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Effect of PSB and Vermicompost on Vegetative Growth, Yield and Quality of Strawberry (*Fragaria×Ananassa* Duch.) cv. Chandler

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ABSTRACT

A trial was conducted at Horticulture Farm, Department of Horticulture, Naini Agriculture Institute (NAI), Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj (UP), India during October 2023 to March 2024 to assess the effects of PSB and vermicompost on the growth, yield, and quality of Strawberry. The experiment was conducted using nine treatments including two levels each of vermicompost (20 and 25 t ha^{-1}) and PSB (6 and 7 kg ha^{-1}) and their combinations along with one control, replicated thrice in randomized block design. Each dose of vermicompost and PSB was applied at the time of planting in the field. The consolidated use of vermicompost @ 25 t ha^{-1} PSB @ 7 kg ha^{-1} significantly expanded the height of plant (16.21 cm), number of leaves (60.00), crowns (6.29) and runners (4.97) plant^{-1}, though the most extreme number of flowers (38.31), fruits set (35.50) plant^{-1} with an expanded duration of harvesting (70.27 days) and the minimum number of days taken to produce first flower (63.99 days) with significantly more yield (344.35 g plant^{-1}) were recorded with vermicompost @ 25 t ha^{-1} PSB @ 7 kg ha^{-1} supplied plants. Plants supplied with vermicompost @ 25 t ha^{-1} PSB @ 7 kg ha^{-1} additionally produced the berries with extreme length (4.13 cm), width (2.45 cm), weight (9.70 g), TSS (9.21°Brix), total sugars (8.31%) and ascorbic acid (57.47 mg 100 g^{-1} edible portion) with least titratable acidity (0.60%) in contrast with different treatments under plains of central Uttar Pradesh.

KEYWORDS: Strawberry, vermicompost, PSB, growth, yield and quality

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1. INTRODUCTION

Strawberry (*Fragaria×ananassa* Duch.), a member of the family Rosaceae, is one of the most popular soft fruits, cultivated in plains and on hills up to 3000 meters in humid or dry regions. Strawberry plants perform well in sandy loam soil with a pH range of 5.5 to 6.5. Its successful cultivation requires an optimum day temperature of 22 to 23°C and night temperature of 7 to 13°C in India (Kumar et al., 2015). Frost, as well as winter injury, seriously reduces the yield of berries.

Strawberry is an herbaceous crop with a prostrate growth habit, which behaves as an annual in the sub-tropical region and perennial in the temperate region. It can be grown successfully up to an elevation of 3000 m above MSL in both humid and dry regions (Dwivedi et al., 2004), wherever irrigation facilities exist. Botanically, the strawberry fruit is an aggregate (etaerio of achenes), and the edible portion is the succulent thalamus. In India, strawberries are commercially cultivated in Himachal Pradesh, Uttarakhand, Jammu and Kashmir, West Bengal, Uttar Pradesh, Punjab, Maharashtra, and Karnataka.

Strawberry is used as fresh fruit, being rich in vitamin C and ellagic acid, which has anti-cancerous properties. 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. (Singh et al., 2015). It is a profitable fruit crop in the shortest possible time as compared to the other fruits. It is the most popular and early paying back fruit in the world.

Nowadays, the use of bio-fertilizers is becoming popular as an essential part of crop production, not only to obtain high yields of quality fruits but also for their cost-effectiveness and a pollution-free environment (Tripathi et al., 2016). Biofertilizers contain microorganisms that are either free-living in soil or symbiotic with plants and contribute directly or indirectly to the nitrogen and phosphorus nutrition of plants. They also produce hormones, vitamins, and other growth factors required for plant growth and development (Tripathi et al., 2015). Bio-fertilisers like PSB provide phosphorus to the plants. The use of phosphate-solubilizing bacteria as inoculants simultaneously increases phosphorus uptake by the plant and crop yield. Strains from the genera *Pseudomonas, Bacillus* and *Rhizobium* are among the most powerful phosphate solubilizers. The application of soil+sand+FYM was found to be better in plant growth, fruit morphological parameters, fruit quality, and biochemical aspects as compared to the control (Asinlu et al., 2025).

The combination of manures and biofertilizers has shown potential to increase crop yield and its nutritive properties under field conditions. Therefore, we concluded that the combination of biofertilizers with organic manures (especially, FYM and vermicompost) should be used for sustainably higher production of quality strawberries, especially under an organic farming system (Negi et al., 2021). Vermicompost also has a significant role in plant nutrient management for fruit crops, helping keep the soil biologically active and healthy. Vermicompost is a rich mixture of major and minor plant nutrients. It increases the total microbial population of nitrogen-fixing bacteria, actinomycetes, and mycorrhizal symbionts in the root system. Vermicompost is widely used in horticultural crop production and is considered one of the most valuable organic manures. It consistently promotes biological activity, which can cause plants to flower and yield better than the commercial media. Therefore, keeping in view the importance of fruits and the enormous rate of phosphate-solubilizing bacteria and vermicompost, an experiment was planned to infer concrete information on the effect of these on vegetative growth, fruiting, and yield of strawberry.

2. MATERIALS AND METHODS

The experiment was conducted at the Horticulture Farm, Department of Horticulture, Naini Agriculture Institute (NAI), Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, U.P., India during October 2023 to March 2024. The experiment was laid out in a randomized block design using nine treatments viz., T_1-Vermicompost 20 t ha^{-1}, T_2-Vermicompost 25 t ha^{-1}, T_3-PSB 6 kg ha^{-1}, T_4-PSB 7kg ha^{-1}, T_5-Vermicompost+PSB 20 t ha^{-1}+6 kg ha^{-1}, T_6-Vermicompost + PSB 25 t ha^{-1}+6 kg ha^{-1}, T_7-Vermicompost+PSB 20 t ha^{-1}+7 kg ha^{-1}, T_8-Vermicompost+PSB 25 t ha^{-1}+7 kg ha^{-1}, T_9-Control (RDF) with three replications. Standard cultural operations, plant protection measures, and basal applications of all treatments were used as per the treatment combinations. The observations were recorded on plant height, number of leaves, number of crowns plant^{-1}, number of runners plant^{-1}, first flower initiation, number of flowers plant^{-1}, number of fruits plant^{-1}, harvesting duration, yield plant^{-1}, berry size, berry weight, along with various other biochemical parameters like TSS, Sugar content, titratable acidity, and ascorbic acid content of fruits. A hand refractometer was used to determine TSS, expressed in °Brix. Other chemical parameters, such as total sugars, ascorbic acid, and titratable acidity, were determined using the standard methods described in Anonymous (1980). The obtained data were analyzed statistically (Panse and Sukhatme, 1985).

3. RESULTS AND DISCUSSION

3.1. Plant growth attributes

3.1.1. Plant height (cm) and number of leaves

The maximum plant height (16.21 cm) was recorded in the plants treated with 25 tonnes of vermicompost with

7 kg of PSB, followed by the plants treated with 20 t ha^{-1} along with 7 kg ha^{-1} of PSB of vermicompost (15.98 cm), whereas the minimum plant height was obtained in the control (12.00 cm). The maximum number of leaves $plant^{-1}$ (60) was recorded when plants were fertilised with 25 kg of vermicompost and 7 kg of PSB ha^{-1} (Table 1). The minimum number of leaves was produced (30) under control. The maximum plant height and the number of leaves $plant^{-1}$ increased significantly with the application of PSB and vermicompost at various levels. The increment in the tallness of plants and the number of leaves $plant^{-1}$ with PSB and vermicompost treatment during the course of investigation supports the discoveries of Yashasvi et al. (2021) in strawberry.

3.1.2. *Number of crowns and runners' plant^{-1}*

The most extreme number of crowns (6.09) $plant^{-1}$ was acquired with the application of 25 tonnes of vermicompost with 7 kg of PSB, which was statistically at par with 25 tons of vermicompost along with 6 kg PSB treatment (6.17), while the minimum number of crowns $plant^{-1}$ was recorded in the control (3.11). The plant fertilised with 25 tonnes of vermicompost and 7 kg of PSB ha^{-1} produced the highest number of runners (4.97) $plant^{-1}$, which was higher than any other treatment under investigation, with the minimum number of runners (2.96) recorded in the control plants (Table 1). During the present examination, the number of runners and crowns $plant^{-1}$ was significantly increased with the application of PSB and vermicompost at different levels. These discoveries are in complete agreement with those of Kumar and Tripathi (2020), Yashasvi et al. (2021), and Tripathi et al. (2010) in strawberry. This increase in the quantity of crown and runners' $plant^{-1}$ may be due to the extended growth of plants, as stature and the number of leaves increased, which produced more photosynthates and subsequently increased the quantity of crown and runners' $plant^{-1}$.

3.2. *Floral characters*

3.2.1. *First flower initiation and number of flowers plant^{-1}*

As detailed in Table 1, the earliest flowering (63.99 days) was recorded with 25 tons of vermicompost with 7 kg of PSB ha^{-1} application, followed by (65.01days) 25 tons of vermicompost with 7 kg of PSB $hectare^{-1}$. However, it was deferred in untreated plants, which took the most extreme days (73.99 days). All portions of PSB and vermicompost also reduced the days to first flower compared with the control (73.99 days). The greatest number of flowers, $plant^{-1}$ was recorded (38.31) with the application of 25 tonnes of vermicompost with 7 kg of PSB ha^{-1}, closely followed by 20 tons of vermicompost and PSB at 7 kg ha^{-1} (32.87); it was the least (17.64) in the untreated plant (Table 1). An increased number of flowers might also have resulted from an increase in the number of crowns $plant^{-1}$. Similar perceptions were also announced by Tripathi et al. (2010), Kumar and Tripathi (2020), and Yashasvi et al. (2021**)** in strawberry.

3.2.2. *Number of fruits plant^{-1}*

The most extreme number of fruits set $plant^{-1}$ (35.50) was seen in vermicompost at 25 t $ha^{-1,}$ along with PSB at 7 kg ha^{-1} fertilized plant (T_8), closely followed by T_7-20 tons of vermicompost ha^{-1} in combination with 7 kg PSB (30.10) and (T_6) 6 kg ha^{-1} PSB along with 30 tons of vermicompost ha^{-1} (26.93) as described in Table 1. While it was minimum (15.40) in unfertilized plants. These outcomes are comparable with the reports of Tripathi et al. (2014); Mishra and Tripathi (2011), who additionally noticed that

Table 1: Effect of PSB and vermicompost on growth and yield of strawberry cv. Chandler

Treatment	Plant height	Number of leaves	Number of crowns	Number of runners	Number of flowers	Number of fruits	Harvesting days	Yield $plant^{-1}$
T_1	13.00	39	3.95	3.62	20.89	19.01	62.14	174.51
T_2	13.60	42	5.12	4.41	24.78	22.99	64.27	212.20
T_3	15.30	41	4.30	4.43	24.84	22.08	67.05	221.26
T_4	15.50	42	4.61	3.98	26.35	24.05	65.74	208.88
T_5	15.70	53	5.37	4.14	22.87	20.35	67.16	196.78
T_6	15.80	55	6.17	4.59	29.07	26.93	67.17	247.49
T_7	15.90	57	5.31	4.05	32.87	30.10	67.58	290.47
T_8	16.20	60	6.29	4.97	38.31	35.50	70.27	344.35
T_9	12.00	30	3.11	2.96	17.64	15.40	53.95	139.53
SEm±	0.53	4.20	0.39	0.22	3.07	2.79	2.02	26.12
CD (p=0.05)	1.83	NS	1.35	0.76	NS	NS	NS	NS

an increment in PSB concentration resulted in heavier fruiting. PSB is expected to hasten plant development and thereby play some role in promoting fruit production.

3.2.3. Harvesting duration

Among all the doses of vermicompost and PSB, the longest duration of harvesting (70.27 days) was recorded with a higher portion of vermicompost (25 t) ha^{-1} along with PSB (7 kg ha^{-1}), closely followed by 20 tonnes of vermicompost ha^{-1} along with 7 kg ha^{-1} PSB (67.58 days). The minimum harvesting duration was recorded for the control (53.95 days). All remaining treatments additionally extended the harvesting period (ranging from 67.16 to 62.14 days), compared with the control (53.95 days). During the current examination, the harvesting duration was significantly extended with PSB and vermicompost applications. These results are in conformity with the findings of Mishra and Tripathi (2011) and Gupta and Tripathi (2012) in strawberry. They also got an advanced duration of harvesting (earliness) by approximately one month, which obviously extended the period of harvesting.

3.2.4. Yield plant^{-1}

The highest yield (344.34 g $plant^{-1}$) was recorded in the plant fertilized with vermicompost at 25 t ha^{-1}, along with PSB at 7 kg ha^{-1}, as shown in Table 1, and was closely followed by vermicompost at 20 t ha^{-1}, along with PSB at 7 kg ha^{-1} (290.47 g $plant^{-1}$). The minimum yield $plant^{-1}$ (139.53g $plant^{-1}$) was recorded in plants kept under control. The current findings are in accordance with the discoveries of Tripathi et al. (2014) and Kumar and Tripathi (2020) in strawberry. This expansion in yield might be a result of the expanded fruit set per plant, berry length and width as well as berry weight, and might be because of the way that nitrogen fixers and phosphorus solubilizers not only expanded the accessibility of nitrogen and phosphorus to the plants but also expanded their movement from root to flower through plant foliage.

3.3. Physical characters

3.3.1. Berry length and width

The berry of most extreme length (4.13 cm) was produced from the plants treated with 25 tons of vermicompost with 7 kg of PSB $hectare^{-1}$, whereas the minimum berry length (2.15 cm) was recorded in untreated plants. The maximum berry width (2.45 cm) was recorded in berries produced from the plants fertilized with 25 tons of vermicompost ha^{-1}, along with PSB at 7 kg ha^{-1}, followed by 20 tons of vermicompost ha^{-1}, along with PSB at 7 kg (2.23 cm). However, the minimum berry width (1.04 cm) was recorded in the berries produced by untreated control plants. In the current study, berry size (length and width) was significantly increased with the use of PSB and vermicompost. Comparable outcomes were obtained by Tripathi et al. (2014) and Mishra and Tripathi (2011) in strawberry. This expansion in berry size and weight during the current examination is perhaps due to the extended photosynthetic capacity of plants supplied with PSB and vermicompost, which in turn may have supported an expanded accumulation of dry matter.

3.3.2. Berry weight

The greatest average berry weight (9.70 g) was observed when plants were fertilized with 25 tons of vermicompost and 7 kg PSB ha^{-1}, closely followed by 20 tons of vermicompost ha^{-1} with 7 kg PSB ha^{-1} (Table 2). This expansion in berry weight observed in the current examination may be due to the increased photosynthetic capacity of plants supplied with PSB and vermicompost, which, in turn, may have supported greater accumulation of dry matter, ultimately resulting in higher berry weight. Comparative outcomes were reported by Tripathi et al. (2010), Mishra and Tripathi (2011) and Tripathi et al. (2010) in strawberry.

3.4. Biochemical characters

3.4.1. TSS and total sugar content

It is clear from Table 2 the greatest total soluble solids (9.21°Brix) content was recorded in the berries produced from the plants fertilized with 25 tons of vermicompost with 7 kg of PSB ha^{-1} followed by PSB at 7 kg along with 20 t of vermicompost ha^{-1} (9.19°Brix) and vermicompost 25 t ha^{-1} with PSB at 6 kg (9.15°Brix) which are statistically at par with each other. The lowest TSS (7.73°Brix) content was seen in untreated plants. The maximum total sugar content was recorded in the berries produced from the plant fertilized with 25 t of vermicompost with 7 kg of PSB ha^{-1} (8.31%), followed by PSB at 7 kg in combination with 20 t of vermicompost ha^{-1} (8.29%), whereas the minimum total sugar content was recorded in the berries of the control (7.09%) plant. Based on the present examination, it was observed that different levels of PSB and vermicompost applications significantly increased the TSS and total sugar content of berries. An increase in TSS and total sugars with PSB and vermicompost application might be attributed to the rapid metabolic conversion of starch and pectin into soluble mixtures and the rapid movement of sugars from leaves to developing fruits. Similar perceptions were recorded by Kumar and Tripathi (2020), Nayyer et al. (2014), Tripathi et al. (2014), Mishra and Tripathi (2011), and Tripathi et al. (2010) in strawberry.

3.4.2. Titratable acidity

The maximum titratable acidity (0.69%) was recorded in the berries produced from unfertilized plants, followed by vermicompost at 20 t ha^{-1} (0.66%) and 20 t (0.64%), and the minimum content (0.60%) was recorded with PSB at 7 kg ha^{-1} in combination with vermicompost 25 t ha^{-1}

Table 2: Effect of PSB and vermicompost on the quality of strawberry cv. Chandler

Treatment	Berry length (cm)	Beery width (cm)	Berry weight (g)	TSS (°Brix)	Total sugar (%)	Titratable acidity (%)	Ascorbic acid (mg 100 g^{-1})
T_1	3.12	1.58	9.18	8.03	7.09	0.66	52.75
T_2	3.29	1.94	9.23	8.09	7.11	0.65	52.98
T_3	3.33	2.09	9.20	8.22	7.41	0.64	53.35
T_4	3.46	2.19	9.46	8.59	7.69	0.62	54.16
T_5	3.43	2.13	9.19	8.61	7.69	0.62	55.23
T_6	4.00	2.17	9.65	9.50	8.25	0.63	55.62
T_7	4.11	2.23	9.67	9.19	8.29	0.61	56.71
T_8	4.13	2.45	9.70	9.21	8.31	0.60	57.47
T_9	2.15	1.04	9.06	7.73	6.91	0.69	51.27
SEm±	0.19	0.14	0.14	0.33	0.25	0.01	1.05
CD (p=0.05)	1.56	0.93	0.50	1.15	0.87	0.05	3.64

fertilized plants, as detailed in Table 2. This reduction in the titratable acidity content of fruits through the application of different organic manures and biofertilizers might be due to the positive influence of various microorganisms in the conversion of acids into sugars and their derivatives by reactions involving the glycolytic pathway. The views are supported by the perceptions of Kumar and Tripathi (2020) and Mishra and Tripathi (2011) in strawberry.

3.4.3. Ascorbic acid

From the Table 2, it is clear that the greatest amount of ascorbic acid (57.47 mg 100 g^{-1} of pulp) was recorded in the berries produced from the plants fertilized with vermicompost 25 t ha^{-1} in combination with PSB at 7 kg ha^{-1} closely followed by vermicompost 20 t ha^{-1} in combination with PSB at 7 kg ha^{-1} (56.71 mg 100 g^{-1} of pulp), whereas, the minimum amount of ascorbic acid (51.27 mg 100 g^{-1} of pulp) was recorded in control plants. The respective expansion in ascorbic acid content might be a result of the expanded effectiveness of microbial inoculants to fix atmospheric nitrogen, expansion in the accessibility of phosphorous and emission of growth-promoting substances which speeds up the physiological interaction like carbohydrates synthesis, and so on. Kumar et al. (2020), Tripathi et al. (2014), Umar et al. (2010) and Mishra and Tripathi (2011) in strawberry, also reported that inoculation with various portions of vermicompost and PSB in soil resulted in higher vitamin C content in strawberry.

3.5. Principal component analysis

The principal component analysis revealed that the first two axes explained 92.08% of the variation (Figure 1). 86.60% of the biochemical variation was captured under PC1, while the remaining 5.48% of the variation was under PC_2. PC_1 was positively and highly correlated with PH, NC, NL, BL, BW, BWT, YP, and TS; thus, these traits are jointly implicated in vigor and yield. On the other hand, PC_2 was represented by TA and AA, thus marking the axis of biochemical quality. The biplot showed all yield and morphological traits on one side of PC_1, while acidity lay on the opposite side, thus proving the inverse relationship between TA and parameters related to sweetness. AA was moderately correlated with sugars but weakly correlated with yield traits, suggesting that it is under different biochemical control. In all, PCA grouped traits into two major functional domains: growth + yield (PC_1) and quality+acidity (PC_2), a pattern also observed in multivariate trait analyses.

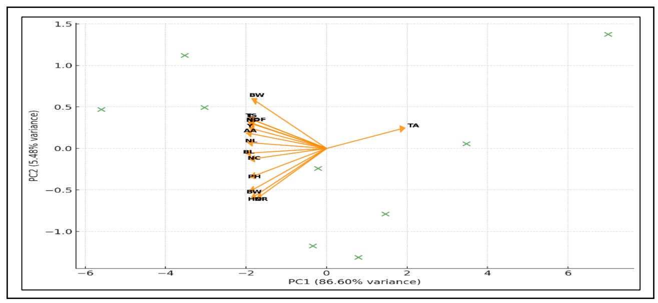

Figure 1: Principal component analysis of growth, yield, and quality of strawberry

3.6. Correlation analysis

The correlogram shows pronounced, highly significant associations among the major growth and yield variables, with correlation coefficients above 0.80 (Table 3 and Figure 2). The variables involved are PH, NL, NC, BL, BW, BWT, and YP, which indicate that vigorous vegetative growth supports large fruit size and high productivity. Total sugar (TS) and TSS also showed positive correlations with yield traits, indicating that higher fruit development favours sugar accumulation. In contrast, a strong negative correlation was

Table 3: Factor loadings of the different traits

Factor loadings	PC1	PC2
Plant height (cm)	-0.9742	-0.2284
Number of leaves	-1.0092	0.0467
Number of crowns	-0.9792	-0.0862
Number of runners	-0.894	-0.3994
Number of flowers	-0.9963	0.204
Number of fruits	-0.994	0.2082
Harvesting days	-0.9725	-0.4004
Yield plant^{-1} (kg)	-0.9887	0.1623
Berry length (cm)	-1.0334	-0.0383
Beery width (cm)	-0.9897	-0.3441
Berry weight (g)	-0.9558	0.3953
TSS (°Brix)	-0.9803	0.2371
Total sugar (%)	-1.0029	0.2405
Titratable acidity (%)	1.0012	0.1629
Ascorbic acid (mg 100 g^{-1})	-1.027	0.124
Eigenvalue	14.6144	0.925
Variance (%)	86.6037	5.4815
Cumulative variance (%)	86.6037	92.0852

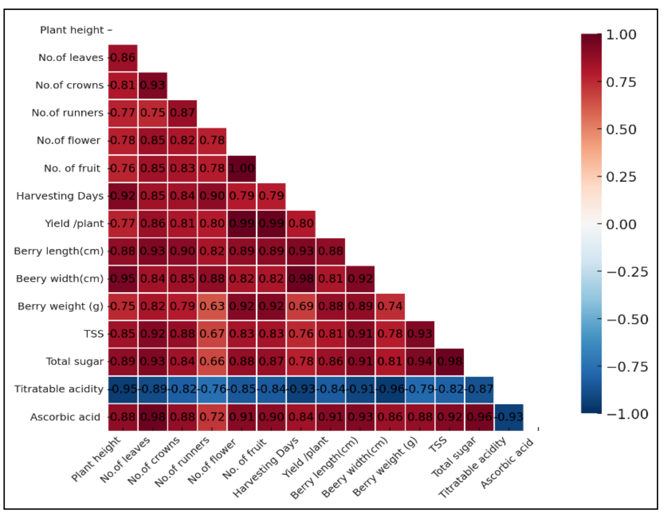

Figure 2: Correlation analysis of growth, yield and quality of strawberry by using PSB and vermicompost

found between TA and most morphological and quality traits (r=-0.76 to -0.96), thus confirming a time-tested relationship between TA and sugar content and maturity. Ascorbic acid (AA) showed a weak association with acidity and moderately positive correlations with sugar traits, implying that antioxidant potential increases with fruit quality. On the whole, the correlogram supports the PCA results: growth and yield traits together form a cohesive positive cluster. At the same time, acidity shows antagonism-the high-yielding and low-acidity genotypes would give high sweetness and vitamin C content.

4. CONCLUSION

Plants fertilized with 25 t ha^{-1} of vermicompost and 7 kg of PSB ha^{-1} (T_8) on Strawberry can significantly improve flowering, fruiting, and ultimately lead to physical and biochemical attributing characters of strawberry in the Prayagraj region of central Uttar Pradesh, India.

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