.) UNDER NATURALLY VENTILATED POLYHOUSE

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DEPARTMENT OF FRUIT SCIENCE
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CERTIFICATE

This is to certify that the thesis entitled '**INFLUENCE OF ORGANIC MANURES ON GROWTH, YIELD AND QUALITY OF STRAWBERRY (*Fragaria* × *ananassa* Duch.) UNDER NATURALLY VENTILATED POLYHOUSE**' submitted in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **FRUIT SCIENCE** to the college of Horticulture, Mudigere. University of Agricultural and Horticultural Sciences, Shivamogga is a bonafide record of research work carried out by **SAHANA, B. J., ID. NO. MH2TAH0198** (sahanayashu1710@gmail.com) during the period of study in this University under my guidance and supervision and no part of this thesis has previously formed the basis for the award of any degree, diploma, associate ship, fellowship or other similar titles.

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(Sahana, B. J.)

Influence of organic manures on growth, yield and quality of strawberry under naturally ventilated polyhouse

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ABSTRACT

The experiment was conducted to know the effect of organic manures on growth, yield and quality of strawberry under naturally ventilated polyhouse at the Department of Fruit Science, College of Horticulture, Mudigere during 2019-20. The experiment was laid out in Randomized Complete Block Design (RCBD) with nine treatments and three replications. Significant differences were noticed among the treatments. The highest values for plant height (28.85 cm), number of trifoliate leaves per plant (27.51), plant spread in North-South and East-West direction (30.42 cm and 30.04 cm, respectively), leaf area (106.78 cm^2), leaf area index (0.881), number of crowns per plant (4.65), number of runners per plant (6.21), plant dry weight (36.87 g) at harvest, number of flowers per plant (24.50), fruit weight (18.41 g), fruit length (4.31 cm), fruit diameter (3.48 cm), fruit volume (21.43 cc), number of fruits per plant (19.05), yield per plant (350.79 g), shelf life (3.52 days), net income (129428 ₹ / 500 m^2) and benefit to cost ratio (2.20) were recorded in the treatment Vermicompost+ Jeevamruth @ 500ml per pot + Beejamruth seedling treatment. The minimum days taken for first flower emergence (55.78) and minimum titratable acidity (0.819 %), maximum TSS (8.030 °Brix), chlorophyll (2.679 mg / g), total sugar (7.568 %), ascorbic acid (58.749 mg/100 g) and sugar to acid ratio (9.240) were recorded in the treatment Vermicompost+ Jeevamruth @ 500ml per pot + Beejamruth seedling treatment. Based on the results obtained, the plants grown with the application of Vermicompost + Jeevamruth @ 500ml per pot + Beejamruth seedling treatment showed the best response to obtain growth, yield and maximum returns.

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ನೈಸರ್ಗಿಕ ವಾತಾಯನ ಹಸಿರು ಮನೆಯಲ್ಲಿ ಸ್ಟ್ರಾಬೆರಿಯ (ಫ್ರಾಗೇರಿಯ x ಅನನಸ್ಸ ಡಚ್.) ಬೆಳವಣಿಗೆ, ಇಳುವರಿ ಮತ್ತು ಹಣ್ಣಿನ ಗಣಮಟ್ಟದ ಮೇಲೆ ಸಾವಯವ ಗೊಬ್ಬರಗಳ ಪ್ರಭಾವ.

(ಸಹನ, ಬಿ. ಜೆ.)

ಸಾರಾಂಶ

ತೋಟಗಾರಿಕೆ ಮಹಾವಿದ್ಯಾಲಯ, ಮೂಡಿಗೆರೆಯ ಹಣ್ಣು ವಿಜ್ಞಾನ ವಿಭಾಗ ನೈಸರ್ಗಿಕ ವಾತಾಯನವಾಗುವ ಹಸಿರು ಮನೆಯಲ್ಲಿ ೨೦೧೯-೨೦ ರಲ್ಲಿ ಸ್ಟ್ರಾಬೆರಿಯ ಬೆಳವಣಿಗೆ, ಇಳುವರಿ ಮತ್ತು ಹಣ್ಣಿನ ಗುಣಮಟ್ಟದ ಮೇಲೆ ಸಾವಯವ ಗೊಬ್ಬರಗಳ ಪ್ರಭಾವದ ಕುರಿತು ಅಧ್ಯಯನವನ್ನು ನಡೆಸಲಾಯಿತು. ಈ ಪ್ರಯೋಗವನ್ನು ಯಾದೃಚ್ಚಿಕ ಸಂಪೂರ್ಣ ಬ್ಲಾಕ್ ವಿನ್ಯಾಸದ ಮೂರು ಪ್ರಕೃತಿಗಳಲ್ಲಿ ಒಂಬತ್ತು ಉಪಚಾರಗಳೊಂದಿಗೆ ಆಯೋಜಿಸಲಾಗಿತ್ತು. ಭಿನ್ನ ಉಪಚಾರಗಳಲ್ಲಿ ಗಮನಾರ್ಹ ವ್ಯತ್ಯಾಸಗಳನ್ನು ಗುರುತಿಸಲಾಯಿತು. ಈ ಅಧ್ಯಯನದ ಪ್ರಕಾರ, ಅತಿಹೆಚ್ಚು ಗಿಡದ ಎತ್ತರ (೨೮.೮೫ ಸೆಂ. ಮೀ), ಪ್ರತಿ ಗಿಡದ ಎಲೆಗಳ ಸಂಖ್ಯೆ (೨೭.೫೧), ಗಿಡದ ಹರಡುವಿಕೆ ಉತ್ತರ-ದಕ್ಷಿಣ ಮತ್ತು ಪೂರ್ವ-ಪಶ್ಚಿಮ ದಿಕ್ಕಿಗೆ (೩೦.೪೨ ಸೆಂ. ಮೀ ಮತ್ತು ೩೦.೦೪ ಸೆಂ. ಮೀ ಕ್ರಮವಾಗಿ), ಗರಿಷ್ಠ ಎಲೆಗಳ ವಿಸ್ತೀರ್ಣ (೧೦೬.೭೮ ಚ ಸೆಂ. ಮೀ), ಎಲೆಗಳ ವಿಸ್ತೀರ್ಣದ ಸೂಚ್ಯಂಕ (೦.೮೮೧), ಪ್ರತಿಗಿಡದ ಮರಿಗಿಡಗಳ ಸಂಖ್ಯೆ (೪.೬೫), ರನ್ನರ್‌ಗಳ ಸಂಖ್ಯೆ (೬.೨೧), ಗಿಡದ ಒಟ್ಟು ಒಣಗಿದ ತೂಕ (೩೬.೮೭ ಗ್ರಾಂ), ಹೂವುಗಳ ಸಂಖ್ಯೆ (೨೪.೫೦), ಹಣ್ಣಿನ ತೂಕ (೧೮.೪೧ ಗ್ರಾಂ), ಹಣ್ಣಿನ ಉದ್ದ (೪.೩೧ ಸೆಂ. ಮೀ), ಹಣ್ಣಿನ ವ್ಯಾಸ (೩.೪೮ ಸೆಂ. ಮೀ), ಹಣ್ಣಿನ ಪರಿಮಾಣ (೨೧೪೩ ಸಿ. ಸಿ), ಪ್ರತಿ ಗಿಡದ ಹಣ್ಣಿನ ಸಂಖ್ಯೆ (೧೯.೦೫), ಪ್ರತಿ ಗಿಡಕ್ಕೆ ಹಣ್ಣಿನ ಇಳುವರಿ (೩೫೦.೭೯ ಗ್ರಾಂ), ಕೊಯ್ಲೋತ್ತರ ಜೀವಿತಾವಧಿ (೩.೫೨ ದಿನಗಳು), ನಿವ್ವಳ ಅದಾಯ (ರೂ.೧.೨೯.೪೨೮/೫೦೦ ಚ. ಮೀ) ಮತ್ತು ಅದಾಯ ಖರ್ಚು ಅನುಪಾತ (೨.೨೦) ಎರೆಹುಳುಗೊಬ್ಬರ + ಜೀವಾಮೃತ ೫೦೦ ಮಿ. ಲೀ ಪ್ರತಿ ಮಡಿಕೆಗೆ + ಬೀಜಾಮೃತ ಸಸ್ಯೋಪಚಾರ ಉಪಚಾರದಲ್ಲಿ ದಾಖಲಾಗಿದೆ. ಮೊದಲು ಹೂವು ಬಿಡಲು ತೆಗೆದುಕೊಂಡ ದಿನಗಳು (೫೫.೭೮), ಕಡಿಮೆ ಟೈಟ್ರೀಕರಣ ಆಮ್ಲ (೦.೮೧೯ ಶೇಕಡ), ಅತಿ ಹೆಚ್ಚು ಟಿ. ಎಸ್. ಎಸ್. (೮.೦೩೦ ಡಿಗ್ರಿ ಬ್ರಿಕ್ಸ್), ಪತ್ರಹರಿತ್ತು (೨.೬೭೩ ಮಿ. ಗ್ರಾಂ/ ಗ್ರಾಂ), ಒಟ್ಟು ಸಕ್ಕರೆ ಪ್ರಮಾಣ (೯.೫೬೮ ಶೇಕಡ), ಅಸ್ಕೋರ್ಬಿಕ್ ಆಮ್ಲ (೫೮.೭೪೯ ಮಿ. ಗ್ರಾಂ/ ಗ್ರಾಂ) ಮತ್ತು ಸಕ್ಕರೆ ಆಮ್ಲದ ಅನುಪಾತವು (೯.೨೪೦) ಕೂಡ ಇದೇ ಉಪಚಾರದಲ್ಲಿ ದಾಖಲಾಗಿದೆ. ಪ್ರಯೋಗದಿಂದ ಪಡೆದ ಫಲಿತಾಂಶಗಳ ಆಧಾರದ ಮೇಲೆ ಎರೆಹುಳುಗೊಬ್ಬರ + ಜೀವಾಮೃತ ೫೦೦ ಮಿ. ಲೀ ಪ್ರತಿ ಮಡಿಕೆಗೆ + ಬೀಜಾಮೃತ ಸಸ್ಯೋಪಚಾರದಲ್ಲಿ ಬೆಳೆದ ಸಸ್ಯಗಳು ಉತ್ತಮ ಬೆಳವಣಿಗೆ ಹಾಗೂ ಇಳುವರಿ ಪಡೆದುದಲ್ಲದೆ ಗರಿಷ್ಠ ಆದಾಯವನ್ನೂ ಹೆಚ್ಚಿಸಲೂ ಸಹಕಾರಿಯಾಗಿದೆ.

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ನವೆಂಬರ್, ೨೦೨೦

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INTRODUCTION

I INTRODUCTION

The commercially important strawberries (*Fragaria* x *ananassa* Duch.) belong to the family Rosaceae and the genus *Fragaria*, which comprises of 23 species (Rousseau-Gueutin *et al.,* 2009). It is one of the most delicious, delicate flavoured, refreshing and attractive red fruits of the world (Sharma, 2002). With its high nutritional value, the strawberry is one of the most popular among berry fruits in the world. All of these strawberries have seven basic types of chromosomes. However, they exhibit a series of ploidy levels, ranging from diploid species such as *Fragaria vesca* (2n = 2x = 14), to decaploid species, such as some accessions of *Fragaria iturupensis* (2n = 10x = 70). The cultivated strawberry, *Fragaria* x *ananassa* is an octoploid (2n = 8x = 56) (Nathewet *et al.,* 2010).

Strawberry (*Fragaria* x *ananassa* Duch.), the fleshy fruit of strawberry, is classified as an aggregate fruit. Strawberries mainly consist of water (91 %), carbohydrates (7.7 %) and only minor amounts of fat (0.7 %). The taste of fruit mainly depends on three different compounds *viz.*, sugars, acids and aromatic compounds. The strawberry fruit contains 0.5 per cent total sugar and 0.90 per cent to 1.85 per cent acidity and also prominently mallic and citric acids (Watt and Merril, 1959). As compared to other berry fruits, strawberries contain a higher percentage of vitamin C, phenolics and flavonoids (Hakkinen and Torronen, 2000). They are also rich in phenolic compounds, including anthocyanins, hydrolyzable tannins and phenolic acids (Giampieri *et al.*, 2012).

The cultivated strawberry is native to North America and originated in Europe early 17th century. It was introduced to India in early sixties at National Bureau of Plant Genetic Resources regional station (NBPGR), Shimla (Himachal Pradesh) from where it has spread to other states. In India, Haryana stands first by contributing around 58.02 per cent share of strawberry production followed by Mizoram 20.15 per cent (Anon., 2018). Strawberries are being grown in Shimla, Bilaspur, Kangra, Kullu, Palampur (Himachal Pradesh), Dehradun, Nainital, Srinagar, West Bengal, Pune and Mahabaleshwar (Maharashtra), Bengaluru and Coorg (Karnataka). It is mainly cultivated as winter season crop from November to March (Singh and Saravanan, 2012).

Production of strawberry is increasing day by day. Growth and production of the crop is governed by their genetic makeup and by environmental factors in which they grow. Yield and quality depend upon many factors such as variety, climatic conditions, cultural practices, soil, nutrition and incidence of pest and diseases. Nutrient management plays an important role to boost up the yield of any crop. These nutrients can be supplied in organic or in inorganic source.

In conventional agriculture, heavy doses of inorganic fertilizers are often used to improve the yield of strawberry to meet up the increasing higher demand. Inorganic fertilizers have high nutrient content and are rapidly taken up by plants. However, the use of excess fertilizer can result in a number of problems, such as nutrient loss, surface water and ground water pollution, soil acidification or basification, reductions in useful microbial communities, and increased sensitivity to harmful insects. In addition, usage of inorganic fertilizer causes health hazard to the person who handle it. Moreover, inorganic fertilizers are relatively expensive that they are out of reach of small and marginal farmers. In this regard, to reduce and eliminate the adverse effects of chemical fertilizers, new agricultural practices have been developed in the so-called organic agriculture, ecological agriculture or sustainable agriculture.

The current global scenario firmly emphasizes the need to adopt eco-friendly agricultural practices for sustainable food production. The use of organic manures in such situation is, therefore, practically a paying proposal. Organic farming is a holistic way of farming with the aim of conserving the natural resources.

Organic manures like Beejamruth, Jeevamruth, Vermicompost and FYM *etc.* have been utilized in agriculture as a significant source of organic manure. Organic manures improve the physical properties of soil (water holding capacity, soil aeration, drainage and water retention capacity) and increase important beneficial microorganism population. Organic agriculture has grown during the last decade and continues to grow as consumers become increasingly concerned about the negative impacts of conventional farming practices on human health and the environment.

Organic manures play direct role in plant growth as a source of all necessary macro and micronutrients in available forms during mineralization and improving physical and chemical properties of soils (Chaterjee *et al.,* 2005). Organically grown strawberry produce higher quality fruit with sweeter in taste, longer shelf life and better flavour (Reganold *et al.,* 2010). The fruit quality and yield of fruits can be increased by using organic manures, which are helpful to reduce fruit drop and increase fruit yield, quality, shelf life and improve the physico-chemical properties of fruits and also increase the marketability as well as demand of fruits.

The Jeevamruth and Beejamruth are eco-friendly organic preparations made from cow products. The use of organic liquid products such as Beejamruth and Jeevamruth result in higher growth, yield and quality of crops. These liquid organic solutions are prepared from cow dung, urine, milk, curd, ghee, legume flour and jaggary. They contain macro nutrients, essential micro nutrients, many vitamins, essential amino acids, growth promoting factors like IAA, GA and beneficial microorganisms (Palekar, 2006; Natarajan, 2007 and Sreenivasa *et al.,* 2010). Jeevamruth promotes immense biological activity in soil and makes the nutrients

available to crop. Beejamruth protects the crop from soil borne pathogens (Devakumar *et al.,* 2008).

Vermicompost and FYM applications are also known to increase strawberry plant growth and yield. Vermicompost and FYM applications in strawberries can increase beneficial microbial populations, which enhance the production of plant growth hormones (auxin, gibberellins and cytokinins) and humic acids. Several experiments in strawberry have indicated that these hormones and acids may improve plant growth *viz.,* leaf area, shoot biomass, number of flowers and runners (Arancon *et al.,* 2004) and yield (Arancon *et al.,* 2004 and Singh *et al.,* 2008).

Vermicompost significantly enhance the growth, development and productivity of plants. It improves the yield of strawberry due to their essential elements, vitamins, enzymes and hormones. It contains organic carbon (9.15-17.98 %), nitrogen (0.5-1.5 %), potassium (0.15 %), phosphorus (0.1-0.3 %), calcium and magnesium (22.70 - 70 mg/100 g), zinc (5.7-11.5 ppm), copper (2–9.3 ppm) and sulphur (128–548 ppm). Due to its better physicochemical and biological characters it serves as easily available organic manure in various farming systems.

Farmyard manure occupies an important position among bulky organic manures. The FYM seems to act directly by increasing crop yield either by acceleration of respiratory process by cell permeability or by hormone growth action. It supplies N, P and K in available forms to plants through biological decomposition.

Modern day intensive crop cultivation results the huge application of chemical fertilizers which are not only in short supply but also expensive and pollute the environment, soil and water too. Therefore, the current emphasis is being given to explore the different organic amendments such as Beejamruth, Jeevamruth, Vermicompost and FYM on growth, yield and fruit quality parameters of strawberry. The present investigation entitled **"Influence of organic manures on growth, yield and quality of strawberry (*Fragaria* x *ananassa* Duch.) under naturally ventilated polyhouse"** was conducted in the Department of Fruit Science, College of Horticulture, Mudigere, during the winter season of 2019 - 2020 with the following objectives.

1. To study the effect of organic manures on growth and yield of strawberry
2. To know the effect of organic manures on fruit quality of strawberry
3. To study the influence of organic manures on fruit growth rate and shelf life of strawberry

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

Strawberry is one of the most important commercial fruit crops grown in temperate regions of the world, renowned for its delicate aroma and flavor. Balanced nutrition is essential for proper growth, development and to get the maximum productivity of any crop plant. Application of nutrients through organic manure supplies the plants all necessary macro and micro nutrients in available form. The fruit quality and yield can be increased by using organic manures, which are helpful to reduce fruit drops and increase fruit yield, quality, shelf life and improves the physico-chemical properties of fruits. The literature pertaining to the topic of study has been reviewed in the present chapter for reference to draw suitable conclusions on the strawberry and other crops observation recorded.

2.1 Effect of organic manures on growth and yield of strawberry

Paydas *et al*. (1996) reported that different fertilizers and their doses have major impact on growth yield and quality of strawberry cultivars. They also revealed that the farm yard manure (FYM) and vermicompost based organic amendments enhanced vegetative growth and improved the quality of strawberry fruits.

Babu (2003) observed the maximum plant height and number of fruits per plant under 20 kg FYM + 1 kg lime treatment and it was significantly higher than other treatments in papaya cv. Co-5.

Bhattacharyya *et al*. (2003) revealed that FYM and vermicompost improve vegetative growth characters in strawberry by increasing soil enzyme activity and improving soil aeration and recorded the maximum plant height (15.21cm) in strawberry crop. Maximum plant height may be due to better uptake of nutrients like nitrogen which has a major role in increasing cell division and improving plant growth.

Arancon *et al.* (2004) applied organic fertilizer produced commercially from cattle manure, market food waste and recycled paper waste to strawberries (*Fragaria* spp.). The result revealed that the marketable yields in all vermicompost-treated trial were consistently better than yields from the inorganic fertilizer-treated plots. Leaf areas, numbers of strawberry suckers, numbers of flowers, shoot weight and total marketable strawberry yields increased considerably in plots treated with vermicompost compared to those that received chemical fertilizers only besides significant increases in shoot, leaf areas and total and marketable fruit yields of plants from plots treated with vermicompost.

Ogendo *et al.* (2008) reported that increase in plant height, leaf area and number of leaves in strawberry with farm yard manure at the rate of 36-54 t ha^{-1} which might be due to increase in crown diameter resulting in better plant growth.

They also found that cytokinin production in roots enhanced vegetative growth and number of leaves in strawberry and high shoot to root ratio was observed with farm yard manure and phosphorus.

Rajbir *et al*. (2008) studied the effect of vermicompost (2.5, 5.0, 7.5 and 10.01 t ha^{-1}) in combination with inorganic fertilizers on growth, physiological disorders, fruit yield and quality of 'Chandler' strawberry under semi-arid region of northern India. Vermicompost application increased plant spread (10.7 %), leaf area (23.1 %) and dry matter (20.7 %) also increased with total fruit yield (32.7 %) and the marketable fruit yield up to 58.6 per cent with better quality parameters. Fruits harvested from plants receiving vermicompost were firmer with higher TSS, ascorbic acid content, lower acidity and attractive colour.

Singh *et al.* (2008) recorded increased plant spread, leaf area, dry matter and total fruit yield in strawberry with the application of vermicompost at the rate of 2.5 to 10 t ha^{-1} in combination with inorganic fertilizers.

Mahadeen (2009) reported higher fruit yield (27.62 t ha^{-1}) of strawberry by application of 40 tonnes of organic fertilizer (FYM) + 60 kg ha^{-1} NPK fertilizers, while the lowest strawberry yield (21.76 t ha^{-1}) was obtained in untreated plot.

Yadav *et al*. (2009) studied the optimization of integrated nutrient supply system for strawberry cv. Chandler in Himachal Pradesh. Farm Yard Manure and vermicompost were used as organic manures. Whereas, CAN, SSP and MOP were used as inorganic sources for the supply for N, P and K respectively. The majority of plant growth parameters, number of runners (11.33 per plant), number of plantlets and fruit characteristics like number of flowers (29.60 per plant), number of berries (22.27 per plant) and fruit yield (101.99 q/ha) were maximum in Azatobacter inoculated treatments with 50 per cent Nitrogen substitution by vermicompost.

Joshi and Vig (2010) observed that the various growth, yield and quality parameters of strawberry like mean stem diameter, plant height, yield $plant^{-1}$, marketable yield/plant, leaf number, total plant biomass, ascorbic acid, titratable acidity, soluble solids, insoluble solids and pH were increased significantly when treated with vermicompost.

Nileema and Sreenivasa (2010) evaluated the influence of liquid organic manures *viz.*, Panchagavya, Jeevamruth and Beejamruth on the growth, nutrient content and yield of tomato in the sterilized soil. Significantly highest plant growth and root length was verified with the application of RDF + Beejamruth + Jeevamruth + Panchagavya and it was found to be significantly superior over other treatments. The application of Beejamruth + Jeevamruth + Panchagavya was next best treatment and resulted in significantly maximum yield as compared to RDF alone. The N, P and

K concentration of plants was significantly highest in the treatment given RDF + Beejamruth + Jeevamruth + Panchagavya.

Rajbir *et al.* (2010) studied the effect of vermicompost (VC) on strawberry cv. Chandler and the results revealed that vermicompost application at 10 t ha^{-1} increased plant spread (16.1 %) and total fruit yield (29.10%).

Singh *et al.* (2010) reported that application of vermicompost @ 10 t/ha in strawberry increased plant spread (16.1 %), leaf area (31.4 %) and dry matter (17.7 %) and increased total fruit yield (29.1 %) over inorganic fertilizer. Fruits harvested from plant receiving vermicompost have higher TSS, ascorbic acid content and lower acidity.

Baviskar *et al.* (2011) reported the maximum fruit weight, fruit length and fruit breadth in sapota with application of vermicompost at the rate of 15 kg/plant.

Herencia *et al.* (2011) investigated the effect of organic fertilized soils on flowering and fruiting in strawberry and found that vegetative stages of strawberries completed earlier on farm yard manure and vermicompost leading to early onset of reproductive stage and minimum days (96.67 days) for flower opening.

Ameri *et al.* (2012) observed that the results of the experiment indicated that application of vermicompost in substrate improved indexes of yield *i.e.* highest crown diameter, fruit length and yield of strawberry.

Gupta and Tripathi (2012) reported that application of Azotobacter at 7 kg/ha along with vermicompost at 30 t/ha significantly increased the strawberry plant height (17.65 and 19.45 cm respectively) and number of leaves (59.60 and 63.60 respectively) per plant in 2009-10 and 2010-11.

Singh *et al*. (2012) studied the effect of integrated nutrient management on strawberry and observed that maximum runners (7.45) per plant were obtained with the application of FYM at 10 t ha^{-1} + Azotobacter + PSB treated plant.

Khalid *et al*. (2013) concluded that FYM induced positive influence on plant height (15.21 cm), canopy spread (20.37 cm), fresh weight of plant (10.71 g), number of runners per plant (2), total number of flowers (58), total number of fruits (42), fruit size (3.04 cm) and fruit weight (8.82 g) of strawberry.

Garhwal *et al.* (2014) reported that the application of FYM @ 80 kg per plant significantly increased fruit length, fruit volume, ascorbic acid, total sugar and fruit yield of kinnow mandarin.

Kumar *et al*. (2015) studied the effect organic manures (Farm Yard Manure, vermicompost and press mud) and biofertilizers (Azotobacter, phosphate solubilizing bacteria and Azospirillum) on strawberry. Each treatment combination showed significant effects on most of the parameters. However, the combination of

vermicompost and PSB showed highest plant height (23.59 cm), leaves per plant (12.67), primary branches per plant (10.50), secondary branches per plant (27.35), first flowering (61.06 days), flowers/plant (15.33), first fruit setting (72.80 days) and fruits per plant (8.33).

Uddin *et al.* (2015) stated the performance of strawberry as affected by different organic manure. The treatment RDF + Vermicompost 5 t ha^{-1} + Neem Cake 4 t ha^{-1} was found significantly superior compared to other treatment combinations, which recorded highest mean value of plant height (21.20 cm), plant spread (26.62 cm^2), number of leaves per plant (16.23), petiole length (13.93 cm), number of fruits per plant (4.20) and average fruit weight (19.51g). The highest yield per plant (286.56 g) and yield per hectare (17.19 t/ha) were also obtained from treatment RDF + Vermicompost 5 t/ha + Neem Cake.

Jain *et al.* (2017) concluded that the treatment (poultry manure + vermicompost + azotobacter + PSB) was found the best in terms of yield (112.63 g $plant^{-1}$) and maximum shelf life (5.69 days) of strawberry fruits.

Soni *et al*. (2018) concluded that the application of 50 percent vermicompost + 50 percent poultry manure with azotobacter on strawberry recorded maximum plant height (19.61 cm), number of fruits (12.41 per plant) and maximum fruit yield (144.77 g/plant), which was closely followed by the application of 50 per cent vermicompost + 50 per cent FYM with azotobacter.

2.2 Effect of organic manures on fruit quality of strawberry

Venkatesh (1995) observed that the application of organic manures *viz.,* vermicompost (4 t ha^{-1}) and farmyard manure (25 t ha^{-1}) in grape resulted in significantly higher amount of ascorbic acid, total sugar content as compared to application of inorganic fertilizers.

Ravishankar *et al.* (2010) conducted a study on effect of organic manures on growth, yield and quality of Coorg Honey Dew papaya was evaluated through seven treatments with three replications. Application of FYM 20 kg/plant recorded maximum total soluble solids, ascorbic acid and total sugar over other organic treatments.

Rajbir *et al.* (2008) conducted an experiment on strawberry of various doses of vermicompost and found that minimum acidity (1.09 %) and maximum ascorbic acid (51.1 mg/100g) recorded in vermicompost at 10 t/ha however, highest TSS (7.42 ^{0}B) was obtained in vermicompost at 7.5 t/ha treated plants.

The potential of vermicompost was investigated as one of the substrate constituent on yield catalogs of three strawberry cultivars. For this, four substrates (0%, 5%, 15% and 25% vermicompost indicated by S_1, S_2, S_3 and S_4 respectively) and

three cultivars (Camarosa, Mrak and Selva) were used. The results of the experiment showed that highest crown diameter, fruit length and yield were found in the interaction of Mrak and S_2 (19.45 mm, 4.47 cm and 264.143 g respectively). The interaction of Selva and S_3 had more fruit number (26.63) than other treatments. Selva cultivar in S_4 had highest of mean of fruit weight (12.33 g) also Mrak in S_4 had 44 more number of inflorescence than other treatments. Camarosa in S_1 had lower fruit length (2.66 cm) and mean fruit weight (8.27 g) than other treatments, also Selva in this substrate had the lowest yield (140.79 g). The lowest of inflorescence number was detected in the interaction of Camarosa and S_3. Selva in S_4 had the lowest new diameter crown (13.47 mm) and fruit number (13.34 g) (Atefe *et al.*, 2012).

Singh *et al.* (2012) reported that application of vermicompost 5 t/ha + Azotobacter + Azospirillum + phosphorus solublising bacteria on strawberry results maximum total soluble solids (10.34° Brix).

Khalid *et al*. (2013) reported that improved quality parameters like fruit size, fruit weight, number of fruits, Total Soluble Solids (8.88° Brix) and ascorbic acid content (64 mg) of strawberry fruits were higher in vermicompost followed by FYM.

Vanilarasu and Balakrishnamurthy (2014) reported that application of vermicompost 5 kg per tree in banana increases the quality attributes (TSS – 23.23 %, Acidity – 0.82 % and Ascorbic acid – 12.92 mg/100 g), Non-reducing and Total sugars (6.06 % and 14.92 % respectively) besides enhancing the shelf life of banana (14.03 days) and reduced physiological loss in weight (7.44 %).

The combination of vermicompost and PSB showed highest plant height (23.59 cm), leaves/plant (12.67), primary branches/plant (10.50), secondary branches/plant (27.35), first flowering (61.06 days), flowers/plant (15.33), first fruit setting (72.80 days) and fruits plant-1 (8.33). Similarly, the treatments combination of vermicompost and PSB significantly affected the Total Soluble Solids (TSS) (10.75° Brix), titratable acidity (0.82), vitamin C (57.24 mg/100 gm fruit), total sugars (5.95 %) and juice content (79.50 %) of strawberry. (Kumar *et al.*, 2015).

2.3 Effect of organic manures on fruit growth rate and shelf life of strawberry

Reganold *et al.* (2010) reported that the organic farms had strawberries with longer shelf life. In one variety, sensory panels judged organic strawberries to be sweeter and have better flavor, overall acceptance and appearance than their conventional counterparts. The organic strawberry farms produced higher quality fruit and that their higher quality soils may have greater microbial functional capability and resilience to stress.

Vanilarasu and Balakrishnamurthy (2014) conducted a study on effect of organic manures and amendments on quality attributes and shelf life of banana cv. Grand Naine. Results revealed that influence of nutrients derived from organic sources had a positive effect on the post harvest characters of banana like highest shelf life (14.03 days) of fruits and least physiological loss in weight (7.44 per cent).

Jain *et al.* (2017) carried out a study on influence of INM on yield, quality, shelf life and economics of cultivation of strawberry (*Fragaria* × *ananassa* Duch.) cv. Sweet Charlie. He reported that the maximum Shelf life (5.69 days) was recorded in vermicompost application. However, the maximum cost: benefit ratio (1: 3.64) was recorded in the treatment Vermicompost + FYM + PSB + Azotobacter.

Mohit *et al.* (2018) conducted an experiment to find the effect of different organic manures and to evaluate the efficacy of these organic manures on physical and chemical characteristics of mango cv. Dashehari at ambient storage conditions. The maximum physiological loss in weight was recorded in control trees fruit, whereas, minimum physiological loss in weight was recorded with application of 75 kg vermicompost per tree.

MATERIAL AND METHODS

III MATERIAL AND METHODS

The research entitled **"Influence of organic manures on growth, yield and quality of strawberry (*Fragaria* × *ananassa* Duch.) under naturally ventilated polyhouse"** was carried out in the Department of Fruit Science, College of Horticulture, Mudigere, during 2019-20 to know the effect of organic manures for commercial cultivation of strawberry in the five-tiered vertical growing system.

The detailed information of materials used and methodologies adopted during the course of investigation are given here under the following headings.

3.1 Geographical location of the experimental site

The research was carried out in a low-cost polyhouse of the Department of Fruit Science, College of Horticulture, Mudigere, which is situated in the Western Ghats, represents the typical climate of hill zone (Zone-9 and Region-V) of Karnataka. It is located at 13^{o} 7 ' North latitude and 74^{o} 37 ' East Longitude with an altitude of 980 m above mean sea level (MSL).

3.2 Weather conditions of the experimental site (During the experimental period)

Mudigere is one of the areas which receives heavy rainfall. The average rainfall received during the experimental period was 30 mm, distributed over five months (1st November 2019 – 31st March 2020). The average maximum and minimum temperature of the experimental site was 32.70 ℃ and 17.34℃, respectively. The average maximum relative humidity of the experimental site was 80.20 per cent. The meteorological data for the period of experimentation was obtained from the meteorological observatory of Zonal Agricultural and Horticultural Research Station, Mudigere and the same is presented in Appendix-I.

3.3 Media and its characteristics

The media combination for the experiment were selected based on their physicochemical properties. The media used and their characteristics are as follows,

3.3.1 Media combination used

Soil: Vermiculite: Cocopeat: Vermicompost in the ratio of 1:1:1:1(v/v)

3.3.1.1 Soil

Soil is the cheapest available growing medium and provides anchorage, nutrients, air, water, *etc.* for plant growth (Ellis *et al.*, 1974). It is a product interaction of several factors over a period of time such as climate, relief (evaluation, orientation and slope of terrain), organisms and the soil's origin materials. Soil continuously undergoes developmental process by way of numerous physical, chemical and biological weathering processes, with associated erosion. The dry bulk density and

particle density of most of soils were found in between the ranges of 1.1 to 1.6 g/cm³ and 2.6 to 2.7 g/cm³, respectively.

3.3.1.2 Vermiculite

Vermiculite is a limited-expansion 2:1 clay with a medium shrink-swell capacity, formed by two tetrahedral sheets for everyone octahedral sheet. It is a hydrous phyllosilicate mineral obtained as a result of weathering of biotite and chemically is hydrated magnesium aluminium iron silicate contains both potassium and magnesium. The professional horticulturist use vermiculite in combination with other substrates such as peat or composted pine bark to produce soilless growing medium. These promote faster growth and give quick anchorage to young roots. The mixture helps in proper air circulation, plant food and moisture. The properties of vermiculite are as follows according to Pardossi *et al.* (2011)

Bulk density- 90-150 kg/m^3

Total porosity- 90-95 per cent (v/v)

3.3.1.3 Cocopeat

Cocopeat is one of the most abundant organic waste materials of coconut industry in many tropical and subtropical countries. The extracted long fibres from the mesocarp soaking were used in the production of matting, brushes preparation and insulating materials and the remaining material constitutes cocopeat, which is used to improve aeration in growing media. The properties of cocopeat are as follows according to Abad *et al.* (2005)

Particle size- 0.25-2 mm (85 %)

Dry bulk density- 56 kg/m³

Total pore space- 96.3 per cent (v/v)

Air content- 41.2 per cent (v/ v)

Available water- 28.1 per cent (v/ v)

3.3.1.4 Vermicompost

Vermicompost is the product obtained by the process of composting, using various species of earthworms to create a mixture of decomposed organic wastes. It is a nutrient rich organic fertilizer than any compost produced by other composting methods, contains nutrients in a water soluble form that is relatively easy to absorb for plants. It is rich in microbial population and converts nutrients in soil to the plant available form. It is used in small scale and sustainable organic farming.

3.3.2 Organic Manures

3.3.2.1 Beejamruth

About 5 kg of Desi cow dung was taken in a cloth and bound by small rope as a small bundle and hung for a night (12 hour) in 20 litre of water. In another container, 50 g of lime was dissolved in 1 litre of water and kept over night. Next day morning, the cow dung was squeezed add handful of soil was added and stirred well. To this solutions, 5 litre of Desi cow urine and lime water was added and stirred well. Seedling roots were dipped in beejamruth for 12 hours at concentration or quantity of 50 ml per seedling.

3.3.2.2 Jeevamruth

200 litre of water was taken in a barrel and ingredients one by one, first desi cow dung followed by jaggery, pulse flour, desi cow urine and collected soil was added. After adding each material stirred well in clock wise direction. Barrel was kept it in shade, which was covered with wet jute bag. The prepared solution was stirred three times a day. Jeevamruth @ 500 ml per plant was drenched at two stages *i.e.,* flowering and fruit development stage.

These two liquid organic manures *viz.,* Beejamruth and Jeevamruth were procured from Organic Farming Research Station, Navile, Shivamogga.

3.3.2.3 Vermicompost

Recommended Dose of Nitrogen (RDN) through VC was calculated based on the weight of the media in the pot. Vermicompost supplies 1.25 per cent Nitrogen, so 100 per cent RDN is supplied by applying 21 g of VC per pot at flowering and fruit development stage.

3.3.2.4 Farm Yard Manure

Recommended Dose of Nitrogen (RDN) through FYM was calculated based on the weight of the media in the pot. FYM supplies 0.5 per cent Nitrogen, so 100 per cent RDN is supplied by applying 52.5 g of FYM per pot at flowering and fruit development stage.

3.4 Experimental details

3.4.1 Design and experimental layout

The experiment was laid out in randomised completely block design (RCBD) with three replications and nine treatments (Table 1).

Table 1: The experimental details are as follows

Location	College of Horticulture, Mudigere.
Number of treatments	09
Number of replications	03
Experimental design	RCBD
Planting method	Vertical farming system
Planting time	07 November, 2019
Plant population	351
Number of plants per treatment	39
Genotype or Variety	Winter Dawn

3.4.2 Treatment details

Four different organic manure in different combination along with control (RDF) were considered as various treatments and RDF @ 150:100:120 kg ha^{-1} and the treatment details are presented in Table 2.

3.4.3 Source of planting material

The strawberry variety "Winter Dawn" was used for conducting experiment. Tissue culture plants procured from KF Bio Planter Private Limited, Kumar capital –Haveli, Pune (Maharashtra) was used for the experimental study.

Table 2: The details of treatments are as follows

T_1	100 per cent RDN through FYM
T_2	100 per cent RDN through FYM + Jeevamruth @ 500 ml per pot at two stages
T_3	100 per cent RDN through FYM + Beejamruth seedling treatment
T_4	100 per cent RDN through FYM + Jeevamruth @ 500 ml per pot at two stages + Beejamruth seedling treatment
T_5	100 per cent RDN through vermicompost
T_6	100 per cent RDN through vermicompost + Jeevamruth @500 ml per pot at two stages
T_7	100 per cent RDN through vermicompost + Beejamruth seedling treatment
T_8	100 per cent RDN through vermicompost + Jeevamruth @500 ml per pot at two stages + Beejamruth seedling treatment
T_9	Recommended Dose of Fertilizers (150:100:120 kg/ha)

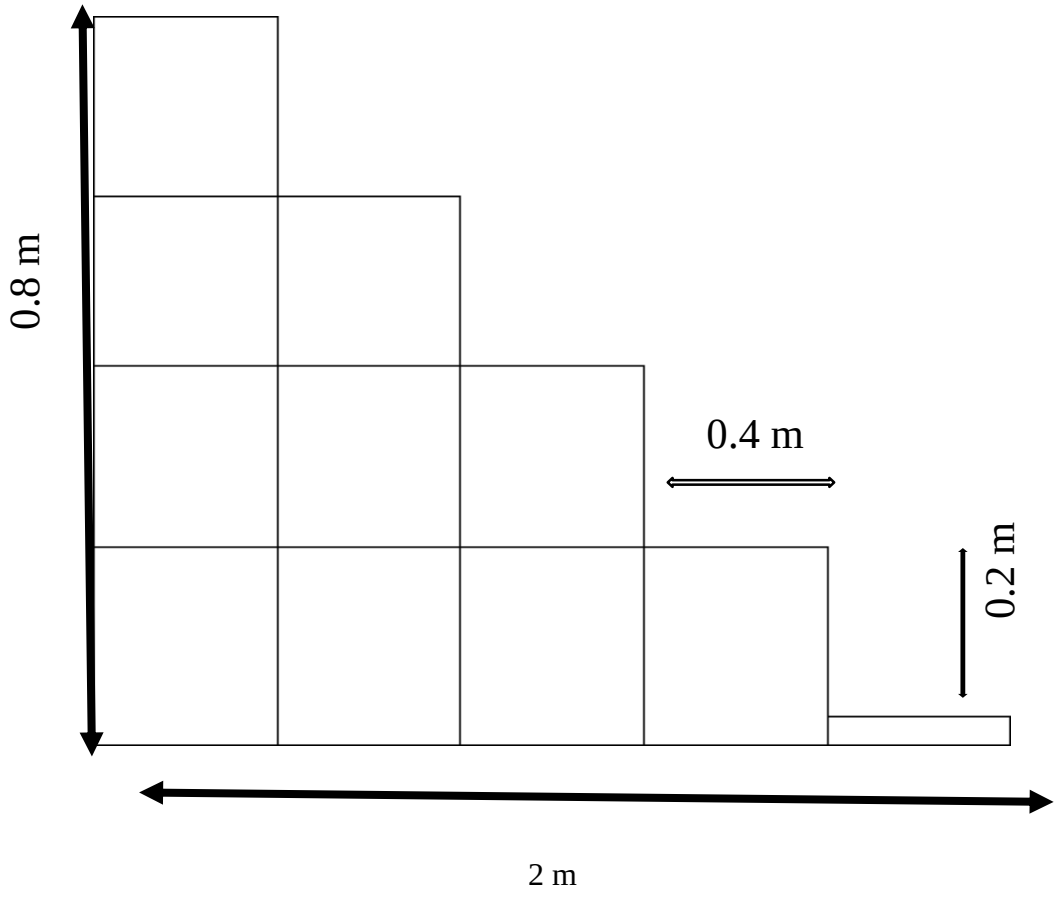

Fig. 1. Schematic representation of vertical farming system

3.5 Cultural operations

The various cultural operations carried out during the course of investigation are mentioned below;

3.5.1 Preparation of experimental plot

The experiment was conducted in the existing permanent vertical growing structures constructed in "V" shape orienting face to face with five tiers in each structure. The growing system was constructed with three walls using solid cement blocks in each structure and was placed with the wooden planks to accommodate pots on it. The height and width of each growing system were 0.8 m and 2 m respectively and the spacing of 0.2 m between each tier was maintained in individual structure to facilitate better light penetration, air circulation and easy intercultural operations. Schematic representation of the vertical growing structure is shown in Fig. 1.

3.5.2 Preparation of growing media

The growing media used for the study such as soil, vermiculite, cocopeat and vermicompost (1: 1: 1: 1) were taken from the Department of Fruit Science and College stores.

3.5.3 Sterilization of polyhouse

Sterilization of polyhouse was done by drenching the soil with 4 per cent formaldehyde solution and covered with polythene sheets for a period of seven days to induce effect of fumigation followed by proper ventilation for three days and watered sufficiently for leaching out the chemical residues.

3.5.4 Pot filling

Pots having a standard size of 10-inch were used for the experiment and pots filled with growing media covering $3/4^{th}$ of total volume by understanding expandable nature of media, pore space for better exchange of gases and moisture for proper plant growth. Pots were provided with a layer of gravel at the base to drain out excess water in the media

3.5.5 Establishment of drip system

The facility of drip unit was established to irrigate during the experimentation period. The drippers, having a discharge capacity of 4 L hr^{-1} were fitted to each pot using laterals of 16 mm diameter, provided with valves to individual laterals to govern the water discharge.

3.5.6 Transplanting

Transplanting in pots was done on 7^{th} November 2019 using tissue cultured plants. Each pot was planted with a single plant and sufficient irrigation was given to

overcome transplanting shock. Plants were planted with a ball of the earth for better establishment.

3.5.7 After care operations

Gap filling was done where ever required after transplanting due to the mortality of few seedlings. The flower clusters appearing at the early stages were removed in order to promote vegetative growth.

3.5.8 Intercultural operations

The pots were kept clean by hand weeding. Irrigation was given through a drip system at an interval of once in two days during the crop growth period. Removal of dried leaves and runners was done at 15 days interval.

3.6 Observations recorded

Five plants were selected randomly and tagged in each treatment and replication for the purpose of recording observations of various parameters *viz.*, growth, flowering, fruit yield and quality. The observations were recorded as per standard procedures. The mean value of the data observed was taken to represent treatment effect with respect to each character.

3.6.1 Growth parameters

Observations on growth parameters *viz.*, plant height, number of leaves, length and breadth of leaves, number of runners and plant spread were recorded at 30, 60, 90 and 120 days after transplanting. While plant dry weight was recorded at harvest.

3.6.1.1 Plant height

The plant height was measured from the ground level to the tip of the plant at 30, 60, 90 and 120 days after transplanting and was expressed in centimetre.

3.6.1.2 Plant spread

The plant spread was measured in two directions *i.e.* from north-south and east-west. The maximum horizontal spread of the plant was worked out and measured in centimetre.

3.6.1.3 Number of trifoliate leaves per plant

The total numbers of fully opened leaves produced in each tagged plant at 30, 60, 90 and 120 days after transplanting were counted manually and the average per plant was calculated and represented.

3.6.1.4 Number of crowns per plant

The total numbers of crowns produced from each plant at 30, 60, 90 and 120 days was counted manually and the average was worked out.

Plate 1. Vertical farming system with drip unit

Plate 2. General view of experimental plot

3.6.1.5 Leaf area

Randomly selected leaves of five plants from each treatment and replication were collected and cleaned. Leaf area was computed by digital leaf area meter (LAM 211) and was expressed in cm^2 per plant.

3.6.1.6 Leaf area index

Leaf area index was computed using the formula given by Watson (1952).

$$LAI = \frac{A}{P}$$

Where,

A=Leaf area

P=Ground area covered by plant or spacing provided

3.6.1.7 Total dry matter at harvest

Five plants from each treatment were uprooted and dried in hot air oven at 65 ºC for 48 hours or till plants reached a constant weight and recorded weight was expressed in gram per plant.

3.6.1.8 Number of runners per plant

The total number of runners produced from the crown of each tagged plant at the end of the crop growing season was counted manually and the average was worked out and expressed in number per plant.

3.6.2 Flowering parameters

3.6.2.1 Days taken for first flower bud emergence

It was recorded as a total number of days taken from the date of planting to the date of appearance of the first flower bud.

3.6.2.2 Number of flowers per plant

The total number of flowers produced from the tagged plant were recorded by counting up to the final harvest and the average number of flowers per plant was worked out.

3.6.2.3 Days taken from flower bud initiation to berry maturity

It was calculated as a number of days taken from flower bud initiation to berry harvest at the fully matured stage.

3.6.3 Yield parameters

3.6.3.1 Number of fruits per plant

The number of fruits per plant was counted manually from randomly selected five plants and then the average value was worked out and presented.

3.6.3.2 Fruit length

The length from the stalk end and floral end of the fruit was measured with the help of digital Vernier calipers and expressed in centimetre.

3.6.3.3 Fruit diameter

Fruit diameter was measured with the help of digital Vernier calipers at the area of maximum width and it was expressed in centimetre.

3.6.3.4 Fruit volume

The volume of the fruits was recorded by water displacement method and expressed in cubic centimetre per fruit.

3.6.3.5 Fruit yield per plant

The fruits were harvested when three fourth of skin developed red colour. The harvesting operation was done in early morning hours to reduce the transpirational losses. The observations on fruit weight and yield was recorded from each treatment after every harvest. The total yield was calculated by adding the values obtained in different flush of harvest and expressed as grams per plant.

3.6.3.6 Fruit growth rate

Fruit growth rate was calculated by taking fruit diameter at fruit set stage and red ripe stage and it is expressed as cm day^{-1}.

$$\frac{Fruit\ diameter\ at\ red\ ripe\ stage - Fruit\ diameter\ at\ fruit\ set\ stage}{Number\ of\ days}$$

3.6.4 Quality and bio chemical parameters

3.6.4.1 Total soluble solids

The total soluble solid of the fruit juice was determined with the digital refractometer at room temperature by putting a few drops of juice on the prism and expressed as degree brix (^{o}Brix). The refractometer was calibrated with distilled water before use.

3.6.4.2 Titratable acidity

Twenty-five grams of fruit pulp was thoroughly homogenized in an electric blender and volume was made to 250 ml. The mixture was filtered through Whatman No. 1 filter paper, then 50 ml of sample was titrated against N/10 NaOH solution

using phenolphthalein indicator till it gave pink coloured endpoint. The total titratable acidity was calculated in terms of citric acid on the basis of 1 ml of N/10 NaOH equivalent to 0.0067 gram of anhydrous citric or per cent citric acid in juice (Ranganna, 1995). The total titratable acidity was expressed in terms of citric acid percentage on fresh fruit weight basis.

$$\text{Titrable acidity (\%)} = \frac{\text{Titre value} \times \text{Normality of Alkali} \times \text{Volume made up} \times \text{Equivalent weight of acid}}{\text{Volume of sample taken} \times \text{Volume of aliquot taken} \times 1000} \times 100$$

3.6.4.3 Reducing sugar

The reducing sugar content of the fruit was estimated by anthrone method and was expressed in percentage. The reducing sugar content of the fruit was estimated by pipetting out 0.5 ml of sample aliquot and different concentrations (0, 0.2, 0.4, 0.6, 0.8 and 1.0 ml) of glucose standard solution in different test tubes were taken and the volume was made up to 2.5 ml each with distilled water to form the standard glucose graph. All the tubes were kept in an ice bath and added 5 ml of anthrone reagent to the test tube slowly. The contents were gently stirred with a glass rod. Then, the contents of test tubes were heated on boiling water bath for exactly 7.5 minutes and were cooled immediately in ice bath. After cooling, the absorbance of the solutions was measured at 630 nm against the blank. The sugar content was calculated through standard glucose curve.

$$\text{Reducing Sugar (\%)} = \frac{\text{Glucose (mg) in sample from standard curve}}{\text{Aliquot taken (ml) for test}} \times \frac{\text{Vol. made (ml) after alcohol evaporation}}{\text{Vol. taken for alcohol evaporation (ml)}} \times \frac{\text{Vol. made (ml) after sample extraction}}{\text{Sample taken for extraction (mg)}} \times 100$$

3.6.4.4 Non-reducing sugars

The percentage of non-reducing sugars was obtained by subtracting the percentage of reducing sugars from the total sugars and expressed in percentage.

Non-reducing sugar (%) = Total sugar – Reducing sugar

3.6.4.5 Total sugar

The total sugar content of the fruit was estimated by following the method of Ranganna (1977) and expressed in percentage.

The total sugar content of the fruit was calculated by using the formula

$$\text{Total Sugars (\%)} = \frac{\text{Glucose (mg) in sample from standard curve}}{\text{Aliquot taken (ml) for test}} \times \frac{\text{Vol. made after hydrolysis (ml)}}{\text{Vol. taken for hydrolysis (ml)}} \times \frac{\text{Vol. made after (ml) alcohol evaporation}}{\text{Vol. taken for evaporation (ml)}} \times \frac{\text{Vol. made after sample extraction (ml)}}{\text{Sample taken for extraction (mg)}} \times 100$$

3.6.4.6 Ascorbic acid

Ascorbic acid was estimated by using 2, 6-dichlorophenol indophenol titration method. The sample was extracted in 4 per cent of oxalic acid, filtered using Whatman No.4 filter paper and made up to a known volume (50 ml). The known volume of filtrate (5 ml) was pipetted out in a conical flask and 5 ml of oxalic acid was added and titrated against 2, 6-Dichlorophenol-indophenol dye. The titration was carried out until an appearance of light pink colour. The dye was prepared using 50 mg of sodium salt of 2, 6- dichlorophenol-indophenol dye in approximately 200 ml of double distilled water containing 4.2 mg of sodium bicarbonate. It was used for titration and standardizing ascorbic acid (Ranganna, 1986) and expressed in milligram per hundred grams of edible pulp.

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Dye factor} \times \text{Titrate value} \times \text{Vol. made up}}{\text{Aliquot of extraction} \times \text{Vol. of the sample taken} \times \text{Sample taken}} \times 100$$

Where, dye factor =0.5

3.6.4.7 Sugar to acid ratio

The sugar to acid ratio was calculated by dividing the total sugar content by the titratable acidity.

3.6.4.8 Shelf life

Shelf life of fruits was decided based on the appearance and marketability of the fruits. When the fruits crossed edible ripe stage, those fruits were considered to have reached the end of their shelf life (Turner, 1997) and was expressed in days.

3.6.4.9 Chlorophyll estimation

The chlorophyll content of leaf was analysed by collecting the healthy fully matured second leaf from the centre of the plant at peak vegetative growth stage. Fresh and fully matured leaves from the plant were brought to the laboratory in polyethylene bag from the research field and were cut into small pieces. Known weight of sample (100 mg) was cut into small pieces and immersed in 7.0 ml of dimethyl sulfoxide and was stored in dark condition for 24 hours to facilitate dispersion of chlorophyll into dimethyl sulfoxide. After the incubation period, supernatant liquid was collected by decanting and leaf tissue was discarded. Then the final volume of the supernatant solution was made up to 10 ml using DMSO.

Chlorophyll-a, chlorophyll-b and total chlorophyll contents of leaf tissue were determined by using dimethyl sulfoxide (DMSO) method as suggested by Shaof and Lium (1976).

The absorbance of the extract was measured at 645 nm and 663 nm using Dimethyl sulfoxide as blank in spectrophotometer.

The Chlorophyll-a, Chlorophyll-b and total chlorophyll contents were calculated by using the formulae given below

$$\text{Total Chlorophyll} = [20.2\ (A645) + 8.02\ (A663)] \times \frac{V}{100 \times W \times a}\ \text{(mg/g fresh weight)}$$

$$\text{Chlorophyll} - \text{a} = [12.7\ (A663) + 2.69\ (A645)] \times \frac{V}{100 \times W \times a}\ \text{(mg/g fresh weight)}$$

$$\text{Chlorophyll} - \text{b} = [22.9\ (A645) - 4.68\ (A663)] \times \frac{V}{100 \times W \times a}\ \text{(mg/g fresh weight)}$$

Where,

A - Absorbance at a specific wavelength (645 nm & 663 nm)

V - Final volume of the chlorophyll extract (10 ml)

W - Fresh weight of the sample (100 mg)

a - Path length of light in the cuvette (1 cm)

3.6.5 Economics of cultivation

3.6.5.1 Cost of cultivation

The cost of all the inputs prevailed at the time of their use and the labour cost were considered to work out the cost of cultivation for standard polyhouse area of 500 m^2.

3.6.5.2 Gross income

The gross income was worked out based on the prevailing market cost of strawberry fruits for standard polyhouse area of 500 m^2.

3.6.5.3 Net income

The net income per standard polyhouse area of 500 m^2 was calculated by using the following formula.

Net income = Gross income – Cost of cultivation

3.6.5.4 Benefit cost ratio

The benefit cost ratio for different treatments was worked out based on the price of inputs used for cultivation and price of marketable produce in local market by using following formula and it is expressed in ratio.

$$\text{Benefit cost ratio} = \frac{\text{Net income (₹/ ha)}}{\text{Cost of cultivation (₹/ ha)}}$$

3.7 Statistical analysis of experimental data

The data on all growth, yield and quality parameters were tabulated and subjected for statistical analysis using method of analysis of variance (ANOVA) as given by Fisher and Yates (1963). Whenever 'F' test was found significance for comparing the means of two treatments, critical differences (C.D. at 5 %) were worked out.

EXPERMENTAL RESULTS

IV EXPERIMENTAL RESULTS

The present investigation **"Influence of organic manures on growth, yield and quality of strawberry (*Fragaria* x *ananassa* Duch.) under naturally ventilated polyhouse"** was conducted during 2019-20 in the Department of Fruit Science, College of Horticulture, Mudigere. The results obtained during the course of investigation are presented under the following headings.

4.1 Influence of organic manures on growth parameters of strawberry

4.1.1 Plant height

The data related to plant height of strawberry was recorded at different stages of crop growth is presented in Table-3. The plant height significantly differed at 30, 60, 90 and 120 days after planting. The treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment showed highest plant height of 13.75 cm and was found on par with the treatment T_4-100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment after 30 DAP. While, at 60, 90 and 120 DAP, treatment T_8 recorded highest plant height of 18.54 cm, 24.31 cm and 28.85 cm respectively followed by treatment T_4. Significantly lower value of plant height was noticed in T_9-Recommended Dose of Fertilizers (Control), which showed 9.98 cm, 13.21 cm, 15.89 cm and 18.65 cm at 30, 60, 90 and 120 DAP respectively.

4.1.2 Number of trifoliate leaves per plant

There was a significant difference between different treatments with respect to number of trifoliate leaves. The data pertaining to the number of leaves per plant was recorded at different stages (30, 60, 90 and 120 days after planting) of crop growth as influenced by different organic manures is presented (Table-4).

Among the different organic manure combinations, treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment showed higher number of trifoliate leaves of 6.54 at 30 DAP which was on par with the treatment T_4-100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment. Significantly higher number of trifoliate leaves of 13.87, 19.58 and 27.51 at 60, 90 and 120 DAP respectively was recorded in treatment T_8 followed by treatment T_4 and minimum number of trifoliate leaves of 3.65, 9.01, 12.93 and 19.21 at 30, 60, 90 and 120 DAP respectively were observed in treatment T_9- Recommended Dose of Fertilizers (Control), which was significantly lower than the other treatments.

Table 3. Effect of organic manures on plant height of strawberry at different intervals after planting

Treatment	Plant height (cm)			
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**
T_1 - 100 per cent RDN through FYM	10.47	14.50	17.29	21.41
T_2 - T_1 + Jeevamruth at 500 ml/pot	11.89	15.73	20.32	24.98
T_3 - T_1 + Beejamruth seedling treatment	11.13	14.97	19.97	22.76
T_4 - T_2 + T_3	12.87	17.24	22.51	27.57
T_5 - 100 per cent RDN through Vermicompost	10.86	14.71	18.37	22.83
T_6 - T_5 + Jeevamruth at 500 ml/pot	12.23	16.57	21.43	25.71
T_7 - T_5 + Beejamruth seedling treatment	11.56	15.62	19.71	23.26
T_8 – T_6 + T_7	13.75	18.54	24.31	28.85
T_9 – Recommended Dose of Fertilizers	9.98	13.21	15.89	18.65
S. Em ±	0.02	0.02	0.04	0.05
C. D. (P = 0.05)	0.06	0.07	0.12	0.15

DAP- Days after planting

RDN- Recommended dose of nitrogen

Table 4. Effect of organic manures on trifoliate leaves of strawberry at different intervals after planting

Treatment	Number of trifoliate leaves per plant			
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**
T_1 - 100 per cent RDN through FYM	4.03	10.20	14.31	20.45
T_2 - T_1 + Jeevamruth at 500 ml/pot	5.13	12.03	17.41	25.23
T_3 - T_1 + Beejamruth seedling treatment	4.54	11.54	16.36	23.01
T_4 - T_2 + T_3	6.05	13.21	18.57	26.53
T_5 - 100 per cent RDN through Vermicompost	4.23	11.19	15.57	21.17
T_6 - T_5 + Jeevamruth at 500 ml/pot	5.71	12.73	17.62	26.12
T_7 - T_5 + Beejamruth seedling treatment	4.80	11.93	16.83	24.34
T_8 – T_6 + T_7	6.54	13.87	19.58	27.51
T_9 – Recommended Dose of Fertilizers	3.65	9.01	12.93	19.21
S. Em ±	0.02	0.02	0.03	0.05
C. D. (P = 0.05)	0.05	0.07	0.09	0.14

DAP- Days after planting

RDN- Recommended dose of nitrogen

4.1.3 Leaf area

The data pertaining to the leaf area recorded at 30, 60, 90 and 120 days after planting significantly varied with the application of different treatments (Table-5).

The maximum leaf area of 56.82 cm^2, 73.91 cm^2, 86.78 cm^2 and 106.78 cm^2 at 30, 60, 90 and 120 DAP was found in treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment followed by treatment T_4-100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment. The lower values of 48.91 cm^2, 59.78 cm^2, 70.14 cm^2, and 89.14 cm^2 at 30, 60, 90 and 120 DAP for leaf area was observed in treatment T_9- Recommended Dose of Fertilizers (Control).

4.1.4 Leaf area index

The data pertaining to the leaf area index recorded at 30. 60, 90 and 120 days after planting significantly varied with the application of different treatments (Table-6).

The maximum leaf area index of 0.468, 0.609, 0.717 and 0.881 at 30, 60, 90 and 120 DAP was found in treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment followed by treatment T_4-100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment. The lower values of 0.404, 0.494, 0.578 and 0.736 at 30, 60, 90 and 120 DAP for leaf area was observed in treatment T_9- Recommended Dose of Fertilizers (Control).

4.1.5 Plant spread

The data pertaining to plant spread recorded at 30, 60, 90 and 120 days after planting in strawberry is presented in Table 7 and 8. For the plant spread in North-South direction treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment showed significantly higher values of 18.54 cm, 22.51 cm, 26.03 cm and 30.42 cm at 30, 60, 90 and 120 DAP, respectively. The minimum plant spread at 30 days after planting was recorded in T_9-Recommnded Dose of Fertilizers (Control) in North -South direction *i.e.*,11.52 cm, 14.19 cm, 20.51 cm and 22.07 cm at 30, 60, 90 and 120 DAP, respectively.

Similar results were also obtained for plant spread in East-West direction. The treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment showed maximum plant spread of 18.05 cm, 23.01 cm, 26.13 cm and 30.04 cm at 30, 60, 90 and 120 DAP, respectively. The minimum plant spread of 11.31 cm, 15.08 cm, 20.98 cm and 23.18 cm at 30, 60, 90 days after planting was recorded in T_9-Recommnded Dose of Fertilizers (Control) in East- West direction.

Table 5. Effect of organic manures on leaf area of strawberry at different intervals after planting

Treatment	Leaf area (cm^2)			
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**
T_1 - 100 per cent RDN through FYM	52.19	64.39	73.78	92.85
T_2 - T_1 + Jeevamruth at 500 ml/pot	54.57	69.82	83.14	96.31
T_3 - T_1 + Beejamruth seedling treatment	54.08	67.13	78.93	94.91
T_4 - T_2 + T_3	55.15	72.08	85.14	100.92
T_5 - 100 per cent RDN through Vermicompost	53.80	66.57	76.54	93.22
T_6 - T_5 + Jeevamruth at 500 ml/pot	54.80	71.13	84.23	98.77
T_7 - T_5 + Beejamruth seedling treatment	54.31	68.79	81.78	95.81
T_8 – T_6 + T_7	56.82	73.91	86.78	106.78
T_9 – Recommended Dose of Fertilizers	48.91	59.78	70.14	89.14
S. Em ±	0.03	0.07	0.09	0.08
C. D. (P = 0.05)	0.10	0.20	0.26	0.24

DAP- Days after planting

RDN- Recommended dose of nitrogen

Table 6. Effect of organic manures on leaf area index of strawberry at different intervals after planting

Treatment	Leaf area index			
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**
T_1 - 100 per cent RDN through FYM	0.430	0.533	0.608	0.767
T_2 - T_1 + Jeevamruth at 500 ml/pot	0.450	0.577	0.687	0.797
T_3 - T_1 + Beejamruth seedling treatment	0.447	0.555	0.654	0.787
T_4 - T_2 + T_3	0.457	0.595	0.704	0.837
T_5 - 100 per cent RDN through Vermicompost	0.447	0.549	0.633	0.767
T_6 - T_5 + Jeevamruth at 500 ml/pot	0.453	0.587	0.696	0.817
T_7 - T_5 + Beejamruth seedling treatment	0.447	0.567	0.676	0.718
T_8 – T_6 + T_7	0.468	0.609	0.717	0.881
T_9 – Recommended Dose of Fertilizers	0.404	0.494	0.578	0.736
S. Em ±	0.002	0.001	0.001	0.001
C. D. (P = 0.05)	0.005	0.003	0.003	0.003

DAP- Days after planting

RDN- Recommended dose of nitrogen

Table 7. Effect of organic manures on plant spread of strawberry at different intervals after planting

Treatment	Plant spread (cm) (N-S)			
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**
T_1 - 100 per cent RDN through FYM	12.98	15.23	21.09	23.54
T_2 - T_1 + Jeevamruth at 500 ml/pot	15.47	19.03	23.17	27.52
T_3 - T_1 + Beejamruth seedling treatment	14.08	17.08	22.05	25.03
T_4 - T_2 + T_3	17.03	21.17	25.82	29.97
T_5 - 100 per cent RDN through Vermicompost	13.72	15.87	21.73	24.14
T_6 - T_5 + Jeevamruth at 500 ml/pot	16.76	19.78	24.31	28.20
T_7 - T_5 + Beejamruth seedling treatment	14.78	17.92	22.87	26.13
T_8 – T_6 + T_7	18.54	22.51	26.03	30.42
T_9 – Recommended Dose of Fertilizers	11.52	14.19	20.51	22.07
S. Em ±	0.03	0.04	0.03	0.04
C. D. (P = 0.05)	0.10	0.13	0.09	0.13

DAP- Days after planting

RDN- Recommended dose of nitrogen

Table 8. Effect of organic manures on plant spread of strawberry at different intervals after planting

Treatment	Plant spread (cm) (E-W)			
	30 DAP	60 DAP	90 DAP	120 DAP
T_1 - 100 per cent RDN through FYM	12.01	16.01	21.08	24.32
T_2 - T_1 + Jeevamruth at 500 ml/pot	14.81	18.77	23.05	28.65
T_3 - T_1 + Beejamruth seedling treatment	13.92	17.52	21.62	26.41
T_4 - T_2 + T_3	16.52	22.52	25.03	29.85
T_5 - 100 per cent RDN through Vermicompost	13.53	16.23	21.41	25.35
T_6 - T_5 + Jeevamruth at 500 ml/pot	15.98	18.87	23.78	29.41
T_7 - T_5 + Beejamruth seedling treatment	14.52	18.03	21.95	27.45
T_8 – T_6 + T_7	18.05	23.01	26.13	30.04
T_9 – Recommended Dose of Fertilizers	11.31	15.08	20.98	23.18
S. Em ±	0.03	0.04	0.03	0.04
C. D. (P = 0.05)	0.10	0.13	0.09	0.12

4.1.6 Number of crowns per plant

The number of crowns per plant was found significantly different for different organic manures at 120 DAP (Table-9). Among the different treatments, T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment showed the highest number of crowns (4.65 per plant) at 120 DAP followed by T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment. The lowest number of crowns per plant (2.22) was recorded in T_9- Recommended Dose of Fertilizers (Control) at 120 DAP.

4.1.7 Number of runners per plant

The data obtained for number of runners per plant showed significant differences at 120 DAP as influenced by different organic manures (Table-9). Treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment showed maximum number of runners per plant (6.21) at 120 DAP, which was found on par with T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment. The treatment T_9- Recommended Dose of Fertilizers (Control) showed significantly lower number of runners per plant (4.82) at 120 DAP.

4.1.8 Total dry matter at harvest

The significant difference was observed for total dry matter at harvest between different organic manures of strawberry as presented (Table- 9). The highest total dry matter (36.87 g) was recorded in treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment followed by treatment T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment. The lowest total dry matter (19.76 g) was recorded in treatment T_9- Recommended Dose of Fertilizers (Control).

4.2 Influence of different organic manures on yield parameters of strawberry

4.2.1 Number of days taken for first flowering

The application of different treatments resulted in significant difference with respect to days taken for first flower bud appearance (Table-10). The minimum number of days taken for first flowering (55.78 days) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment, which was followed by T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (56.53 days). The maximum number of days taken for flowering (64.55 days) was recorded in T_9- Recommended Dose of Fertilizers (Control).

4.2.2 Number of flowers per plant

The application of different organic manures showed significant difference with respect to number of flowers per plant (Table-10). The maximum number of flowers per plant (24.50) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment, which was followed by T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (23.92). The minimum number of flowers (19.12) was observed in T_9- Recommended Dose of Fertilizers (Control).

4.2.3 Number of fruits per plant

There was a significant difference among the treatments with respect to number of fruits per plant (Table-10). The maximum number of fruits per plant (19.05) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment, which was on par with T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (18.56). The minimum number of fruits per plant (14.41) was recorded in T_9- Recommended Dose of Fertilizers (Control).

4.2.4 Fruit weight

The weight of fruit differed significantly among the various treatments with different organic manures and the data on mean weight of fruits are presented in Table-10. The maximum fruit weight (18.41 g) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment, which was on par with T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (17.26). The minimum fruit weight (13.80 g) was recorded in T_9- Recommended Dose of Fertilizers (Control).

4.2.5 Fruit length

The data pertaining to the effect of different organic manures on fruit length of strawberry is furnished in Table-11. The maximum fruit length (4.31 cm) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment, which was on par with T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (3.89). The minimum fruit length (2.35 cm) was recorded in T_9- Recommended Dose of Fertilizers (Control).

4.2.6 Fruit diameter

The data indicated that different treatments exerted a significant influence on fruit diameter (Table-11). The maximum fruit diameter (3.48 cm) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment, which was on par with T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (3.36 cm). The minimum fruit diameter (2.32 cm) was observed in T_9- Recommended Dose of Fertilizers (Control).

4.2.7 Fruit volume

The significant difference was observed in fruit volume of strawberry with respect to different treatments (Table-11). The maximum fruit volume (21.43 cc) was observed in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment, which was on par with T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (21.22 cc). While, minimum volume (16.81 cc) was observed in T_9- Recommended Dose of Fertilizers (Control).

4.2.8 Yield per plant

Significant difference was observed for fruit yield per plant when different organic manures were applied in strawberry (Table-11). The maximum fruit yield per plant (350.79 g) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment, which was followed by T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (320.35 g). The minimum fruit yield per plant (198.89 g) was recorded in T_9- Recommended Dose of Fertilizers (Control).

4.3 Influence of different organic manures on biochemical parameters of strawberry

4.3.1 Chlorophyll content in leaf

The chlorophyll content of leaves varied significantly among the treatments are furnished (Table-12).

4.3.1.1 Chlorophyll - a

The maximum chlorophyll -a content (1.910 mg/g of fresh weight) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment, which was on par with T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (1.797 mg/g of fresh weight). The minimum chlorophyll- a content (1.482 mg/g of fresh weight) was recorded in T_9- Recommended Dose of Fertilizers (Control).

Table 9. Effect of organic manures on number of crowns, runners and total dry matter at harvesting stage of strawberry

Treatment	Number of crowns/plant	Number of runners/plant	Total dry matter (g)
T_1 - 100 per cent RDN through FYM	2.39	5.05	21.85
T_2 - T_1 + Jeevamruth at 500 ml/pot	3.31	5.78	29.25
T_3 - T_1 + Beejamruth seedling treatment	2.87	5.43	24.89
T_4 - T_2 + T_3	4.21	6.02	33.51
T_5 - 100 per cent RDN through Vermicompost	2.56	5.21	22.32
T_6 - T_5 + Jeevamruth at 500 ml/pot	3.92	5.89	31.13
T_7 - T_5 + Beejamruth seedling treatment	3.15	5.65	27.82
T_8 – T_6 + T_7	4.65	6.21	36.87
T_9 – Recommended Dose of Fertilizers	2.22	4.82	19.76
S. Em ±	0.01	0.01	0.09
C. D. (P = 0.05)	0.04	0.02	0.27

RDN- Recommended dose of nitrogen

Table 10. Effect of organic manures on yield parameters of strawberry

Treatment	Number of days taken for first flowering	Number of flowers per plant	Number of fruits per plant	Fruit weight (g)
T_1 - 100 per cent RDN through FYM	63.98	20.18	15.07	14.63
T_2 - T_1 + Jeevamruth at 500 ml/pot	59.61	22.57	17.31	15.82
T_3 - T_1 + Beejamruth seedling treatment	61.14	21.18	16.22	15.48
T_4 - T_2 + T_3	56.53	23.92	18.56	17.26
T_5 - 100 per cent RDN through Vermicompost	63.45	20.43	15.65	15.39
T_6 - T_5 + Jeevamruth at 500 ml/pot	58.91	23.21	17.85	16.53
T_7 - T_5 + Beejamruth seedling treatment	60.98	21.89	16.82	15.45
T_8 – T_6 + T_7	55.78	24.50	19.05	18.41
T_9 – Recommended Dose of Fertilizers	64.55	19.12	14.41	13.80
S. Em ±	0.05	0.03	0.02	0.02
C. D. (P = 0.05)	0.14	0.09	0.07	0.06

RDN- Recommended dose of nitrogen

Table 11. Effect of organic manures on length, diameter, volume and yield of strawberry fruit

Treatment	Fruit length (cm)	Fruit diameter (cm)	Fruit volume (cc)	Yield/plant (g)
T_1 - 100 per cent RDN through FYM	2.64	2.54	17.50	220.49
T_2 - T_1 + Jeevamruth at 500 ml/pot	3.58	3.13	20.13	273.85
T_3 - T_1 + Beejamruth seedling treatment	3.01	2.82	19.56	251.13
T_4 - T_2 + T_3	3.89	3.36	21.22	320.35
T_5 - 100 per cent RDN through Vermicompost	2.87	2.63	18.90	240.93
T_6 - T_5 + Jeevamruth at 500 ml/pot	3.71	3.25	20.75	295.17
T_7 - T_5 + Beejamruth seedling treatment	3.32	2.97	19.87	260.01
T_8 – T_6 + T_7	4.31	3.48	21.43	350.79
T_9 – Recommended Dose of Fertilizers	2.35	2.32	16.81	198.89
S. Em ±	0.01	0.01	0.02	0.73
C. D. (P = 0.05)	0.03	0.02	0.07	2.20

RDN- Recommended dose of nitrogen

Table 12. Effect of organic manures on Chlorophyll content of strawberry leaves

Treatment	Chlorophyll content of leaves (mg/g)		
	Chlorophyll a (mg/g)	**Chlorophyll b (mg/g)**	**Total Chlorophyll content (mg/g)**
T_1 - 100 per cent RDN through FYM	1.520	0.452	1.970
T_2 - T_1 + Jeevamruth at 500 ml/pot	1.650	0.609	2.261
T_3 - T_1 + Beejamruth seedling treatment	1.570	0.528	2.100
T_4 - T_2 + T_3	1.797	0.719	2.528
T_5 - 100 per cent RDN through Vermicompost	1.550	0.492	2.040
T_6 - T_5 + Jeevamruth at 500 ml/pot	1.719	0.649	2.371
T_7 - T_5 + Beejamruth seedling treatment	1.609	0.559	2.171
T_8 – T_6 + T_7	1.910	0.769	2.679
T_9 – Recommended Dose of Fertilizers	1.482	0.411	1.890
S. Em ±	0.002	0.003	0.004
C. D. (P = 0.05)	0.007	0.008	0.013

RDN- Recommended dose of nitrogen

4.3.1.2 Chlorophyll - b

The chlorophyll- b content in leaf varied significantly among the different treatments. The maximum chlorophyll -b content (0.769 mg/g of fresh weight) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment, which was followed by T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (0.719 mg/g of fresh weight) and the minimum chlorophyll -b content (0.411 mg/g of fresh weight) in leaf was recorded in T_9- Recommended Dose of Fertilizers (Control).

4.3.1.3 Total Chlorophyll content

The total leaf chlorophyll content varied significantly among treatments. The maximum total chlorophyll (2.679 mg/g of fresh weight) content was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment, which was followed by T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (2.528 mg/g of fresh weight). The minimum total chlorophyll (1.890 mg/g of fresh weight) was recorded in T_9- Recommended Dose of Fertilizers (Control).

4.4 Influence of different organic manures on quality parameters of strawberry

4.4.1 Total soluble solids

Significant difference was observed in the total soluble solids with respect to application of different organic manures on strawberry is presented in Table-13. The maximum TSS (8.030 ºB) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment followed by T_4- 100 per cent RDN through FYM

+ Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (7.850 ºB). The minimum TSS (6.221 ºB) was recorded in T_9- Recommended Dose of Fertilizers (Control).

4.4.2 Ascorbic acid

The data on influence of organic manures on ascorbic acid is presented in Table-13. From the results it is evident that, the maximum ascorbic acid content (58.749 mg/100 g) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment followed by T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (56.130 mg/100 g). The minimum ascorbic acid content (51.950 mg/100 g) was recorded in T_9- Recommended Dose of Fertilizers (Control).

4.4.3 Titratable acidity

A significant difference was noticed in the titratable acidity among the application of different organic manures on strawberry fruits (Table-13). The maximum

titratable acidity (1.579 %) was recorded in T_9- Recommended Dose of Fertilizers (Control), which was on par with T_1-100 per cent RDN through FYM (1.321 %), while the minimum (0.819 %) was recorded in T_8 which was applied with 100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment.

4.4.4 Sugars to acid ratio

The data pertaining to effect of different treatments on sugars to acid ratio of the fruits differed significantly (Table-13). The maximum sugars to acid ratio (9.240) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment, which was on par with T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (7.462). The minimum sugars to acid ratio (3.166) was recorded in T_9- Recommended Dose of Fertilizers (Control).

4.4.5 Reducing sugar

It is observed from the result that reducing sugar of strawberry fruits was significantly altered due to the treatment effect (Table-14). The maximum reducing sugar content (4.819 %) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment followed by T_4- 100 per cent RDN through FYM + Jeevamruthat 500 ml pot^{-1} + Beejamruth seedling treatment (4.410 %). The minimum reducing sugar content (3.130 %) was recorded in T_9- Recommended Dose of Fertilizers (Control).

4.4.6 Non reducing sugar

The non- reducing sugars of fruits varied significantly among different treatments (Table-14).

The maximum non- reducing sugars (2.749 %) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment which was on par with T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (2.679 %). The minimum values for non- reducing sugars (1.870 %) was recorded in T_9- Recommended Dose of Fertilizers (Control).

4.4.7 Total sugars

The significant variations were observed for total sugar content of strawberry (Table-14). The maximum total sugar (7.568 %) was observed in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment was significantly on par with T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (7.089 %) and the minimum total sugars (5.000 %) was recorded in T_9- Recommended Dose of Fertilizers (Control).

Table 13. Effect of organic manures on TSS, ascorbic acid, titrable acidity and sugars: acid ratio of strawberry fruits

Treatment	TSS (°B)	Ascorbic acid (mg/100 g)	Titratable acidity (%)	Sugars: acid ratio
T_1 - 100 per cent RDN through FYM	6.350	52.850	1.321	4.167
T_2 - T_1 + Jeevamruth at 500 ml/pot	7.420	55.181	1.070	5.879
T_3 - T_1 + Beejamruth seedling treatment	6.870	53.589	1.311	4.524
T_4 - T_2 + T_3	7.850	56.130	0.950	7.462
T_5 - 100 per cent RDN through Vermicompost	6.630	53.472	1.271	4.476
T_6 - T_5 + Jeevamruth at 500 ml/pot	7.609	55.311	1.020	6.548
T_7 - T_5 + Beejamruth seedling treatment	7.030	54.231	1.120	5.473
T_8 – T_6 + T_7	8.030	58.749	0.819	9.240
T_9 – Recommended Dose of Fertilizers	6.221	51.950	1.579	3.166
S. Em ±	0.010	0.033	0.004	0.029
C. D. (P = 0.05)	0.032	0.099	0.011	0.086

RDN- Recommended dose of nitrogen

Table 14. Effect of organic manures on reducing, non-reducing and total sugars of strawberry fruits

Treatment	Reducing sugars (%)	Non -Reducing sugars (%)	Total sugars (%)
T_1 - 100 per cent RDN through FYM	3.380	2.121	5.501
T_2 - T_1 + Jeevamruth at 500 ml/pot	3.950	2.341	6.291
T_3 - T_1 + Beejamruth seedling treatment	3.720	2.211	5.931
T_4 - T_2 + T_3	4.410	2.679	7.089
T_5 - 100 per cent RDN through Vermicompost	3.550	2.140	5.690
T_6 - T_5 + Jeevamruth at 500 ml/pot	4.100	2.579	6.679
T_7 - T_5 + Beejamruth seedling treatment	3.809	2.321	6.130
T_8 – T_6 + T_7	4.819	2.749	7.568
T_9 – Recommended Dose of Fertilizers	3.130	1.870	5.000
S. Em ±	0.008	0.005	0.011
C. D. (P = 0.05)	0.024	0.014	0.034

4.4.8 Shelf life

The number of days required after fully ripening of fruits until spoilage is the shelf life which was found to be significant between the treatments (Table-15).

The maximum shelf life (3.52 days) was observed in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment, which was on par with T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (3.31 days). Minimum shelf life (1.78 days) was recorded in T_9- Recommended Dose of Fertilizers (Control).

4.5 Influence of organic manures on fruit growth rate of strawberry

The fruit growth rate was significantly influenced by different organic manures (Table-16). The fruit growth rate was highest in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment *i.e.,* 0.192 cm day^{-1}. The minimum fruit growth rate (0.144 cm day^{-1}) was recorded in T_9- Recommended Dose of Fertilizers (Control).

4.6 Benefit cost ratio

The benefit-cost ratio in strawberry differed significantly due to the application of organic manures (Table-17). The maximum net income (₹ 129428 / 500 m^2) was accounted by T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment followed by treatment T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (112487 / 500 m^2), whereas the lowest net income (₹ 43848 / 500 m^2) was accounted by treatment T_9- Recommended Dose of Fertilizers (Control).

The maximum benefit-cost ratio (2.20) was obtained from T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment followed by T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (2.05) while, treatment T_9- showed lowest benefit-cost ratio of 1.42.

Table 15. Effect of organic manures on shelf life of strawberry fruits

Treatment	Shelf life (Days)
T_1 - 100 per cent RDN through FYM	2.18
T_2 - T_1 + Jeevamruth at 500 ml/pot	2.87
T_3 - T_1 + Beejamruth seedling treatment	2.56
T_4 - T_2 + T_3	3.31
T_5 - 100 per cent RDN through Vermicompost	2.34
T_6 - T_5 + Jeevamruth at 500 ml/pot	3.03
T_7 - T_5 + Beejamruth seedling treatment	2.72
T_8 – T_6 + T_7	3.52
T_9 – Recommended Dose of Fertilizers	1.78
S. Em ±	0.01
C.D. (P = 0.05)	0.03

Table 16. Effect of organic manures on fruit growth rate of strawberry fruits

Treatment	Fruit growth rate (cm day^{-1})
T_1 - 100 per cent RDN through FYM	0.150
T_2 - T_1 + Jeevamruth at 500 ml/pot	0.183
T_3 - T_1 + Beejamruth seedling treatment	0.165
T_4 - T_2 + T_3	0.184
T_5 - 100 per cent RDN through Vermicompost	0.151
T_6 - T_5 + Jeevamruth at 500 ml/pot	0.179
T_7 - T_5 + Beejamruth seedling treatment	0.173
T_8 – T_6 + T_7	0.192
T_9 – Recommended Dose of Fertilizers	0.144
S. Em ±	0.001
C. D. (P = 0.05)	0.003

RDN- Recommended dose of nitrogen

Table 17. Effect of organic manures on economics of strawberry cultivation under naturally ventilated polyhouse (per 500 m^2)

Treatment	Total cost of cultivation (₹ /500 m^2)	Returns from yield (₹/ 500 m^2)	Returns from runners (₹/ 500 m^2)	Gross income (₹ /500m^2)	Net income (₹/500m^2)	Benefit: cost ratio
T_1 - 100 per cent RDN through FYM	102937.00	109760.00	50277.00	160037.00	57100.00	1:1.55
T_2 - T_1 + Jeevamruth at 500 ml/pot	106670.00	136322.00	57546.00	193868.00	87198.00	1:1.81
T_3 - T_1 + Beejamruth seedling treatment	103185.00	125012.00	54062.00	179074.00	75889.00	1:1.73
T_4 - T_2 + T_3	106918.00	159470.00	59935.00	219405.00	112487.00	1:2.05
T_5 - 100 per cent RDN through Vermicompost	103041.00	119934.00	51871.00	171805.00	68764.00	1:1.66
T_6 - T_5 + Jeevamruth at 500 ml/pot	106774.00	146935.00	58641.00	205576.00	98802.00	1:1.92
T_7 - T_5 + Beejamruth seedling treatment	103289.00	129432.00	56251.00	185683.00	82394.00	1:1.79
T_8 – T_6 + T_7	107022.00	174623.00	61827.00	236450.00	129428.00	1:2.20
T_9 – Recommended Dose of Fertilizers	103147.00	99007.00	47988.00	146995.00	43848.00	1:1.42

DISCUSSION

V DISCUSSION

The cultivated Strawberry (*Fragaria* x *ananassa* Duch.) is one of the attractive, delicious, tasty and nutritious fruits having distinct and pleasant flavor. It has a unique place among cultivated berry fruits. Like other fruit-plant, strawberry also requires a number of mineral nutrients for proper growth and development. Farmer shows tendency of mixing more chemical fertilization for strawberry production to improve yield. The clean discarding of organic wastes by composting is an environmentally sound and economically viable technology resulting in the production of organic fertilizer which is a basic and valuable input in organic farming. Uses of organic matters have long been recognized as beneficial for plant growth and yield and maintenance of soil fertility. Organic matters are excellent source of nutrients and it could maintain high microbial population's activities. Addition of organic matter increase yield with corresponding improvements of soil quality (Johnston *et al.,* 1995). The organic matter application is one of the useful methods to renew the depleted soil fertility and augment the available pool of nutrients and conserve more water, maintain soil quality and conserve additional biological resources. It is used as a main source of 'N' and 'P' is a significant nutrient as a part of some key plant structural components and worked as catalyst in the change of numerous key of biochemical reactions in plants and also contains plant growth regulators and other plant growth influencing materials created by microorganisms (Tomati *et al.,* 1990) as well as humates (Atiyeh *et al.,* 2000), cytokinins and auxins (Krishnamoorthy and Vajrabhiah, 1986). It also limits the losses caused by leaching and maintains balanced nutrient status of the soil. However, nitrogen is the most important essential plant nutrient which plays great role in increasing vegetative growth and fruit production of the plant.

Therefore, present investigation was undertaken to evaluate the influence of organic manures on growth, yield and fruit quality of strawberry (*Fragaria* x *ananassa* Duch.) at Department of Fruit Science, College of Horticulture, Mudigere during 2019-2020. The results obtained during the course of investigation have been discussed as under.

5.1 Influence of organic manures on growth parameters of strawberry

5.1.1 Plant height

In the present study, application of different organic manure significantly influenced the plant height in strawberry *cv*. Winter Dawn. The maximum plant height (13.75, 18.54, 24.31 and 28.85 cm at 30, 60, 90 and 120 days after planting, respectively) was observed in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment and the minimum plant height was observed in T_9 (9.98 cm, 13.21 cm, 15.89 cm and 18.65 cm at 30, 60, 90 and 120 days after planting, respectively). The probable reason may be the use of

combination of different organic matter *viz.,* Vermicompost, Jeevamruth and Beejamruth. Enhancement of growth might be attributed to the role of Vermicompost in terms of nutrient availability and increase in beneficial enzymatic activities, increased population of beneficial microorganisms or the presence of biologically active plant growth influencing substances such as plant growth regulators or plant hormones and humic acids (Arancon *et al.*, 2006). The fermented liquid organic manures also contain microbial load and plant growth promoting substances in addition to nutrients that help in improving plant growth. The beneficial microorganisms present in Beejamruth produced IAA and GA and resulted in improvement in seedling length. Similar results were also obtained by Arancon *et al*. (2006), Nileema and Sreenivasa (2010) and Chauhan *et al*. (2016).

5.1.2 Number of trifoliate leaves per plant

The significant differences were observed for number of trifoliate leaves among the different organic manure combinations at 30, 60, 90 and 120 days after planting. Among the different organic manure combinations, treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment showed a higher number of trifoliate leaves (6.54, 13.87, 19.58 and 27.51 at 30, 60, 90 and 120 DAP, respectively). Organic matter helps in increased growth of the plant by easy absorption of nutrients as it has the highest total pore space, high water holding capacity and available nutrients, which might lead to production of higher number of leaves. The research findings are in line with the results obtained by Nileema and Sreenivasa (2010).

5.1.3 Leaf area

The leaf area of strawberry was influenced by different organic manure combinations at 30, 60, 90 and 120 DAP respectively. The maximum leaf area of 56.82, 73.91, 86.78 and 106.78 cm^2 at 30, 60, 90 and 120 DAP was found in treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment which was significantly higher than other treatments. The increase in leaf area was due to the availability of plant growth-influencing materials of vermicompost such as plant growth regulators and humic acids, produced by the increased microbial populations resulting from earthworm activity. The fermented liquid organic manures also contain microbial load and plant growth promoting substances in addition to nutrients that help in improving plant growth. Similar results were also obtained by Krishnamoorthy and Vajrabhiah, (1986), Arancon *et al*. (2004), Singh *et al*. (2008) and Nileema and Sreenivasa (2010).

5.1.4 Leaf area index

The leaf area index of strawberry was influenced by different organic manure combinations at 30, 60, 90 and 120 DAP respectively. The maximum leaf area index of

0.468, 0.609, 0.717 and 0.881 at 30, 60, 90 and 120 DAP was found in treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment which was significantly higher than other treatments. The significant increase in leaf area index might be due to the availability of plant growth-influencing materials in organic manures. The increase in leaf area and number of leaves per plant will naturally result in increase of leaf area index. Similar results were also obtained by Arancon *et al*. (2004).

5.1.5 Plant spread

The plant spread of strawberry as influenced by different organic manure combination showed significant differences at 30, 60, 90 and 120 days after planting. For the plant spread treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment showed significantly higher values of 18.54, 22.51, 26.03 and 30.42 cm at 30, 60, 90 and 120 DAP, respectively. Also, the similar results were obtained for plant spread in East-West direction. The treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment showed maximum plant spread of 18.05, 23.01, 26.13 and 30.04 cm at 30, 60, 90 and 120 DAP, respectively. The reason might be that vermicompost treated plants might be due to sufficient nutrients supply and helped in good photosynthesis, which help the plants in vegetative growth and vermicompost has plant growth regulating substances like cytokinins and auxins produced by microorganisms and earth worms which in turn would have increased the vegetative growth by increasing cell division and cell elongation. These liquid organic manures are prepared from cow dung, urine, milk, curd, ghee, legume flour and jaggary. They contain macro nutrients, essential micro nutrients, many vitamins, essential amino acids, growth promoting factors like IAA, GA and beneficial microorganisms and increases growth as reported by Palekar, (2006), Natarajan, (2007), Nileema and Sreenivasa (2010).

5.1.6 Number of crowns per plant and number of runners per plant

Significant difference was observed with respect to number of crowns per plant and number of runners per plant. Among the different treatments, T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment showed the highest number of crowns per plant and number of runners per plant (4.65 and 6.21, respectively) at 120 DAP. The increase in number crowns was due to the fermented liquid organic manures also contain microbial load and plant growth promoting substances in addition to nutrients that help in improving plant growth and metabolic activities. Vermicompost enhances the nutrient availability, increase the beneficial enzymatic activities and increased the population of beneficial microorganisms or the presence of biologically active plant growth influencing

substances such as plant growth regulators or plant hormones, which leads to increase the number of crowns per plant and intern increased runners per plant. The results are in line with the findings of Umar *et al*. (2009), Nileema and Sreenivasa (2010) and Chauhan *et al*. (2016).

5.1.7 Total dry matter at harvest

The significant difference was observed for total dry matter at harvest between different organic manure combinations of strawberry. The highest total dry matter (36.87 g) was recorded in treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment. The increased dry matter was due to Jeevamruth promotes immense biological activity in soil and enhance nutrient availability to crop. Beejamruth protect the crop from soil born, seed born pathogens and also improves seedling length, which led to highest plant growth and root length. Vermicompost contain plant growth regulators and other plant growth influencing materials produced by microorganisms including humates and helps in higher photosynthesis and resulted in highest dry matter of the plant. The results are in conformity with Arancon *et al*. (2004), Nileema and Sreenivasa (2010) and Chauhan *et al*. (2016).

5.2 Influence of different organic manures on yield parameters of strawberry

5.2.1 Number of days taken for first flowering

Significant difference for number of days taken for first flower emergence was observed among various treatments. The treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment has taken least number of 50.13 days for first flower emergence. The similar results for first flower emergence in strawberry observed by Ogendo *et al*. (2008) and Sharma and Godhra (2017), in that vermicompost application enhances photosynthates production, which helped to break bud dormancy leading to early onset of the reproductive stage in strawberry. The earliness may be due to an optimum supply of plant nutrients and growth hormones in right amount during the entire crop period which induces the vegetative development of plant and ultimately more photosynthesis. The results are in conformity with Umar *et al*. (2010), Yadav *et al*. (2009), Tripathi *et al*. (2015) and Chauhan *et al*. (2016).

5.2.2 Number of flowers per plant

The number of flowers per plant of strawberry showed a significant difference for different organic manure combinations. The maximum number of flowers per plant (24.50) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment. The increase in number of flowers per plant was due to increase in photosynthate production due to phosphorus contents in

1. Flower bud stage

2. Fully opened flower

3. Petal fall stage

4. Fruit set stage

8. Red ripe stage

7. Pink stage

6. Pink tinge stage

5. Developing fruit

Plate 3. Different stages of flower and fruit development

Plate 4. View of experimental plot at reproductive stage

farm vermicompost, which helped to break bud dormancy and increased flowering sites and also due to overall improvement in soil physico-chemical and biological properties due to combined application of organic liquid manures. Arancon *et al.* (2003) reported that vermicompost applications enhanced flowering and fruiting in strawberry. The results are in conformity with Nileema and Sreenivasa (2010) and Chauhan *et al*. (2016).

5.2.3 Number of fruits per plant

The number of fruits per plant showed significant difference among the different organic manure combinations. The maximum number of fruits per plant (19.05) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment. The increase in the number of fruits might be due to maximum flowers production, fruit set percentage and production of more photosynthates due to maximum vegetative growth of plants as influenced physio-chemical status of media combination and presence of available nutrients in the form of nitrate, phosphate, soluble potassium exchangeable calcium and magnesium which in turn helped the photosynthesis process and phosphorus content enhanced the bud break to increase fruit set percentage, resulting in increased flowering and fruit set in strawberry (Edwards and Burrows, 1988; Sardoei *et al*. 2014). The similar results were also obtained by Cantliffe *et al.* (2003), Paranjpe *et al.* (2003), Arancon *et al.* (2004), Iling *et al*. (2006), Ogendo *et al.* (2008), Sangwan *et al*. (2010) and Gupta *et al*. (2014).

5.2.4 Fruit weight and fruit volume

There was a significant difference observed for fruit parameters of strawberry for different organic manure combinations. Among different treatments significantly maximum fruit weight (18.41 g) and fruit volume (21.43 cc) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment respectively. The increase in weight and volume of fruits might be due to the increased photosynthetic ability of plants fertilized with combination of vermicompost, Jeevamruth and Bejamruth, which in turn might have favored an increased accumulation of dry matter. Fruit size, weight and fruit volume are highly correlated with dry matter content and their translocation. Similar results were obtained by Kachot *et al*. (2001), Shukla *et al*. (2009) and Beer *et al*. (2017).

5.2.5 Length and diameter of fruit

Significantly maximum length (4.31 cm) and diameter (3.48 cm) of strawberry fruits were recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment. Increase in above parameters maybe due to combination of vermicompost, Jeevamruth and Beejamruth enhance the photosynthetic ability, accumulation of photosynthates and their translocation to berries

and level of hormones as well as synthesis of different growth regulators. The results are in conformity with Shukla *et al*. (2009), Yadav *et al*. (2010) and Beer *et al*. (2017).

5.2.6 Yield per plant

There was a significant difference observed for fruit yield per plant among the different organic manure combinations of strawberry (Figure-2). The highest fruit yield of 350.79 grams per plant was obtained in treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (Fig-2). The increase in yield was due to the presence of higher number of berries per plant and increased fruit length, diameter, fruit weight as influenced by media containing vermicompost induce the protein production that caused more meristem cells and cell division. It might be due to more available phosphorous nutrient, high organic matter and total organic nitrogen percentage that enhanced the fruit size in strawberry by the formation of carbohydrates and composted manure has the potential to faster the biological process in soil, help in the creation and preservation of soil fertility and enhances the yield. The results are in conformity with Funt and Bierman (2000) Meissner-Smejkal (2000) and Chauhan *et al*. (2016).

5.3 Influence of different organic manures on biochemical parameters of strawberry

5.3.1 Chlorophyll content

The application of different organic manures on strawberry showed significant difference with respect to chlorophyll content. The maximum total chlorophyll content (2.679 mg/100 g) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment. The increased total chlorophyll content in T_8 plants could be referred to the role of VC, Jeevamruth and Beejamruth, which contain different plant growth regulators and enhances the metabolic and enzymatic activities, which inturn enhances the chlorophyll content. Vermicompost contains available nutrients, thereby they had a significant beneficial effect on primary and secondary nutrient content of plants, which inturn affected the chlorophyll content in leaves of strawberry. Similar results were also obtained by Edwards and Burrows, (1988), Arancon *et al*. (2004), Nileema and Sreenivasa (2010), Sardoei *et al*. (2014) and Abul-Soud *et al*. (2015).

5.4 Influence of different organic manures on quality parameters of strawberry

5.4.1 Total Soluble Solids, Reducing sugars, Non -reducing sugars, Total sugars, and Sugars: acid ratio

The significantly highest reducing sugar, non-reducing sugar and total sugars content of 4.819, 2.749 and 7.568 per cent were recorded in treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling

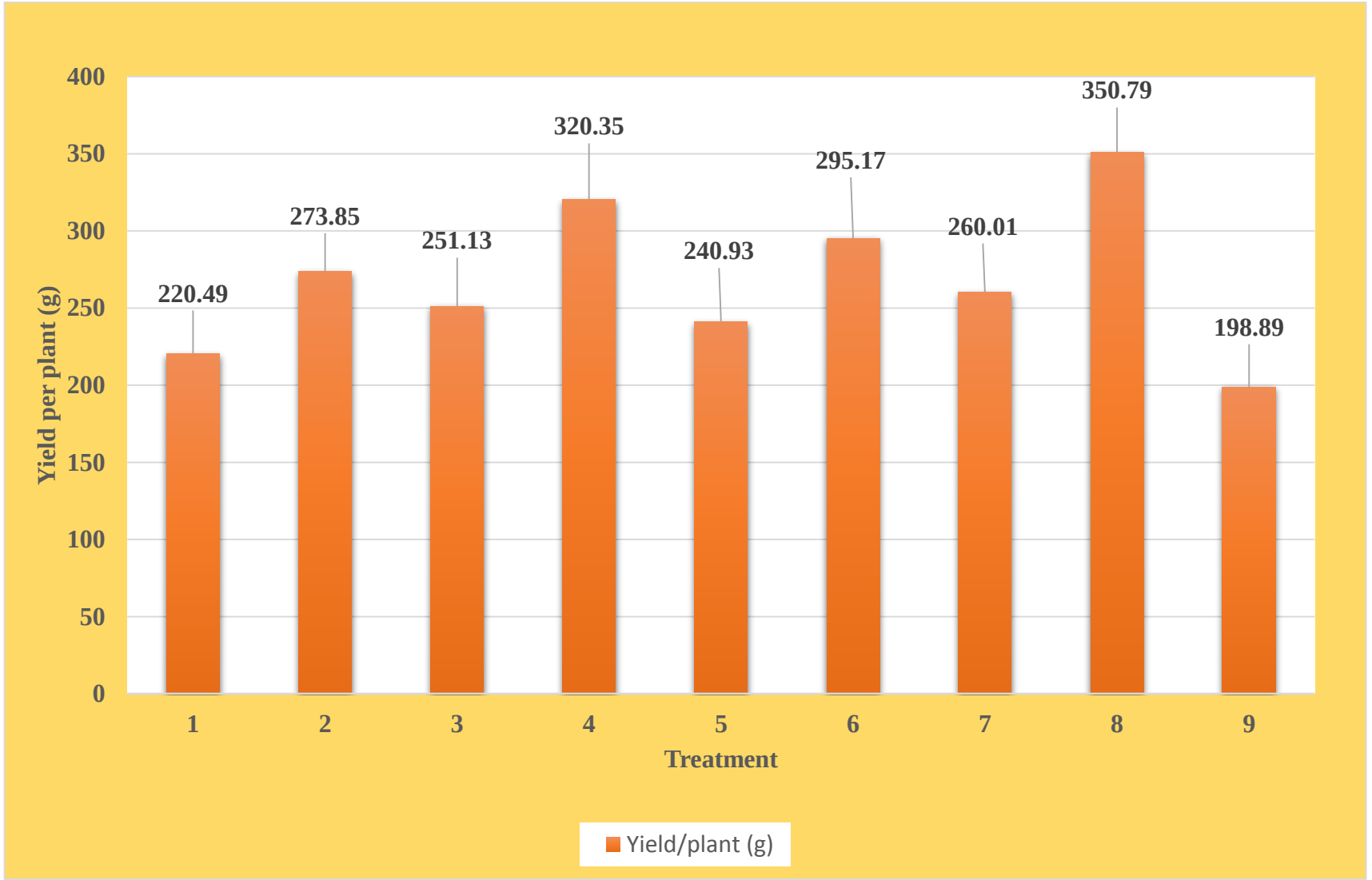

Fig. 2. Effect of organic manures on fruit yield per plant (g) of strawberry under naturally ventilated polyhouse

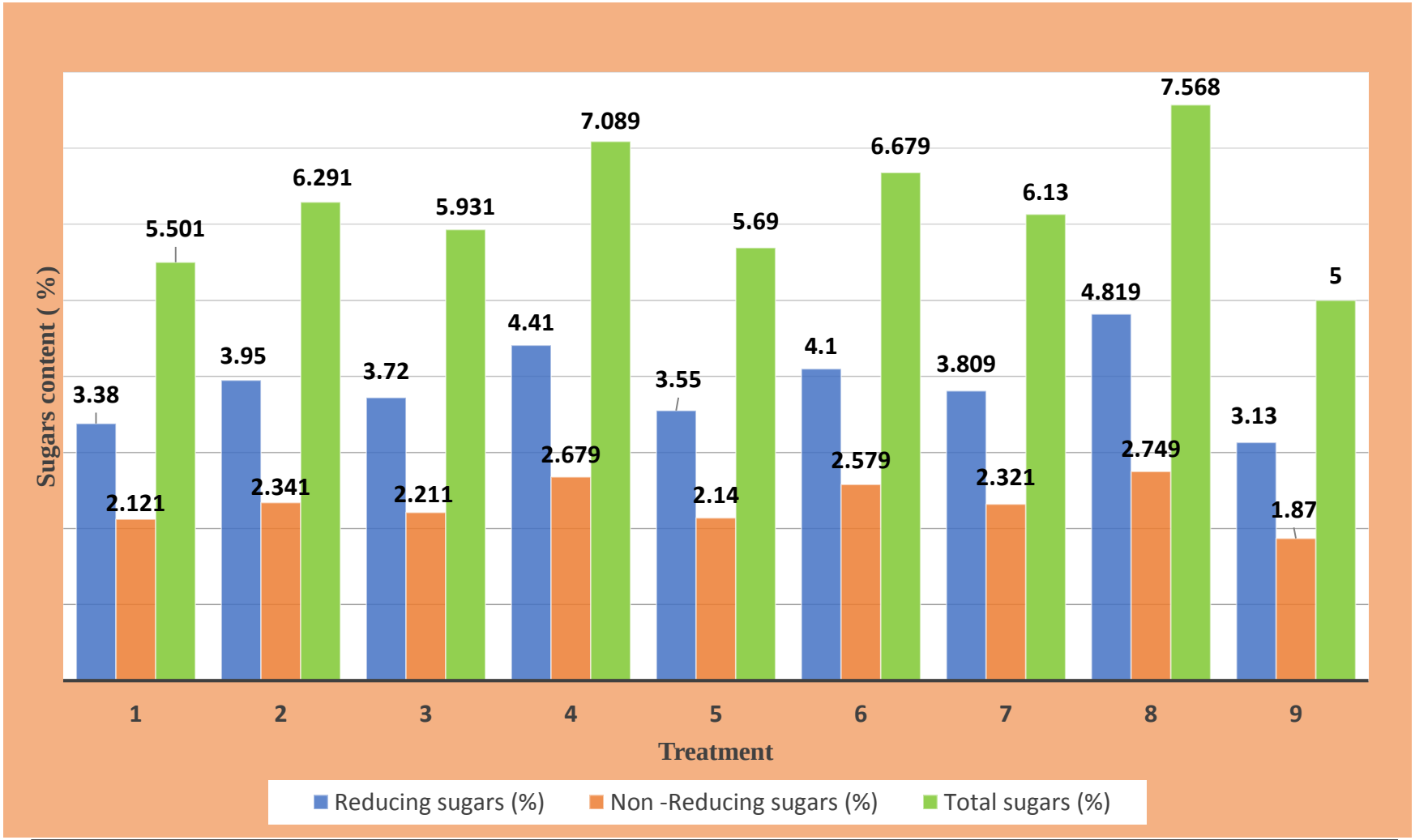

Fig. 3. Effect of organic manures on sugars content of strawberry under naturally ventilated polyhouse

treatment (Figure-3) The lowest reducing sugar, non-reducing sugar and total sugars content of 3.130, 1.870 and 5.000 per cent was recorded in treatment T_9- Recommended Dose of Fertilizers (Control). The highest sugars to acid ratio of 9.240 was recorded in treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment and the lowest sugars to acid ratio of 3.166 was recorded in control.

The increase in the content of sugars and Total Soluble Solids of fruits might be due to the vermicompost application as it fasten the metabolic transformation of starch and pectin into soluble compounds and rapid translocation of sugars from leaves to the developing fruits and also due to increased micro nutrients, macro nutrients, carbohydrate (%) and protein (%) content. Also, the potassium (K) promotes sugar accumulation in berries and balance of N, P and K found essential for proper sugar accumulation of fruits, the increase in total sugars ultimately yielded higher sugars to acid ratio. These findings are in agreement with the results of Ghazvini *et al.* (2007), Recamales *et al.* (2007), Attia *et al*. (2009), Singh *et al*. (2010), Ameri *et al*. (2012), Khalid *et al*. (2013), Joshi *et al*. (2014) and Lata (2017).

5.4.2 Ascorbic acid

The ascorbic acid content of the fruits differed significantly between the treatments with the application of organic manures. The maximum ascorbic acid (58.749 mg/100g) was recorded in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment while, minimum ascorbic acid (51.950 mg/100g) was recorded in T_9- Recommended Dose of Fertilizers (Control). Increase in ascorbic acid content might be due to the availability of micro and macronutrients and increased efficiency of microbial inoculants to fix atmospheric nitrogen, increase in availability of phosphorous and secretion of growth promoting substances which accelerates the physiological process like carbohydrates synthesis, *etc.* These findings are in agreement with the results of Tripathi *et al*. (2010) and Chauhan *et al*. (2016).

5.4.3 Titratable acidity

The significantly lowest titratable acidity of 0.819 per cent was recorded in treatment T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment while, the highest titratable acidity of 1.579 per cent was recorded in treatment T_9- Recommended Dose of Fertilizers (Control). The decrease in titratable acidity might be due to the vermi compost treatment decreases the soil pH, titratable acidity and makes soil slightly acidic thus helps to increase the sweetness of strawberry and conversion of higher amounts of organic acids and photosynthates into sugars during the fruit ripening stage. These findings are in agreement with the results of Sharma *et al.* (2014) and Federico *et al*. (2007).

5.4.4 Shelf life

Significant difference was observed among different treatments for shelf life of strawberry fruit. The maximum shelf life (3.52 days) was observed in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment and minimum shelf life (1.78 days) was noticed in T_9- Recommended Dose of Fertilizers (Control). The possible reason for reduction in weight loss and spoilage by microbial consortium might be due to reduced respiration of fruits as influenced by the presence of a higher amount of calcium and potassium resulting in increased the membrane integrity of fruits, so that the fruits could retain more water against the force of evaporation and possibly they might have also altered some of the proteinaceous constituents. Beejamruth seedling treatment and application of vermicompost reduces the disorders and soil borne diseases like botrytis rot. The fermented liquid organic manures also contain microbial load and plant growth promoting substances in addition to nutrients that help in improving plant growth, metabolic activities and resistance to pest and diseases and reduces the postharvest diseases and increased shelf life of fruits. These findings are in agreement with the results of Singh *et al*. (1995), Singh *et al*. (2008) and Nileema and Sreenivasa (2010).

5.5 Influence of organic manures on fruit growth rate of strawberry

The application of different organic manures on strawberry showed significant difference with respect to fruit growth rate. The maximum fruit growth rate 0.192 cm day^{-1} was observed in T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment and minimum fruit growth rate 0.144 cm day^{-1} was noticed in T_9- Recommended Dose of Fertilizers (Figure-4). Highest fruit growth rate may be due to the use of combination of Vermicompost, Jeevamruth and Beejamruth, which influences physico-chemical status of media combination and presence of available nutrients in the form of nitrate, phosphate, soluble potassium exchangeable calcium and magnesium which in turn helped the photosynthesis process, accumulation of photosynthates, their translocation to berries and level of hormones as well as synthesis of different growth regulators. The results are in conformity with Yadav *et al*. (2009) and Beer *et al*. (2017).

5.6 Benefit cost ratio

The benefit-cost ratio in strawberry differed significantly due to the application of organic manures is presented (Table-17). The maximum net income (₹ 129428 / 500 m^2) was accounted by T_8-100 per cent RDN through Vermicompost + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment followed by treatment T_4- 100 per cent RDN through FYM + Jeevamruth at 500 ml pot^{-1} + Beejamruth seedling treatment (112487 / 500 m^2), whereas the lowest net income (₹ 43848 / 500 m^2) was accounted by treatment T_9- Recommended Dose of Fertilizers (Control).

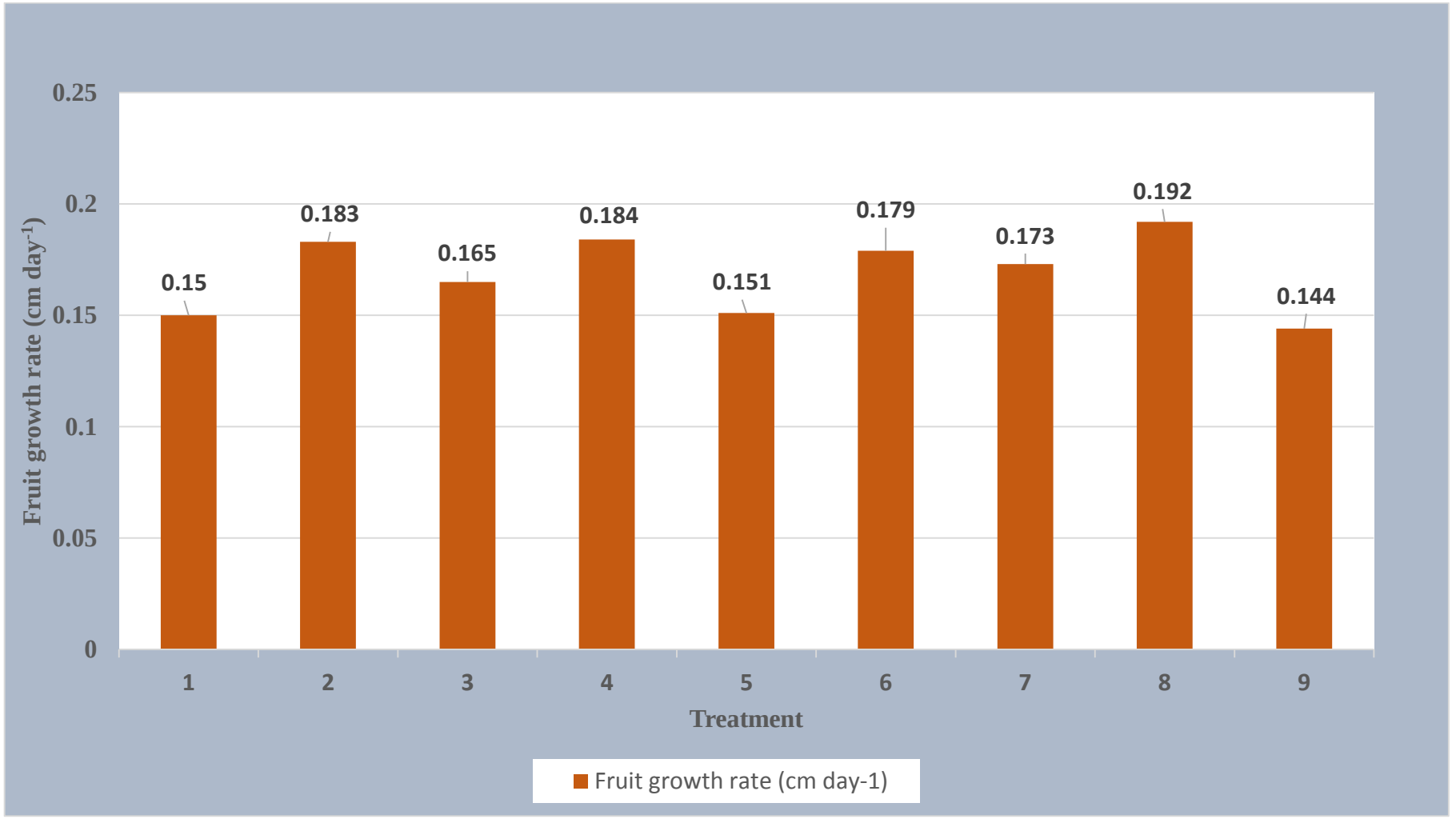

Fig. 4. Effect of organic manures on fruit growth rate (cm day^{-1}) of strawberry under naturally ventilated polyhouse

The maximum net returns and benefit to cost ratio achieved by treatment T_8 was due to the significantly higher growth and yield of strawberry as influenced by the combination of Vermicompost, Jeevamruth and Beejamruth. Whereas, the lowest net returns and benefit to cost ratio achieved by treatment T_9 was due to lower yield as compared to other treatments.

5.7 Conclusion

The present investigation on Influence of organic manures on growth, yield and fruit quality of strawberry, suggested that cultivation of strawberry with the application of combination of vermicompost, Jeevamruth and Beejamruth was found effective to increase growth, yield, benefit to cost ratio and also highest shelf life followed by application of Farm yard manure, Jeevamruth and Beejamruth. Application of this organic manures helps in improving growth, yield and nutritional quality of strawberry and thus yields fruitful results ensuring highest net returns per unit area in strawberry cultivation.

5.8 Future line of work

1. Effect of organic manures on antioxidants and phytochemical properties of strawberry.
2. Effect of organic manures on nutrient uptake pattern of soil in strawberry.
3. Organic manures in combination with bio fertilizers need to be studied.

SUMMARY

VI SUMMARY

The present investigation was conducted to know the "Influence of organic manures on growth, yield and quality of strawberry (*Fragaria* x *ananassa.* Duch) under naturally ventilated polyhouse". The experiment was conducted at College of Horticulture, Mudigere, during 2019-2020. The results obtained from the study are summarized here under.

The strawberry grown with the application of Vermicompost, Jeevamruth and Beejamruth recorded the highest plant height of (28.85 cm), trifoliate leaves (27.51/ plant), plant spread (30.42 and 30.04 cm in North-South and East-West directions, respectively), leaf area (106.78 cm^2) and leaf area index (0.881) at 120 days after planting.

The highest number of crowns per plant (4.65), runners per plant (6.21) and total dry weight at harvest (36.87 g) were obtained in strawberry grown with the application of Vermicompost, Jeevamruth and Beejamruth.

Significantly minimum number of days taken (55.78 days) for first flowering was observed in treatment Vermicompost, Jeevamruth and Beejamruth. The highest number of flowers per plant (24.50) and highest number of fruits per plant (19.05) were observed in the treatment Vermicompost, Jeevamruth and Beejamruth.

The highest fruit weight (18.41 g), fruit length (4.31 cm), fruit diameter (3.48 cm), fruit volume (21.43 cc) and yield per plant (350.79 g) were recorded in the treatment Vermicompost, Jeevamruth and Beejamruth.

The highest chlorophyll-a content (1.910 mg / g of fresh weight), chlorophyll- b content (0.769 mg / g of fresh weight) and total chlorophyll content (2.679 mg / g of fresh weight) were recorded in the treatment Vermicompost, Jeevamruth and Beejamruth.

The highest TSS (8.030 ºB), ascorbic acid (58.749 mg/100 g), sugars:acid ratio (9.240) and minimum titratable acidity (0.819 %) were recorded in the treatment Vermicompost, Jeevamruth and Beejamruth.

The highest reducing sugars content (4.819 %), non-reducing sugar content (2.749 %) and total sugar content (7.568 %) were observed with the application of Vermicompost, Jeevamruth and Beejamruth.

The maximum shelf life (3.52 days) was observed in the treatment Vermicompost, Jeevamruth and Beejamruth.

The highest fruit growth rate 0.192 cm day^{-1} was observed with the application of Vermicompost, Jeevamruth and Beejamruth.

The application of VC, Jeevamruth and Beejamruth resulted in maximum net income of ₹ 129428.00 / 500 m^2 resulting in highest benefit cost ratio of 1:2.20 compared to that of other treatments.

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APPENDICES

VIII APPENDICES

Appendix-I: Monthly mean meteorological data recorded during the experimental period (1st November 2019 – 31st March 2020) recorded at the ZAHRS, Mudigere

Months	Rainfall (mm)	Relative Humidity (%)	Temperature (^{0}C)	
		Maximum	Maximum	Minimum
November	26.3	80.26	25.26	18.93
December	1.4	80.12	26.25	19.00
January	0	80	29.00	18.06
February	0	80.413	30.27	17.34
March	2.3	80.25	32.70	18.61

Appendix-II: Quantity of different media used for potting on weight basis

Media	Volume (kg)
Cocopeat	0.180
Soil	1.660
Vermicompost	0.630
Vermiculite	0.790
Total	**3.26**

Appendix-III: Economics of strawberry cultivation under naturally ventilated polyhouse (500 m^2)

Sl. No.	Particulars	Total cost (₹)	Depreciation cost (₹/7 months)
I.	**Non-recurring contingency (NRC) (for a life span of 10 years)**		
a)	**Construction of polyhouse @ ₹ 800/m^2** Top: UV stabilized polyfilm Side: 70 % Agro shade net	400000	24080
b)	**Irrigation system and other**	50000	3541
c)	**Cost of 2489 plastic pots @ ₹35/ pot**	88000	10265
d)	**Cost of wooden planks**	25000	4374
	Total of NRC	**563000**	**42260**
II.	**Recurring contingency (ORC) for a life span of one season (500 m^2).**		
1.	**Inputs**		
a)	Planting material (2489 plants/500 m^2 @ 9 ₹/plant)	22401	
b)	Soil sterilization	1000	
	Plant protection chemicals	1000	
	Cost of media/2489 pots	35000	
	Cost of FYM/kg	2	
	Cost of VC/kg	7	
	Cost of Jeevamruth/litre	3	
	Cost of Beejamruth/litre	2	
	Total	**59416**	
c)	Treatment combination	Cost each treatment combination for 2489 pots or 500 m^2	
1	T_1 - 100 per cent RDN through FYM	261	
2	T_2 - T_1 + Jeevamruth at 500 ml/pot	3994	
3	T_3 - T_1 + Beejamruth seedling treatment	509	
4	T_4 - T_2 + T_3	4242	
5	T_5 - 100 per cent RDN through Vermicompost	365	
6	T_6 - T_5 + Jeevamruth at 500 ml/pot	4098	
7	T_7 - T_5 + Beejamruth seedling treatment	613	
8	T_8 – T_6 + T_7	4346	
9	T_9 – Recommended Dose of Fertilizers	471	
2.	**Labour charges**		
a)	Planting, weeding and harvesting (10 labours)	1000	
	Grand total (NRC + ORC)		
1	T_1 - 100 per cent RDN through FYM	102937	
2	T_2 - T_1 + Jeevamruth at 500 ml/pot	106670	
3	T_3 - T_1 + Beejamruth seedling treatment	103185	
4	T_4 - T_2 + T_3	106918	
5	T_5 - 100 per cent RDN through Vermicompost	103041	
6	T_6 - T_5 + Jeevamruth at 500 ml/pot	106774	
7	T_7 - T_5 + Beejamruth seedling treatment	103289	
8	T_8 – T_6 + T_7	107022	
9	T_9 – Recommended Dose of Fertilizers	103147	

Note- Price of strawberry fruits/marketable price at 200 ₹/kg.
Cost of strawberry runners/ marketable price at 4 ₹/ runner

Appendix-IV: List of symbols and abbreviations

Symbols	Abbreviations
%	Per cent
@	At
°C	Degree centigrade
C. D.	Critical difference
cm	Centimetre
mm	Millimeter
cm^2	Centimetre square
cv.	Cultivar
et al.	And others
g	Gram
i.e.	That is
kg	Kilogram
mg	Milligram
ml	Millilitre
S. Em ±	Standard Error of Mean
S. D.	Standard deviation
viz.	As follows
TSS	Total soluble solids
CAN	Calcium ammonium nitrate
SSP	Single super phosphate
MOP	Murate of potash
DAP	Days after planting
N	Nitrogen
P	Phosphorous
K	Potassium
RDF	Recommended dose of fertilizers
RDN	Recommended dose of nitrogen
PSB	Phosphorous solubilising bacteria
IAA	Indole acetic acid
GA	Gibberellic acid
FYM	Farm yard manure
VC	Vermi compost
L^{-1}	Per litre
cc	Cubic centimetre
^oB	Degree brix
µg	Microgram
₹	Rupee