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Short Communication

Vermicompost substitution influences growth, physiological disorders, fruit yield and quality of strawberry (*Fragaria* x *ananassa* Duch.)

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A B S T R A C T

Studies were conducted to determine the effect of vermicompost on growth, physiological disorders, fruit yield and quality of 'Chandler' strawberry. For this, 4 levels of vermicompost (2.5, 5.0, 7.5 and 10.0 t ha^{-1}) were supplemented with inorganic fertilizers to balance fertilizer requirement of strawberry under semi-arid region of northern India. The vermicompost was incorporated into top 10 cm layer of soil, which was supplemented on the basis of chemical analysis, with amount of inorganic N, P, K fertilizer calculated to equalize the recommended dose of nutrients. Vermicompost application increased plant spread (10.7%), leaf area (23.1%) and dry matter (20.7%), and increased total fruit yield (32.7%). Substitution of vermicompost drastically reduced the incidence of physiological disorders like albinism (16.1–4.5%); fruit malformation (11.5–4.0%) and occurrence of grey mould (10.4–2.1%) in strawberry indicating that vermicompost had significant role in reducing nutrient-related disorders and disease like *Botrytis* rot, and thereby increasing the marketable fruit yield up to 58.6% with better quality parameters. Fruit harvested from plant receiving vermicompost were firmer, have higher TSS, ascorbic acid content and lower acidity, and have attractive colour. All these parameters appeared to be dose dependent and best results were achieved @ 7.5 t ha^{-1}, however, beyond this dose of vermicompost, there was not significant influence on these parameters.

1. Introduction

Vermicompost is a product of biodegradation and stabilization of organic materials by interaction between earthworms and microorganisms. It is a finely-divided, peat-like material, with high porosity, aeration, drainage, water holding capacity and microbial activity, which make it an excellent soil conditioner (Edwards and Burrows, 1988; Edwards, 1998; Atiyeh et al., 2001). Addition of different vermicomposts, produced from different sources, like cattle manure, pig manure, food waste etc., increases the rate of germination and growth, and yield of many high value crops (Atiyeh et al., 2000). Vermicompost contains plant-growth regulating materials, such as humic acids (Senesi et al., 1992; Masciandaro et al., 1997; Atiyeh et al., 2002) and plant growth regulators like auxins, gibberellins and cytokinins (Krishnamoorthy and Vajrabhiah, 1986; Grappelli et al., 1987; Tomati et al., 1988, 1990), which are responsible for increased plant growth and yield of many crops (Atiyeh et al., 2002). These plant growth-regulating materials are produced by action of microbes like fungi, bacteria, actinomycetes (Edwards, 1998; Tomati et al., 1987) etc., and earthworms. Vermicompost provides large particulate surface areas that provide many microsites for microbial activities and for strong retention of nutrients (Shi-wei and Fu-zhen, 1991). As a result, most nutrients are in available forms such as nitrates, phosphates, and exchangeable calcium and soluble potassium (Orozco et al., 1996; Edwards, 1998). Further, vermicompost application also suppresses the growth of many fungi, like *Pythium*, *Rhizoctonia* and *Verticillium*, as a result, many plant diseases are suppressed when vermicompost is applied in ample quantity in the field (Hoitink and Fahy, 1986). Sometimes, vermicompost also controls the population of plant parasitic nematodes (Johnston et al., 1995; Arancon et al., 2006). Hence, vermicompost exhibits similar effects on growth and yield of plants as shown by soil-applied inorganic fertilizers or plant growth regulators or hormones (Muscolo et al., 1999). However, most research work conducted on the use of vermicompost has only been in the greenhouse conditions, and only a few workers have reported its use and effects under field conditions.

Strawberry is one of the most important fruit crops of the world. It has become the most favourite fruit crop among the Indian growers near towns and cities, because of its remunerative prices and higher profitability, which has resulted a phenomenal increase in its area and production in the recent years (Sharma and Sharma, 2004; Sharma et al., 2006; Singh et al., 2006, 2007b). Strawberry requires higher amount of nutrients for higher

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yield of quality fruit. Consequently, efforts have been made to determine the doses of inorganic nutrients for strawberry cultivation (Sharma and Sharma, 2004). During the last 2–3 years, some reports have appeared in the literature, which clearly suggest that application of vermicompost along with chemical fertilizers result in increased yield and fruit quality (Arancon et al., 2004, 2006) mainly due to production of plant growth regulators by microorganisms during the process of vermicomposting (Muscolo et al., 1999; Atiyeh et al., 2002). However, we have reported earlier that there is production of albino and malformed fruit in large number in field-grown strawberries, which affect fruit yield and quality (Singh et al., 2007a). Hence, we hypothesized that with the use of vermicompost in strawberry, production of albino and malformed fruit may be reduced due to the presence of plant-growth-influencing substances and suppression of *Botrytis* rot in strawberry. Considering these points, we proposed to conduct systematic studies to determine the effect of different doses of vermicompost along with chemical fertilizers on growth, occurrence of albinism, fruit malformation disorders, and yield and fruit quality of 'Chandler' strawberry.

2. Methods

2.1. Experimental site and material

The studies were conducted at Central Institute of Post Harvest Engineering and Technology, Abohar (Lat 30° 09′ N, Long. 74° 13′ E, 185.6 m above mean sea level), Punjab, India during the cropping season of 2004–05 and 2005–06. This region falls in semi-arid zone having hot summers (May–June) and mild winter (December–mid-February) with annual rainfall of about 180 mm, restricted mainly during July and August. Soil of the experimental farm was sandy-loam (Ustic Haplocambid), having pH 8.42, which was low in organic carbon (0.42%), medium in available phosphorus, and high in potash. Soil was thoroughly ploughed and raised beds of 25 cm height, five meter in length and one-meter width were prepared at a distance of 50 cm. Healthy and disease free runners of 'Chandler' strawberry were procured from Dr. Y.S. Parmar University of Horticulture and Forestry, Solan and planted on raised beds at a spacing of 25 × 25 cm during first week of October every year. Irrigation was provided with micro-sprinkler system during early stage of plant establishment, which was replaced by drip system after 15 days of planting.

2.2. Treatments

The vermicompost (VC) was prepared from vegetable waste mixed with cow dung in 2:1 ratio by employing epigeic species (*Eisena foetida* Sav.) at research farm of CIPHET, Abohar, which was applied @ 2.5, 5.0, 7.5 and 10.0 t ha^{-1}, and inorganic fertilizers (NPK) served as control. Vermicompost was first analyzed for major nutrients (N = 0.92%, P = 1.21% and K = 1.45%), and on the basis of available nutrients in it, vermicompost treated plots were supplemented with appropriate amount of inorganic fertilizers, to equalize the recommended rate/dose of nutrients (120–170–150 kg NPK ha^{-1}) among the treatments (Table 1). The required quantity of vermicompost (as per treatment) and the inorganic fertilizers were applied and incorporated to the top 10 cm layer of soil in experimental beds. Plastic mulch and drip irrigation systems were installed on beds after 15 days of planting of the runners. Each treatment combination consisted of 64 plants in a plot size of 400 × 100 cm. Treatments were replicated five times in a complete randomized block design. All necessary cultural practices and plant protection measures were followed uniformly for all the plots during the entire period of experimentation.

2.3. Observations recorded

Observations on plant spread (cm), leaf area (cm^2) and plant dry weight (%) were recorded on five plants from each replication at 90, 135 and 180 days after planting (DAP). The plants were harvested for assessment of mean leaf area, fresh and dry weight. For recording leaf area, all leaves of the randomly selected plants were removed and passed through leaf area meter (Singh et al., 2007a). Leaves and stems were placed in paper bags, dried at 60 °C for 92 h and weighed to measure dry weight. Data on fruit yield and yield attributing parameters were recorded on all harvest dates. Total fruit yield was calculated by taking all the harvested fruit on each picking and thereafter, fruit which were free from injury, albinism and malformation incidence and those with *Botrytis* rot symptoms were sorted out to calculate the marketable fruit yield. Randomly selected 100 normal fruit were taken to calculate mean berry weight. The titratable acidity (TA), total soluble solids (TSS), firmness and external fruit colour were determined at each harvest. Quality parameters like acidity, TSS, ascorbic acid content were measured as per A.O.A.C. (1989).

Firmness was determined on 25 fruit samples from each replicate with texture analyzer (TA-Hdi, Stable Micro Systems, UK) with the 2 mm diameter stainless steel probe (Singh et al., 2007a). Fruit were tested equatorially at their maximum diameter with speed of cross-head at 50 cm min^{-1}. The force was expressed in Newton (N).

The fruit colour in terms of *L*, *a*, *b* values was determined using Hunterlab miniScan XE Pluscolourimeter (HAL, USA, Model45/0-L), in which, 'L' denotes the lightness or darkness, '*a*' green or red, and '*b*', blue or yellow colour of the samples. Before measuring colour of samples, the colourimeter was standardized with black and white calibration tiles provided with the instrument (Singh et al., 2007a).

Incidence of albinism and malformation fruit were determined at each harvest by counting all albino, malformed and normal fruit and represented as percentage (Singh et al., 2007a). Similarly, incidence of grey mould (*Botrytis cinerea*) was determined by counting all healthy and infected fruit at each harvest, and represented as percentage (%).

Table 1
Contribution of vermicompost and inorganic fertilizers in different treatments for meeting recommended supply of nutrients in strawberry

Treatments	N applied			P applied			K applied		
	VC (kg/ha)	IF (kg/ha)	Total (kg/ha)	VC (kg/ha)	IF (kg/ha)	Total (kg/ha)	VC (kg/ha)	IF (kg/ha)	Total (kg/ha)
Inorganic fertilizers	Nil (0.0)	120 (100.0)	120.0	Nil (0.0)	170.0 (100.0)	170.0	Nil (0.0)	150.0 (100.0)	150.0
VC @ 2.5 t ha^{-1}	23.0 (19.2)	97.0 (80.8)	120.0	30.2 (17.6)	139.8 (82.6)	170.0	36.2 (24.1)	113.8 (75.9)	150.0
VC @ 5.0 t ha^{-1}	46.0 (38.4)	74.0 (61.6)	120.0	60.5 (35.6)	109.5 (64.4)	170.0	72.5 (48.3)	77.5 (51.7)	150.0
VC @ 7.5 t ha^{-1}	69.0 (57.5)	51.0 (42.5)	120.0	90.7 (53.3)	79.3 (46.7)	170.0	108.7 (72.5)	41.3 (27.5)	150.0
VC @ 10 t ha^{-1}	92.0 (76.7)	28.0 (23.3)	120.0	121.0 (71.2)	49.0 (28.8)	170.0	145.0 (97.0)	5.0 (3.0)	150.0

VC: Vermicompost; IF: inorganic fertilizer. Figures in parenthesis indicate the percentage of total nutrients.

2.4. Data analysis

Since yearly interaction was found non-significant, the data obtained from the observations of both years were pooled, averaged, and then subjected to analysis, following standard procedures (Panse and Sukhatme, 1984). Data in percentage units (incidence of albinism, malformation and grey mould) underwent arcsin transformation before subjected to analysis. Differences between means were evaluated using Duncan's multiple range test at $P \leqslant 0.05$.

3. Results and discussion

3.1. Plant growth parameters

Plant growth parameters like plant spread, leaf area and dry weight were significantly influenced in plots receiving vermicompost than those receiving inorganic fertilizers only (Table 2). Such influence of vermicompost on plant growth of strawberry may be attributed to better availability of plant growth regulators and humic acid in vermicompost, which is produced by the increased activity of microbes (Arancon et al., 2004). As demonstrated scientifically that microbes like fungi, bacteria, yeasts, actinomycetes, algae etc., are capable of producing auxins, gibberellins etc., in appreciable quantity during vermicomposting (Brown, 1995; Arancon et al., 2004), which affects plant growth appreciably (Tomati et al., 1987; Arancon et al., 2006). Increase in vermicompost dose from 2.5 to 7.5 t ha^{-1} increased all growth parameters significantly, but vermicompost dose beyond 7.5 t ha^{-1} could not influence these parameters significantly. This differential response of plants to differed doses of vermicompost might be due to production of growth-promoting substances in lesser quantity by lower doses of vermicompost than higher doses (Arancon et al., 2004). However, the growth of plants with vermicompost at 7.5 t ha^{-1} was significantly at par with that of 10 t ha^{-1} indicating that this dose of VC (7.5 t ha^{-1}) was enough for supplying the desirable amount of growth-promoting substances for higher growth and fruit yield of strawberry (Atiyeh et al., 2002).

The influence of vermicompost on growth parameters was lesser effective at 90 days after planting but was more prominent at 135 and 180 days after planting (DAP). Further, all plant growth parameters showed increasing trend with the duration of observations (90–180 DAP), and vermicompost amended treatments showed consistently better growth over plots receiving inorganic fertilizer only, indicating positive and significant influence of vermicompost ($p < 0.05$) on growth parameters of strawberry. This increasing trend in growth parameters with increase in duration might be due to the fact that initially (90 DAP), only few growth-promoting substances might be available to plants due to lower doses of vermicompost than at later stage, as a result, progressive improvement in growth was observed.

3.2. Days to flowering, fruit number and total yield

Vermicompost has influenced the days taken to 1st flowering, fruit number/plant, individual berry weight and total fruit yield over inorganic fertilizers (Table 3). Plants took only 86.8 days to flower when vermicompost was applied @ 10 t ha^{-1} as compared to 93.1 days when plants received inorganic fertilizers only (Table 3). Similarly, fruit per plant (27.9), individual berry weight (14.2 g), and total fruit yield (396.2 g/plant) were maximum when strawberry plants received vermicompost @ 10 t ha^{-1}, whereas those, which received inorganic fertilizers only, have produced minimum fruit/plant (25.5), had lowest berry weight (11.7 g) and total fruit yield (298.4 g/plant). Further, increasing the dose of vermicompost from 2.5 to 10 t ha^{-1}, has significantly ($p < 0.05$) reduced the number of days taken to flowering (90.2–86.8), but increased fruit number (25.6–27.9/plant), individual berry weight (12.5–14.2 g) and total fruit yield (320.0–396.2 g/plant). These results clearly indicated that plants from plots receiving inorganic amended vermicompost had significantly ($p < 0.05$) taken lesser days to flower and produced large-sized fruit with higher total yield/plant than those receiving inorganic fertilizers only (Table 3). Such effects of vermicompost on flowering and fruiting of strawberry might be attributed to the fact that higher doses of vermicompost have resulted in to better growth of plants and consequently they took lesser days to flower and produced higher fruit yield than those receiving inorganic fertilizers only (Brown, 1995; Atiyeh et al., 2000, 2001; Arancon et al., 2004, 2006). However, the increased growth and higher fruit yield of strawberry in the present study could not be explained on the basis of availability of macronutrients in soil treated with the different doses of vermicompost because the nutrient content were equalized at the time of planting and analysis of soil samples after planting and at subsequent sampling at different intervals confirmed that the concentration of macronutrients in all plots were statistically the same (data not presented). This confirms the findings of earlier workers who postulated that increased microbial population and subsequent production of plant growth regulators resulted from earthworm activity in the vermicompost might have influenced the plant growth indirectly, which might have helped in attaining higher plant growth and fruit yield of many crops (Atiyeh et al., 2000, 2001; Arancon et al., 2004, 2006). Thus, our study also indicated that the growth and yield of strawberry is dose dependant and can be well correlated with the plant growth hormones present in the vermicompost.

Table 3
Effect of vermicompost on flowering, fruit number and weight, and total fruit yield of Chandler' strawberry

Treatment	Days taken to 1st flowering	No. of fruits/ plant	Individual berry weight (g)	Total fruit yield (g/plant)
Inorganic nutrients	93.1a	25.5a	11.7a	298.5a
VC @ 2.5 t ha^{-1}	90.2b	25.6a	12.5b	320.0b
VC @ 5.0 t ha^{-1}	88.1c	26.7b	13.0bc	347.1c
VC @ 7.5 t ha^{-1}	87.4d	27.7c	13.4c	371.2c
VC @ 10.0 t ha^{-1}	86.8e	27.5c	14.2d	396.2 d

Means within the column with the same letter are not significantly different by Duncan multiple range test at $P \leqslant 0.05$.

Table 2
Effect of vermicompost on growth parameters of "Chandler" strawberry

Treatments	Plant spread (cm)			Leaf area (cm^2)			Dry weight (g/plant)		
	90 DAP	135 DAP	180 DAP	90 DAP	135 DAP	180 DAP	90 DAP	135 DAP	180 DAP
Inorganic fertilizers	12.7a	17.5a	21.4a	87.4a	261.3a	411.2a	13.5a	18.3a	24.1a
VC @ 2.5 t ha^{-1}	12.5a	18.0a	22.0b	89.9a	287.5b	434.7b	13.7a	19.2b	26.2b
VC @5.0 t ha^{-1}	13.0a	18.7b	22.5b	94.1b	320.1c	489.3c	14.0a	19.9c	27.1c
VC @ 7.5 t ha^{-1}	13.9b	20.2c	23.2c	97.8c	339.7d	501.9d	14.9b	20.8d	28.8d
VC @ 10 t ha^{-1}	13.8 b	19.5c	23.7c	99.4c	352.1d	507.6d	15.2b	20.7d	29.1d

Means within the column with the same letter are not significantly different by Duncan multiple range test at $P \leqslant 0.05$.

3.3. Physiological disorders, grey mould and marketable fruit yield

Interestingly, strawberries grown in plots treated with inorganically amended vermicompost had influenced the occurrence of physiological disorders, like albinism and fruit malformation, and grey mould incidence and marketable fruit yield of 'Chandler' strawberry significantly over control (Table 4). Plants receiving inorganic fertilizers only, produced significantly ($p < 0.05$) higher proportion of albino (16.1%) and malformed fruit (11.5%) and, had higher incidence of grey mould (10.4%), as a result, marketable fruit yield was lower (198.7 g/plant) than those receiving vermicompost. Further, the incidence of albinism (8.2–4.5%), fruit malformation (7.1–4.0%) and grey mould incidence (4.5–2.1%) showed decreasing trend with the increase in the dose of vermicompost from 2.5 to 10 t ha^{-1}, and as a result, marketable yield showed progressively increasing trend (256.2–315.1 g/plant) (Table 4). The lowest incidence of albinism (4.5%), fruit malformation (4.0%), grey mould (2.1%), and highest marketable yield (315.1 g/plant) were observed when plants received vermicompost @ 10 t ha^{-1}, which was however, at par with those receiving vermicompost @ 7.5 t ha^{-1} (Table 4). These are, in fact, very interesting observations because albinism and fruit malformation disorders are becoming serious problems in strawberry crop in India (Sharma et al., 2006; Singh et al., 2007a). Plants receiving vermicompost might have received nutrition in a balanced and sustained way than those receiving inorganic fertilizers only (Arancon et al., 2004), and it might have helped the plants in producing albino and malformed fruit in lesser number. In addition, vermicompost contains most nutrients in available forms such as nitrates, phosphates, and exchangeable calcium and soluble potassium (Edwards and Burrows, 1988; Orozco et al., 1996). Similarly, vermicompost has large particulate surface area that provides many microsites for microbial activity and for the strong retention of nutrients (Shi-wei and Fu-zhen, 1991). Thus, in our study, we postulated that positive effects of vermicompost on the availability of nutrients on one hand, and production of plant-growth-influencing materials on the other hand, might have resulted in the production of albino and malformed fruit in lesser proportion in vermicompost amended treatments. Further, the increase in dose of vermicompost from 2.5 to 10 t h^{-1} had resulted in further reduction in albino and malformed fruit number, indicating that vermicompost had influencing role on the availability of balanced nutrition and other growth influencing substances. Although, there is no report in the literature about the available form of B in presence of vermicompost, but it is our speculation that under semi-arid climatic conditions, B remains unavailable to the plants, and with the addition of vermicompost, it might have become available to plants, and as a result, malformed fruit were produced in lesser number as boron availability is considered as influencing factor in deciding production of malformed fruits in strawberry (Singh et al., 2007a). Lesser incidence of *Botrytis* rot in strawberry fruits following vermicomposting may be attributed to its effect on suppression of *Botrytis cinerea* fungi causing *Botrytis* rot. Although, there is no report in the literature, which indicates that vermicompost suppresses the growth of *Botrytis cinerea*, however, Hoitink and Fahy (1986) have demonstrated that vermicompost suppresses the growth of many fungi, which may be true with our observations as well. Higher marketable fruit yield with substitution of vermicompost doses might be due to the production of healthy fruit in higher number with higher individual berry weight. Similarly, differential response of different doses of vermicompost on physiological disorders, grey mould and marketable yield may be due to the differed effects of vermicompost on the reduction of albinism, fruit malformation and grey mould incidence with best results in plants receiving vermicompost @ 7.5 t ha^{-1}. Thus, our study indicated that substituting the vermicompost in strawberry can result in higher marketable fruit yield by reducing not only the proportion of albino and malformed fruits and lesser incidence of *Botrytis* rot, but increasing individual berry weight.

Table 4
Effect of vermicompost on physiological disorders, grey mould and marketable fruit yield of 'Chandler' strawberry

Treatment	Albinism incidence (%)	Fruit malformation (%)	Grey mould (%)	Marketable fruit yield (g/plant)
Inorganic nutrients	16.1a	11.5a	10.4a	198.7a
VC @ 2.5 t ha^{-1}	8.2b	7.1b	4.5b	256.2b
VC @ 5.0 t ha^{-1}	5.3c	5.1c	3.2c	291.7c
VC @ 7.5 t ha^{-1}	4.6d	4.1d	2.7d	311.3d
VC @ 10.0 t ha^{-1}	4.5d	4.0d	2.1d	315.1d

Means within the column with the same letter are not significantly different by Duncan multiple range test at $P \leqslant 0.05$.

3.4. Fruit firmness, colour and fruit quality

Application of vermicompost had influenced the fruit firmness, colour and fruit quality of 'Chandler' strawberry significantly over control (Table 5). Fruit harvested from plants receiving vermicompost were significantly ($p < 0.05$) firmer, had better colour, TSS, ascorbic acid, and had lower acidity than those harvested from plants receiving inorganic fertilizers only. Among different doses of vermicompost, plants receiving vermicompost @ 7.5 t ha^{-1} produced firmer and brighter fruit with high TSS (7.42%), lower acidity (1.10%) and higher ascorbic acid content (50.8 mg/100 g pulp) than those receiving vermicompost at 2.5, 5.0 or 10 t ha^{-1} (Table 5). Plants receiving vermicompost @ 10 t ha^{-1}, although produced much firmer, brighter or sweeter fruits than those receiving inorganic fertilizers only, but were not superior than those receiving vermicompost @ 7.5 t ha^{-1} (Table 5). In colour, *L*, *a* and *b* values were all time higher in fruits receiving vermicompost than those receiving inorganic fertilizers only, although some values were non-significant when compared with different doses of vermicompost, indicating that plants receiving vermicompost have produced attractive coloured and firmer fruits with comparatively better quality attributes than those receiving inorganic fertilizers only. It may be attributed to better growth of plants under different doses of vermicompost, which might have favoured the production

Table 5
Effect of vermicompost doses on fruit firmness, colour and quality of 'Chandler' strawberry

Treatment	Firmness (N)	Colour			TSS (%)	Acidity (%)	Ascorbic acid content (mg/100 g pulp)
		L	*a*	*b*			
Inorganic nutrients	1.44a	37.8a	24.8a	19.7a	7.21a	1.21a	47.3a
VC @ 2.5 t ha^{-1}	1.57b	38.0a	24.1b	19.2a	7.29b	1.18b	48.1b
VC @ 5.0 t ha^{-1}	1.63b	38.5b	23.2c	18.9a	7.31b	1.17b	49.3c
VC @ 7.5 t ha^{-1}	1.72c	39.1b	23.8bc	19.4a	7.42c	1.10c	50.8d
VC @ 10.0 t ha^{-1}	1.70c	40.1c	23.1c	19.0a	7.36bc	1.11c	50.7d

Means within the column with the same letter are not significantly different by Duncan multiple range test at $P \leqslant 0.05$.

of firmer, better coloured and quality fruit. Although, there is no report in the literature to support this contention, however many authors have reported that strawberry plants with better growth produce fruit of better colour and quality (Singh et al., 2006, 2007b). Further, differential response of strawberry to fruit texture, colour and quality may be attributed to variable growth attained by the plants, primarily due to differential rate of release of growth-promoting substances owing to differed doses of vermicompost (Arancon et al., 2004; Brown, 1995; Tomati et al., 1988).

4. Conclusions

The present study revealed that substitution of vermicompost with chemical fertilizers is quite useful in field-grown strawberries for higher growth, reduction in physiological disorders (albinism and malformation), occurrence of grey mould, and it helps in getting higher marketable fruit yield of firmer fruit with attractive colour and good quality attributes. However, the dose of vermicompost can vary according to agro-climatic condition of the production region, but a dose of 7.5 t ha^{-1} is sufficient for higher productivity of better quality strawberries.

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