

Effect of Bio Fertilizers on the Growth, Yield, and Economic Analysis of Strawberry (*Fragaria x ananassa* Duch.) with different media composition in Vertical Farming System cv. Winterdown

ABSTRACT

A field experiment was carried out during 2021-2022 to see the effect of biofertilizers on growth, yield and quality of strawberry cv. Winterdown in vertical farming system with 10 treatments with different combinations of organic and microbial sources of nutrients (Vermicompost, FYM, *Azotobacter* and PSB) replicated thrice with 3 plants per replication in Randomized Block Design. Observations were recorded for vegetative growth, fruit yield and quality. In different combinations (organic manure+ biofertilizers and organic manure) the treatment T₉ (Soil (50%) +Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g) recorded highest plant height, plant spread, number of leaves and leaf area as compared to T₇ (Soil (50%) + FYM (50%) + PSB (2g) + *Azotobacter* (2g). The maximum number of fruits plant⁻¹, yield plant⁻¹(g) & fruit diameter (cm) fruit length (cm) were recorded with plants treated with T₉ (Soil (50%) +Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g) followed by T₇ (Soil (50%) + FYM (50%) + PSB (2g) + *Azotobacter* (2g) at 90 DAP followed by T₈ (Soil (50%) + coir pith (50%) + *Azospirillum* (2g) + PSB (2g) treatment. The highest yield and best quality in terms of TSS (° Brix), Acidity (%), Ascorbic Acid (mg/100g) were recorded in the combination of T₉ (Soil (50%) +Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g). The maximum Benefit: Cost ratio (1: 3.39) was recorded in the T₉ (Soil (50%) +Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g) than T₇ (Soil (50%) + FYM (50%) + PSB (2g) + *Azotobacter* (2g) due to its lower cost of production.

Key words: Vertical farming, Strawberry, Biofertilizers, Organic manure.

INTRODUCTION

Strawberry (*Fragaria × ananassa* Duch.) belongs to the family Rosaceae. The cultivated strawberry (*Fragaria × ananassa* Duch.) was originated from the hybridization of two American species viz., *Fragaria chiloensis* Duch. and *Fragaria virginiana* Duch. All the cultivated varieties of strawberry are octaploid (2n = 8x = 56) in nature. It is herbaceous crop with prostrate growth habit, which behaves as an annual in sub-tropical region and perennial in temperate region. (Gallette and Bringhurst, 1990).

Strawberry is used as fresh fruit being rich in vitamin C (30-120 mg/100g fruit pulp) and ellagic acid, which has anti cancerous property. Fruits are attractive with distinct pleasant aroma and flavour, consumed as dessert and also have a special demand by the fruit processing units for the preparation of jams, ice cream, syrups etc. Vermicompost contains plant growth regulating materials, such as humic acids and plant growth regulators like auxins, gibberellins and cytokinin's; (Grappelli *et al.*, 1987), which are responsible for increased plant growth and yield of strawberry fruit crops. Biofertilizers are one of the best modern tools for agriculture and are used to improve the fertility and quality of the soil. It offers an economically attractive and ecologically sound route for augmenting nutrient supply that enables to plant growth and development of strawberry. Keeping these facts in view, the present investigation was initiated to study. Low-enter agricultural gadget which is based at the input of natural substances preserve terrific promise now no longer simplest to limit the usage of artificial fertilizer,

however additionally to enhance crop productiveness and to make sure surroundings sustainability towards nutrient mining and degradation of soil and water resources (Tilman *et al.*, 2002; Kravchenko *et al.*, 2017).

Among the natural amendment, farmyard manure (FYM) has been extensively utilized in agricultural fields and the composted shape of this manure is desired over clean manure to dispose of the hazard of N loss thru leaching and floor runoff, boom soil natural matter, suppress soil-borne pathogens and to mitigate greenhouse gas emissions (Darby *et al.*, 2004; Evanylo *et al.*, 2008; Kim *et al.*, 2014; Escribano, 2016). Vermicompost is organic material that has been broken down in a mesophilic process by interactions between microorganisms and earthworms to produce fully stabilized organic soil amendments with low C:N ratios (Ramasamy *et al.*, 2011). Vermicompost contains significant amounts of nutrients, a large valuable microbial population, and biologically active metabolites (gibberellins, cytokinins, auxins), as well as vitamins B, which can be used alone or in combination with other inorganic or organic fertilizers to improve crop quality (Atiyeh *et al.*, 2002; Arancon *et al.*, 2006). in soils is influenced by soil physicochemical properties (organic matter, pH, temperature, soil depth, soil moisture) and microbiological properties (microbial interactions). is a well-studied plant growth promoting bacteria due to its ability to colonise the roots of various plant species, the majority of which are agriculturally important (Cessán *et al.*, 2008).

Vertical farming is crop husbandry in which crops are planted in vertically managed layers in order to harness the untapped vertical area that is otherwise overlooked in almost all cultivation practises. Furthermore, approximately 80% of total arable land is currently underutilized globally. (Ellingsen & Despommier, 2008) Some urban planners and agricultural leaders have argued that cities must produce food internally in order to manage the demand-supply ratio and avoid falling food prices, harmful pollution, and inflation (Kodmany, 2018). Growing media/substrates are the materials in which the plant will grow and play an important role in productivity. They provide anchorage for plant roots, air spaces for respiration, and the ability to retain enough available water for plant growth. For growing plants, a variety of growth substrates are available. For growing plants, the growing medias are used solely or in combinations (Arancon N.Q and Edwards C.A, 2005). The types of media combinations vary depending on the plant species, as well as the grower and stage of growth, such as nursery raising or transplanting. Nowadays, various types of growing media are available on the market, such as coco-peat, coir, vermicompost, perlite, bagasse, sawdust, and so on, but some media performed well despite being insignificant in yield. (Rawahya *et al.*, 2009).

MATERIALS AND METHODS

The area of Prayagraj district comes under subtropical belt in the South East of Uttar Pradesh, which experience extremely hot summer and fairly cold winter. The maximum temperature of the location reaches up to 46°C – 48°C and seldom falls as low as 4°C – 5°C. The relative humidity ranged between 20–94 percent. The average rainfall in this area is around 1013.4 mm annually. However, occasional precipitation is also not uncommon during winter months. The experiment was conducted at the experimental site of Department of Horticulture, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Prayagraj during 2021 2022. Treatments namely T₀ CONTROL (sand, soil, coir pith), T₁ Sand (25%) + Soil (50%) +

Vermicompost (25%) + *Azotobacter* (2g), T₂ Sand (25%) + Soil (50%) + Vermicompost (25%) + PSB (2g), T₃ Sand (25%) + Soil (50%) + Vermicompost (25%) + *Azospirillum* (2g), T₄ Soil (50%) + coir pith (25%) + FYM (25%) + *Azotobacter* (2g), T₅ Soil (50%) + coir pith (25%) + FYM (25%) + PSB (2g), T₆ Soil (50%) + coir pith (25%) + FYM (25%) + *Azospirillum* (2g), T₇ Soil (50%) + FYM (50%) + PSB (2g) + *Azotobacter* (2g), T₈ Soil (50%) + coir pith (50%) + *Azospirillum* (2g) + PSB (2g), T₉ Soil (50%) + Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g) were tested in randomized block design with three replications. The observations were recorded on three randomly selected plants from each treatment. Vegetative characters [Plant height (cm), Plant spread (cm), Number of leaves per plant, Leaf Area Index (cm²)], yield and economic attributes [Number of fruits per plant (90 days), Yield plant⁻¹(g) (90 days), Fruit diameter (cm) (90 days), Fruit length (cm) (90 days), TSS (°Brix) (90 days), Acidity (%) (90 days), Ascorbic Acid (mg/100g) (90 days), Net return (₹ /100²), Benefit: Cost ratio].

RESULTS AND DISCUSSION

VEGETATIVE CHARACTERS

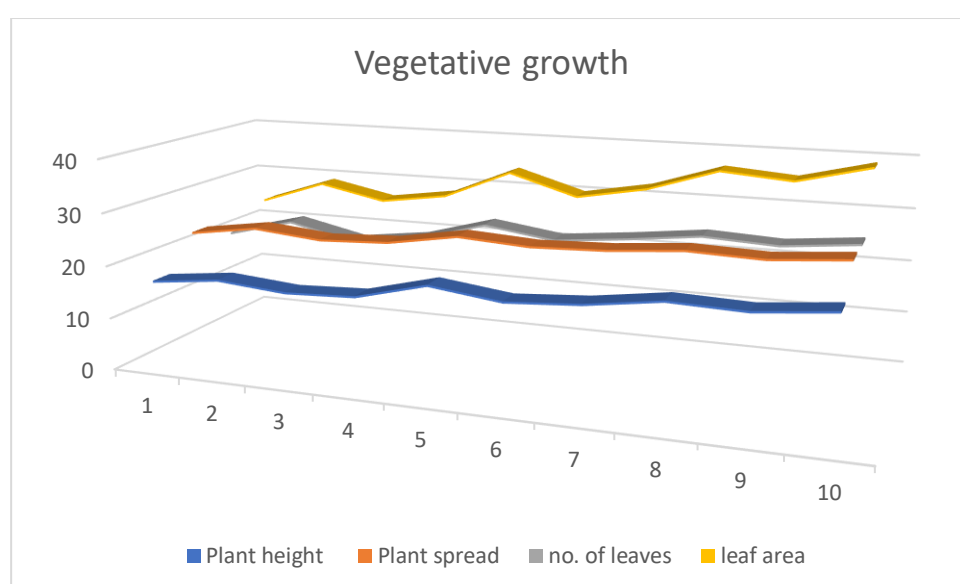
It is clear from the (Table 1) & (Graph 1) that the maximum plant height (8.56 cm, 15.79 cm, 22.89 cm) was recorded in T₉ (Soil (50%) + Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g)). The minimum plant height per plant (5 cm, 9.9 cm, 16.67 cm) was recorded in T₀ (CONTROL (sand, soil, coir pith)). Vermicompost is regarded as a more abundant source of plant nutrients (Arancon *et al.*, 2003 and 2004). *Azotobacter* is the most extensively studied free living nitrogen fixing bacteria, and it is known to synthesizes biologically active growth promoting substances in addition to fixing atmospheric nitrogen (Yadav *et al.*, 2010) and are further influenced by plant vegetative growth. PSB stimulated plant growth by promoting phosphate dissolution (Nowsheen *et al.*, 2006) as well as the biosynthesis of auxin (Sattar and Gaur, 1987) and IAA (Sattar and Gaur, 1987).

The maximum plant spread (28 cm) was recorded in T₉ (Soil (50%) + Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g)) The minimum plant spread (23.07 cm) was recorded in T₀ (CONTROL (sand, soil, coir pith)). Vermicompost is regarded as a more abundant source of plant nutrients, growth regulators, enzymes, antifungal and antibacterial compounds (Arancon *et al.*, 2003 and 2004). PSB stimulated plant growth via phosphate dissolution (Nowsheen *et al.*, 2006) and the biosynthesis of auxin (Sattar and Gaur, 1987) and IAA (Sattar and Gaur, 1987). Vermicompost has previously been shown to have a positive effect on plant growth in strawberries (Aroncon *et al.*, 2003 and 2004, Singh *et al.*, 2008, Nazir *et al.*, 2006, Yadav *et al.*, 2010).

The maximum number of leaves (27.56) was recorded in T₉ (Soil (50%) + Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g)) and the minimum number of leaves per plant (20.11) was recorded in T₀ (CONTROL (Sand, soil, coir pith)). The memoir fertilisers had a significant impact on the number of strawberry leaves per plant *Azotobacter* is the most hugely studied tone- ruling living nitrogen setting up bacteria, and in addition to its goods to dispose atmospheric nitrogen, it's grasped to synthesise biologically alive excrescence advancing quiddities likewise as IAA, GA, and others (Yadav *et al.*, 2010). The developments acquired are in attestation with the judgments of Yadav *et al.*, (2010) who reported that conjugated exercise of life conditions, vermicompost with inorganic conditions significantly

compounded the number of leaves and flake demesne of strawberry and Nowsheen *et al.*, (2006) plant that the exercise of P.S.B.

The maximum leaf area (38.8 cm) was recorded in T₉ (Soil (50%) +Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g)). The minimum leaf area (24.41 cm²) was recorded in T₀ (CONTROL (sand, soil, coir pith)). The mechanisms by which PSB stoked plant growth is through phosphate dissolution (Nowsheen *et al.*, 2006) and in the biosynthesis of auxin (Sattar and Gaur, 1987) and IAA (Bareae *et al.*, 1976). Positive effect of vermicompost on plant growth has also been recorded by (Nazir *et al.*, 2006, Yadav *et al.*, 2010). Combined operation of memoir diseases, vermicompost with inorganic fertilisers significantly increased the number of leaves and splint area of strawberry (Aroncon *et al.*, 2003 & 2004, Singh *et al.*, 2008).



Graph 1: Effect of biofertilizers on vegetative growth characters of strawberry

Table1: Effect of biofertilizers on vegetative growth characters of strawberry

Treatment	Treatment combination	Plant height (cm) (90 days)	Plant spread (cm) (90 days)	Number of leaves (90 days)	Leaf area (cm ²) (90 days)
T ₀	CONTROL (sand, soil, coir pith)	16.67	23.07	20.11	24.41
T ₁	Sand (25%) + Soil (50%) + VC (25%) + <i>Azoto</i> . (2g)	18.11	24.97	23.44	28.9
T ₂	Sand (25%) + Soil (50%) + VC (25%) + PSB (2g)	17	23.77	20.56	26.17
T ₃	Sand (25%) + Soil (50%) + VC (25%) + <i>Azosp</i> . (2g)	17.56	24.37	22.22	28
T ₄	Soil (50%) + coir pith (25%) + FYM (25%) + <i>Azoto</i> . (2g)	20.89	26.57	22.89	33.67
T ₅	Soil (50%) + coir pith (25%) + FYM (25%) + PSB (2g)	19.22	25.77	24	29.8
T ₆	Soil (50%) + coir pith (25%) + FYM (25%) + <i>Azosp</i> . (2g)	20.11	26.23	25.33	32.17
T ₇	Soil (50%) + FYM (50%) + PSB (2g) + <i>Azoto</i> . (2g)	22	27.33	26.89	36.5
T ₈	Soil (50%) + coir pith (50%) + <i>Azosp</i> . (2g) + PSB (2g)	21.56	26.9	26.22	34.41
T ₉	Soil (50%) + VC (50%) + <i>Azoto</i> .(2g) + <i>Azosp</i> .(2g)	22.89	28	27.56	38.8
F-test		S	NS	S	S
SE. d (+)		1.01	2.06	1.87	2.68
CD (5%)		2.12	4.33	3.93	5.7

VC: vermicompost, Azoto: *Azotobacter*, Azosp: *Azospirillum*, PSB: Phosphate solubilizing bacteria

YIELD AND ECONOMIC ATTRIBUTES

Numerically in (Table 2) & graphically in (Graph 2) the maximum number of fruits plant⁻¹ (21) was recorded in T₉ (Soil (50%) +Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g)) and the minimum number of fruits per plant (11.89) was recorded in T₀ (CONTROL (Sand, soil, coir pith)). It is clear from the table that there are significant differences among the treatments at 90 days after planting number of fruits plant⁻¹ may be due to increase in the number of leaves which worked as an effective photosynthesis structure and produced high quantum of carbohydrates in the plant system. Further number of flowers, which redounded advanced fruits per plant, under present study due to capability of vermicompost in producing growth hormone, enzymes, antifungal and antibacterial composites, which in turns

enhanced marketable yield over other treatments. Analogous findings also reported by Wang (1996), Yadav *et al.*, (2010), Umar *et al.*, (2009), Singh *et al.*, (2008), Rana and Chandel (2003), Zargar *et al.*, (2008), Umar *et al.*, (2010) Dadashpour and Jouki (2012) and Verma and Rao (2013) in strawberry.

The maximum fruits yield plant⁻¹ (638.40 g) was recorded in T₉ (Soil (50%) +Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g)) and the minimum number of fruits yield per plant (216.08 g) was recorded in T₀ (CONTROL (sand, soil, coir pith)). Increase in fruit yield may be due to increase in the number of leaves which worked as an effective photosynthesis structure and produced high quantum of carbohydrates in the plant system. Vermicompost contains plant growth regulating accoutrements, similar as humic acids and plant growth controllers like auxins, gibberellins and cytokinin (Grappelli *et al.*, 1987), Analogous findings also reported by Wang (1996), Yadav *et al.*, (2010), Umar *et al.*, (2009), Singh *et al.*, (2008), Rana and Chandel (2003), Zargar *et al.*, (2008), Umar *et al.*, (2010) Dadashpour and Jouki (2012) and Verma and Rao (2013) in strawberry.

The maximum fruit diameter (3.36 cm) was recorded in T₉ (Soil (50%) +Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g)). The minimum fruit diameter (2.47 cm) was observed in T₀ (CONTROL (sand, soil, coir pith)). Increase in fruit diameter may be due to balanced clearness of macro and micronutrients and growth promoting hormones produced by different bio-fertilizers applied in different treatment combinations. This could be linked to superior fruit fillers as a result of more balanced nutrient intake, which could have led to improved metabolic conditioning in the plant, leading to a high protein and carbohydrate admixture (Singh *et al.*, 1970). Also, the different partitioning of photosynthesis towards the cesspool by *Azotobacter* inoculation increased the fruit size and fruit diameter (Rana and Chandel, 2003).

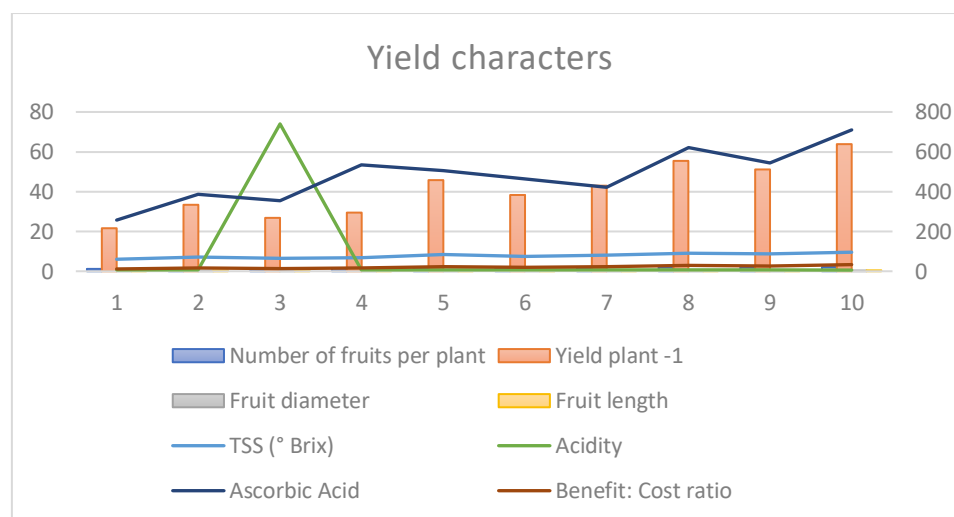
The maximum fruit length (4.46 cm) was recorded in T₉ (Soil (50%) +Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g)) & the minimum fruit length (3.1 cm) was observed in T₀ (CONTROL (sand, soil, coir pith)). Fruit length growth can be because of balanced availability of macro and micronutrients and boom selling hormones produced with the aid of using unique bio-fertilizers carried out in unique remedy combinations. This can be attributed to higher fillings of culmination because of extra balanced uptake of vitamins which may also have caused higher metabolic sports withinside the plant in the long run main to excessive protein and carbohydrate synthesis (Singh *et al.*, 1970). Also, the unique partitioning of photosynthesis toward the sink with the aid of using *Azotobacter* inoculation multiplied the fruit duration (Rana and Chandel, 2003 and Tripathi *et al.*, 2010). Suthar (1993) confirmed that amongst diverse natural sources, vermicompost had the maximum critical position accompanied with the aid of using FYM.

The maximum (TSS 9.57°B) was recorded in T₉ (Soil (50%) +Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g)) and the minimum (TSS 5.31°B) was observed in T₀ (CONTROL (sand, soil, coir pith)). Increased TSS and general sugars in berry with the utility of *Azotobacter* and vermicompost can be attributed because of the fast metabolic transformation of starch and pectin into soluble compounds and speedy translocation of sugars from leaves to the growing fruits. These findings trust the consequences of Singh and Singh, (2006); Haynes and Goh (1987); Singh *et al.*, (2008) in strawberry; Rathi and Bist (2004) in pear and Baksh *et al.*, (2008) in guava. Badr *et al.*, (2003) pronounced that sugar is produced through breaking the starch withinside the leaves and Anthocyanin will even increase with growing glucose ranges because of mobileular metabolism, ensuing withinside the accumulation of soluble sugars withinside the mobileular.

The maximum acidity 0.74% was observed in T₀ (CONTROL (sand, soil, coir pith)) and minimum acidity 0.59% was recorded in Soil T₉ (50%) +Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g). The similar findings also reported by (Singh *et al.*, 2008) who noticed that the fruit harvested plant receiving vermicompost were TSS and ascorbic acid increases, acidity decreased and color more attractive.

The maximum ascorbic acid (71mg/100g) was observed in T₉ (Soil (50%) +Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g)) and minimum ascorbic acid (25.7mg/100g) was recorded in T₀ (CONTROL (sand, soil, coir pith)). Increased ascorbic acid at better tiers of nitrogen would possibly have resulted in view that absorption of nitrogen can be exerted regulatory function as a vital and all through ripening of culmination the carbohydrate reserves of the roots and stem are drawn upon closely through culmination which would possibly have resulted into better ascorbic acid in culmination. Increased ascorbic acid in culmination is the settlement with the findings of EI-Hamid *et al.*, (2006) who mentioned that the utility of P.S.B. on strawberry resulted growth in ascorbic acid and Singh *et al.*, (2008) who mentioned that the fruit harvested from plant receiving vermicompost have been farmer, TSS and ascorbic acid increases, acidity reduced and satiation greater attractive.

The greatest net return was obtained 2,29,050 Rs/100m² in T₉ (Soil (50%) +Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g)) and cost benefit ratio was found (3.34) in T₉ (FYM+ Vermicompost+ PSB+ *Azotobacter*). The minimum cost benefit ratio was recorded (1.16) in T₀ (CONTROL (sand, soil, coir pith)). Many workers also reported the higher net return and cost benefit ratio with the application of organic fertilizers and bio fertilizers viz. Yadav *et al.*, (2010), Verma and Rao, (2012) in strawberry.



Graph 2: Effect of biofertilizers on yield characters and yield plant⁻¹ of strawberry

Table2: Effect of biofertilizers on yield characters and yield plant⁻¹ of strawberry

Treatment	Treatment combination	Number of fruits per plant (90 days)	Yield plant ⁻¹ (gram) (90 days)	Fruit diameter (cm) (90 days)	Fruit length (cm) (90 days)	TSS (° Brix) (90 days)	Acidity (%) (90 days)	Ascorbic Acid (mg/100g) (90 days)	Net return (₹ /100 ²)	Benefit: Cost ratio
T ₀	CONTROL (sand, soil, coir pith)	11.89	216.08	tss	3.1	6.03	0.74	25.7	15,700	1.16
T ₁	Sand (25%) + Soil (50%) + VC (25%) + <i>Azoto</i> . (2g)	15.56	333.82	2.8	3.57	7.03	0.71	38.7	74,350	1.78
T ₂	Sand (25%) + Soil (50%) + VC (25%) + PSB (2g)	13.56	268.17	2.57	3.27	6.36	0.74	35.3	40,550	1.41
T ₃	Sand (25%) + Soil (50%) + VC (25%) + <i>Azosp.</i> (2g)	14.33	294.56	2.74	3.43	6.77	0.69	53.3	54,300	1.57
T ₄	Soil (50%) + coir pith (25%) + FYM (25%) + <i>Azoto</i> . (2g)	18.33	457.72	3.23	3.97	8.44	0.64	50.7	1,37,170	2.41
T ₅	Soil (50%) + coir pith (25%) + FYM (25%) + PSB (2g)	16.89	383.04	2.97	3.7	7.6	0.66	46.3	98,970	2.01
T ₆	Soil (50%) + coir pith (25%) + FYM (25%) + <i>Azosp.</i> (2g)	17.56	419.79	3.03	3.84	8.06	0.65	42.3	1,17,920	2.21
T ₇	Soil (50%) + FYM (50%) + PSB (2g) + <i>Azoto</i> . (2g)	19.89	554.33	3.47	4.33	9.1	0.60	62	1,86,740	2.93
T ₈	Soil (50%) + coir pith (50%) + <i>Azosp.</i> (2g) + PSB (2g)	19	511.30	3.33	4.03	8.6	0.61	54.3	1,64,350	2.69
T ₉	Soil (50%) + VC (50%) + <i>Azoto</i> . (2g) + <i>Azosp.</i> (2g)	21	638.40	49.56	4.46	9.57	0.58	71	2,29,050	3.34
F-test		S	S	S	S	S	S	S		
SE. d (+)		1.77	54.45	1.74	0.23	0.36	0.04	2.93		
CD (5%)		3.71	114.4	3.66	0.47	0.76	0.09	6.16		

VC: vermicompost, Azoto: *Azotobacter*, Azosp: *Azospirillum*, PSB: Phosphate solubilizing bacteria

CONCLUSION

On the basis of present investigation 2020-2022, it is concluded that the treatment T₉ (Soil (50%) + Vermicompost (50%) + *Azotobacter* (2g) + *Azospirillum* (2g)) was found the best in terms of vegetative growth (Plant height (cm), Plant spread (cm), Number of leaves, Leaf area)(cm²) and yield and quality parameters (Number of fruits per plant Yield plant⁻¹(gram) Fruit diameter (cm), Fruit length (cm), TSS (°Brix), Acidity (%), Ascorbic Acid (mg/100g) Net return (₹ /100²), Benefit: Cost ratio). The maximum gross return (Rs. 3,26,800), net return (Rs. 2,29,050) and Benefit cost ratio (1: 3.34) followed by (2.93) in T₇ (Soil (50%) + FYM (50%) + PSB (2g) + *Azotobacter* (2g)) under vertical farming system in Prayagraj agro-climatic condition.

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