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EFFECT OF ORGANIC AMENDMENTS AND ARBUSCULAR MYCORRHIZAL FUNGI ON PLANT GROWTH, YIELD AND QUALITY OF STRAWBERRY

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Abstract

An experiment was conducted at the research field and the laboratory of the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh from October 2018 to March 2019 to investigate the effect of organic amendments and arbuscular mycorrhizal fungi (AMF) on growth, yield and quality of strawberry var. *BARI Strawberry-2*. The experiment was laid out in RCBD design with three replications taking into eight treatments including control viz., T_1: vermicompost (324 g/pot), T_2: biochar (324 g/pot), T_3: AMF (324g/pot), T_4: vermicompost (162 g/pot) + biochar (162 g/pot), T_5: biochar (162 g/pot) + AMF (162 g/pot), T_6: vermicompost (162 g/pot) + AMF (162 g/pot), T_7: vermicompost (108 g/pot) + biochar (108 g/pot) + AMF (108 g/pot) and T_8: control (no manure or AMF). Results of the study revealed that the highest plant height (18.40 cm), number of leaves/plant (37.00), leaf area (578.60 cm^2), root length (24.50 cm), fresh and dry weight of root (30.00 g and 12.5 g) and shoot (131 g and 41.00 g), number of flowers (32.67/plant) and fruits (22.33/plant), single fruit weight (21.60 g) and yield/plant (401.99 g) were recorded in T_6 treatment which was significantly superior to all other treatments. Among the fruit nutrient and mineral contents, ascorbic acid (36.20 mg/100 g), total sugar (9.10 g/100 g), Ca (11.87 mg/100 g), Mg (36.67 mg/100 g) and K (73.33 mg/100 g) were also measured maximum in T_6 treatment. On the other hand, TSS (8.49 %) and water percentage in fruit (66.95 %) were found significantly higher in T_7 and T_4 treatments, respectively while the lowest was estimated in the control. A significant influence of T_6 treatment [vermicompost (162 g/pot) + AMF (162 g/pot)] on growth, yield and qualitative characters was observed. Therefore, vermicompost and AMF combination has reflected a positive impact on good quality strawberry production. However, it needs to be investigated under the open field condition before conferring recommendation to the end users.

Keywords: Strawberry, vermicompost, biochar, AMF, growth and yield attributes, fruit quality.

Introduction

Strawberry (*Fragaria* × *ananassa*) is a widely grown hybrid species which belongs to the family *Rosaceae* and genus *Fragaria*. This fleshy aggregate fruit is native to Europe and Great Britain and now cultivated throughout the countries of the globe having minimum winter period. The fruit has become one of the most popular berries in the world and widely appreciated for its highly desirable

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taste, characteristic aroma, bright red color, juicy texture, sweetness, excellent source of vitamins, potassium, fibre and higher percentage of phenolics and flavonoids (Häkkinen and Törrönen, 2000) and thus important for human health (Halvorsen *et al*., 2002). Besides being eaten as raw, the fruit is used in making ice-creams, jams, jellies, pickles, chocolates, biscuits, cakes and milkshakes. The fruit is widely adapted to the sub-tropical countries like Bangladesh (Barney, 1999) and commercial strawberry farming has been gaining momentum in the Rajshahi region as the fruit is gradually becoming popular both to the growers and to the consumers. Strawberry plants need large amounts of fertilizer application for its high production despite the tiny size of the plant (Morgan, 2006). Application of chemical fertilizers may increase its yield but indiscriminate use of inorganic fertilizers changes physical, chemical and biological properties of soil and creates problem to the environment and health hazard due to toxic residual effects like outbreak of pests and diseases including weeds; affecting the productivity (Sultana *et al.*, 2022). So, the modern farmers in recent decades have adopted to reduce the chemical fertilizer by using alternatives. The use of organic manures or biofertilizer 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 (Sahana *et al*., 2020). Organic fertilizers like vermicompost, poultry manure, farm yard manure, biochar, cowdung, *Pseudomonas* strains, arbuscular mycorrhizal fungi, etc. help in improving soil condition and overall production. A number of studies pointed out that organic farming approaches offered the most sustainable way of crop production besides contributing to environmental protection through minimizing degradation. Further, the organically raised crops besides being nutritious, eliminates the risk of pesticide residues to the consumers, thus ensuring food safety. Moreover, demand for organically produced product has been rising day by day. In view of this, there is a need to increase the production of good qualities strawberry through organic way. Therefore, the present study aimed at finding out the effects of vermicompost, biochar and arbuscular mycorrhyzal fungi on plant growth, yield and quality of strawberry.

Materials and Methods

Experimental site and design

The pot experiment was conducted at the research field and laboratory of the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur during the period from October 2018 to March 2019. The field was in about 24.09 ^{0}N latitude and 90.26 ^{0}E longitude with an elevation of 8.40 m from sea level. According to the objective of the research, two organic manures namely vermicompost and biochar, and single fungi named arbuscular mycorrhizal fungi (AMF) were applied to strawberry (BARI Strawberry-2) in seven (7) separate combinations viz., T_1: vermicompost (324 g/pot), T_2: biochar (324g/pot), T_3: AMF (324g/pot), T_4: vermicompost (162 g/pot) + biochar (162 g/pot), T_5: biochar (162 g/pot) + AMF (162 g/pot), T_6: vermicompost (162 g/pot) + AMF (162 g/pot), T_7: vermicompost (108 g/pot) + biochar (108 g/pot) + AMF (108 g/pot) and T_8: control in pot culture condition. The

experiment was conducted in Randomized Complete Block Design (RCBD) with three replications where three pots each containing single plant represented a replication.

Treatment application and crop management

Apparently healthy and uniform seedlings of the strawberry variety BARI Strawberry-2 were collected from the Biotechnology Division, BARI, Gazipur. Plastic pots of 30 cm × 24 cm in size were filled with treatment based organic manures (vermicompost and biochar) and AMF mixed garden soil up to the brim 7 days before planting. The strawberry saplings were transplanted on 20th October 2018. For controlling from birds and maintaining the quality of strawberry, the plots were covered with nets upto the fruit harvest. Besides, dry straw was used as mulch to protect the fruit from being rotten due to soil contact. Mature fruits were harvested when fruits turned to red in color with waxy layer on the surface of fruits. Other intercultural operations like weeding, irrigation, etc were done as per requirement.

Data collection

Data were collected on plant height (cm), number of leaf, leaf area (cm^2), root length (cm), fresh and dry weight of shoot and root (g), days to first flower bud initiation, days to first flowering, number of flower/plant, number of fruits/plant, days to first fruit harvest, single fruit weight (g), fruit length (cm), fruit diameter (cm), yield (g/plant), ascorbic acid (mg/100g), total sugar (g/100g), reducing sugar (g/100g), non-reducing sugar (g/100g), calcium content (mg/100g), magnesium content (mg/100g) and potassium content (mg/100g).

Statistical analysis

The mean for every treatment and analysis of variance for each character was estimated using the Statistix-10 software. Duncan's Multiple Range test (DMRT) was performed for all the characters to test the differences between the means at 5% level of significance.

Results and Discussion

Plant height

The plant height was recorded at the time of first harvesting (Table 1). Significantly the tallest plant was recorded from T_6 (18.40 cm) treatment while the shortest plant was noticed in control (12.80 cm) which was statistically similar to T_2 (13.73 cm) treatment. Maximum plant height may be due to better uptake of nutrients which has a major role in increasing cell division and improving plant growth. Vermicompost and AMF improve vegetative growth characters in strawberry by increasing soil enzyme activity and improving soil aeration. These results are in agreement with those of Arancon *et al*. (2004) and Singh *et al*. (2015).

Leaf number

There was a gradual rising trend of leaf number at different days after planting and number of leaves per plant differed significantly. Maximum number of leaves was counted from T_6 (37.00) treatment. The fewest number of leaves was observed in the control T_8 (18.33) treatment. This result is in line with that of Singh *et al*. (2015) who reported increase in plant height and number

Table 1. Effect of different organic manures and their combination on plant height, leaf number, leaf area and root length of strawberry plant

Treatment	Plant height (cm)	Leaf number	Leaf area (cm^2)	Root length (cm)
T_1: Vermicompost	14.17cd	27.67cd	497.80d	14.00d
T_2: Biochar	13.73de	24.67d	453.00f	16.33cd
T_3: AMF	14.50cd	27.67cd	440.70g	13.33de
T_4: Vermicompost + Biochar	14.70cd	30.67bc	507.47c	20.50abc
T_5: Biochar + AMF	14.93c	27.33cd	460.60e	19.17bc
T_6: Vermicompost + AMF	18.40a	37.00a	578.60a	24.50a
T_7: Vermicompost + Biochar + AMF	16.70b	32.33b	539.13b	22.33ab
T_8: Control	12.80e	18.33e	425.07h	8.67e
Level of significance	*	*	*	*
CV (%)	4.06	7.99	3.73	11.72

Means bearing same letter(s) in a column do not differ significantly at 5% level of probability; *=significant at 5% level of probability

of leaves in strawberry with the application of vermicompost plus biofertilizers.

Leaf area

Leaf area of strawberry under different treatments as well as a control varied from 425.07-578.60 cm^2 at first harvesting stage (Table 1). Maximum leaf area was measured in T_6 (578.60 cm^2) treatment which was statistically superior to all other treatments. On the other hand, the minimum leaf area was found in the control T_8 (425.07 cm^2) which was statistically different from all other treatments. Singh *et al*. (2008) reported that the leaf area of strawberry plant increased due to the application of vermicompost combination with other fertilizers and improve soil characteristics.

Root length

The longest root (23.06 cm) was found in T_6 which was statistically identical to T_7 (22.48 cm) while the plants under control (T_8) had the smallest roots (9.29 cm). These results are in agreement with that of Khalid *et al*. (2013) who reported that organic amendments enhanced vegetative growth, root length, fresh weight and improved quality of strawberry fruits. Paszt *et al*. (2015) and Fan *et al*. (2011) also observed similar results earlier.

Root weight (fresh and dry)

Significant variation was observed in fresh and dry weight of root as influenced by different treatments of manures and AMF combinations (Table 2). The highest fresh and dry weight of root was noted in T_6 (30.00 g and 8.83 g, respectively) treatment having statistical uniformity with T_7 for fresh weight (27.83 g). On the other hand, the lowest root fresh and dry weight was calculated in control (9.67 g and 3.00 g, respectively) which was statistically similar to T_3 treatment for fresh weight and T_1, T_2 and T_3 treatments for root dry weight. Organic amendments affect plant metabolic processes such as cell division and

Table 2. Effect of different organic manures and their combination on fresh weight of root, dry weight of root, fresh weight of shoot and dry weight of shoot of strawberry plant

Treatment	Root fresh weight (g)	Root dry weight (g)	Shoot fresh weight (g)	Shoot dry weight (g)
T_1: Vermicompost	13.33c	3.67d	51.33 d	18.00c
T_2: Biochar	13.00c	4.00d	30.00e	17.67c
T_3: AMF	11.83cd	3.83d	46.00d	18.33c
T_4: Vermicompost + Biochar	21.67b	6.83c	94.00b	31.23b
T_5: Biochar + AMF	21.67b	6.67c	76.00c	26.97b
T_6: Vermicompost + AMF	30.00a	12.50a	131.00a	41.00a
T_7: Vermicompost + biochar + AMF	27.83a	8.83b	99.33b	37.67a
T_8: Control	9.67d	3.00d	30.67e	11.07d
Level of significance	*	*	*	*
CV (%)	7.32	12.02	11.39	13.31

Means bearing same letter in a column do not differ significantly at 5% level of probability; *=significant at 5% level of probability

enzyme activity and produce ameliorating effect on root volume, fresh weight of shoot and root, and enhance quality of strawberries. The present findings are agreed with the findings of Khalid *et al*. (2013) and Ansari *et al*. (2018). Moradi and Sheikhi (2015) also reported that the root dry weight increased with the application of vermicompost with arbuscular mycorrhizal fungi.

Shoot weight (fresh and dry)

Fresh and dry weight of strawberry shoot varied significantly due to application of different manures and MAF combinations (Table 2). Statistically maximum fresh and dry weight of shoot was registered in T_6 (131.00 g and 41.00 g, respectively) treatment and statistically similar to T_7 treatment for dry weight. Whereas, fresh and dry weight of shoot was recorded minimum in T_2 (30.0 g) and T_8 (11.07 g) treatments, respectively. T_8 (30.67 g) treatment had statistically uniform shoot fresh weight to T_2. The fresh weight of shoot may be increased due to balanced mineral composition and better nutrient acquisition. The similar result was obtained by Moradi and Sheikhi (2020) who reported that the application of organic manure and arbuscular mycorrhizal fungi increased the shoot fresh and dry weight of strawberry plant through increased nutrient uptake.

Days to first flower bud initiation and flowering

The number of days taken to the first budding in strawberry ranged from 72.00 to 109.33 DAP (Table 3). Plants under T_8 treatment required the longest time to bud initiation (109.33 days) as well as flowering (116.67 days) while the earliest bud initiation and flowering was recorded in T_6 (72.00 and 79.00 days, respectively) treatment followed by T_3 and T_2 treatments. The high level of nutrients found in vermicompost with biofertilizer

accelerated the early flower bud initiation and flowering. Similar findings were noticed by Singh *et al*. (2015) and Rahman *et al*. (2018).

Number of flowers/plant

Total number of flowers per plant of strawberry was significantly varied due to the application of different treatments. Significantly, maximum number of flowers was recorded in T_6 (32.67) which was statistically superior to all other treatments. Minimum flower number recorded in control (11.00) treatment. Herencia *et al*. (2011) reported that organic fertilizers contained nitrogen and phosphorus which enhanced vegetative growth and increased number of flowers and fruits. Tagliavini *et al*. (2005) also observed identical results with organic manure amendment application.

Days to first fruit harvest

The first fruit was harvested in T_6 treatment after 111.33 days of transplating which was statistically similar to T_7 (114 days) while T_8 required maximum days (136.00) to the first fruit harvest. Vermicompost with AMF treated plant produced early flowering and fruiting, which triggered early harvesting of fruits. These findings got support of the observation of Atefe *et al*. (2012) in strawberry.

Number of fruits/plant

Strawberry plants responded significantly in producing fruits due to application of different organic fertilizers (Table 3). Maximum number of fruits was counted in T_6 22.33/plant treatment which was statistically identical to T_7 21.33/plant and minimum in control

Table 3. Effect of different organic manures and their combination on flower bud initiation, flowering, fruiting, number of flower/plant, first harvest and number of fruit/plant of strawberry

Treatment	Days to first flower bud initiation	Days to first flowering	Number of flowers/ plant	Days to first fruit harvest	Number of fruits/plant
T_1: Vermicompost	83.33c	91.00c	24.33c	123.00bc	18.33c
T_2: Biochar	91.00b	100.67b	25.33bc	124.00b	12.67de
T_3: AMF	87.67b	97.33b	28.00b	126.00b	15.33d
T_4: Vermicompost+Biochar	82.00c	90.67c	25.33bc	117.67d	19.33bc
T_5: Biochar+AMF	83.00c	92.33c	27.67b	120.00cd	13.67de
T_6: Vermicompost+AMF	72.00e	79.00e	32.67a	111.33e	22.33a
T_7: Vermicompost+Biochar+AMF	76.33d	83.67d	27.00bc	114.00e	21.33ab
T_8: Control	109.33a	116.67a	11.00d	136.00a	11.33e
Level of significance	*	*	*	*	*
CV (%)	2.73	2.27	6.74	2.44	9.52

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11.22/plant treatment which was statistically homogeneous to T_2 12.67/plant. These findings are in agreement with the observation of Arancon *et al*. (2003) who reported that application of vermicompost increased fruit number of strawberry and pepper.

Single fruit weight

The influence of organic fertilizers and AMF on single fruit weight of strawberry was found to be significantly different (Table 4). The heaviest fruit was observed in T_6 (21.60 g) treatment which was statistically at par with T_7 treatment and the lowest in control T_8 (11.55 g) treatment which was statistically inferior to all other treatments. Arancon *et al*. (2006) found that the application of vermicompost increased the fruit weight of strawberry and pepper. Vermicompost with biofertilizer has enhanced growth promoting substances that normally increase the fruit size and shape. Rahman *et al*. (2018) also noted identical results in strawberry.

Fruit size (length and diameter)

Strawberry plants also exhibited significant variations in fruit length and diameter due to the different treatment application (Table 4). The largest fruit in terms of length and diameter was harvested from T_6 treated plants (4.53 cm × 3.92 cm) which showed statistical harmony with T_7 treatment (4.29 cm × 3.69 cm). On the other hand, fruit size was the lowest in control (L-2.27 cm × D-2.42 cm) being statistically inferior to all other treatments. These findings are in agreement with Alidadi *et al*. (2014) who reported that the application of vermicompost leachates increased the length and diameter of tomato fruits. Manatad and Jaquias (2008) also examined that vermicompost boosted up the diameter of fruit in various crops like watermelon, tomatoes, sweet pepper.

Table 4. Effect of different organic manures and their combinations on different yield attributes of strawberry

Treatment	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Yield per plant (g)	Water content (%)
T_1: Vermicompost	15.42cd	3.54bc	2.76c	280.67d	66.58a
T_2: Biochar	14.75cd	3.44c	3.14b	186.25e	55.25b
T_3: AMF	14.27d	3.63bc	2.93bc	219.37e	61.52a
T_4: Vermicompost + Biochar	18.23b	3.78b	2.95bc	353.20c	66.95a
T_5: Biochar + AMF	16.33c	3.77b	2.94bc	222.58e	65.54a
T_6: Vermicompost + AMF	21.60a	4.53a	3.92a	479.87a	66.48a
T_7: Vermicompost + Biochar + AMF	20.27a	4.29a	3.69a	430.67b	63.25a
T_8: Control	11.55e	2.27d	2.42d	131.10f	55.38 b
Level of significance	*	*	*	*	*
CV (%)	5.53	4.51	5.85	8.06	9.89

Means bearing same letter in a column do not differ significantly at 5% level of probability; *=significant at 5% level of probability

Fruit Yield

Different organic sources of nutrients produced markedly and significantly better yields than that of the control treatment (Table 4). Plants treated with T_6 treatment gave the highest yield (401.99 g/plant) which was statistically similar to T_7 (387.56 g/plant). The lowest yield was found in T_8 treatment (144.82 g/plant) showing statistical disparity to all other treatments. Sheikhi *et al*. (2012) showed that the growth and yield of soybean can be significantly increased by the application of vermicompost as biofertilizers. The present result also got support from the findings of Moradi and Sheikhi (2015) and Paul *et al*. (2017) in strawberry.

Water content

The amount of water in strawberry fruit is the most important parameter because it is the indication of fruit mineral nutrition. Fruits of T_4 treatment had maximum water (66.95 %) which was statistically uniform with T_1, T_5, T_6 and T_7 treatments. Minimum water content in fruits was estimated in T_2 (55.25 %) which was statistically similar to T_3 and T_8 treatments (Table 4). The findings are in agreement with the observation of Yuan *et al*. (2004).

Ascorbic acid

Ascorbic acid of strawberry fruits significantly varied due to different organic fertilizer treatments (Table 5). The highest quantity of ascorbic acid was found in T_6 (36.20 mg/ 100g) treatment and the lowest was in T_2 (13.90 mg/ 100g) which was statistically similar to T_8 and T_3. Similar result was obtained by Khalid *et al*. (2013) in strawberry.

Table 5. Effect of different organic manures and their combination on qualitative parameters of strawberry

Treatment	Ascorbic acid (mg/100g)	TSS (%)	Total Sugar (g/100g)	Reducing sugar (g/100g)	Non-reducing sugar (g/100g)
T_1: Vermicompost	24.16b	7.81b	4.93c	3.78d	1.15cd
T_2: Biochar	13.90c	7.15de	4.06d	3.07e	0.99d
T_3: AMF	17.13c	7.38cd	5.26c	3.93d	1.33c
T_4: Vermicompost + Biochar	28.94b	7.45c	6.90b	4.81bc	2.08a
T_5: Biochar + AMF	28.45b	7.27cd	6.47b	4.77c	1.70b
T_6: Vermicompost + AMF	36.20a	8.39a	8.17a	5.49a	2.68a
T_7: Vermicompost + Biochar + AMF	26.29b	8.49a	6.96b	5.31b	1.65b
T_8: Control	16.54c	6.89e	3.09e	2.22f	0.88d
Level of significance	*	*	*	*	*
CV%	11.48	2.09	5.88	6.83	11.11

Means bearing same letter(s) in a column do not differ significantly at 5% level of probability; *=significant at 5% level of probability

Total soluble solids (TSS)

There had a significant variation in TSS content of fruits when the plants were treated with different levels of organic fertilizers (Table 5). Maximum TSS was estimated in T_7 (8.49%) which was statistically similar to T_6. The lowest quantity was found in plant under control (6.89%) treatment. Increased TSS and total sugars in berry are in agreement with the findings of Singh and Singh (2006) and Singh *et al*. (2012) who reported that inoculation of biofertilizers with organic manures resulted in higher TSS and total sugars in strawberry fruit.

Sugar (Total, reducing and non-reducing)

Total sugar, reducing and non-reducing sugar varied significantly among the treatments (Table 5). The treatment T_6 exhibited superiority to all other treatments in terms of total, reducing and non-reducing sugar contents (8.17 %, 5.49 % and 2.68 %, respectively). Treatment T_4 had statistically similar non-reducing sugar to that of the best treatment. Reversely, statistically minimum total sugar, reducing sugar and non-reducing sugar content was recorded in control treatment (3.09 %, 2.22 % and 0.88 %, respectively). T_2 also exhibited statistically similar non-reducing sugar content (0.99 %) to the inferior treatment. Maximum sugar content in fruits of vermicompost treated plant might be due to its ability to make quality promoting micronutrient readily available form for plant responsible for sweetness of strawberry. Kirad *et al*. (2009) and Singh and Singh (2006) in strawberry was supported these present findings. Sahana *et al*. (2020) also stated that the application of organic fertilizers improved the sugar content and other quality of strawberry.

Mineral concentration

Significant variation was found in mineral contents (K, Ca and Mg) after applying

Table 6. Effect of different organic manures and their combinations on mineral concentrations (K, Ca and Mg) of strawberry fruit

Treatment	K (mg/100g)	Ca (mg/100g)	Mg (mg/100g)
T_1: Vermicompost	53.33d	9.11c	22.00c
T_2: Biochar	43.67e	7.91cd	19.33cd
T_3: AMF	58.00cd	9.49bc	28.33b
T_4: Vermicompost + Biochar	61.67bc	8.00cd	31.33ab
T_5: Biochar + AMF	61.33bc	7.11de	30.00b
T_6: Vermicompost + AMF	73.33a	11.87a	36.67a
T_7: Vermicompost + Biochar + AMF	66.67ab	11.16ab	31.67ab
T_8: Control	32.67f	5.96e	15.33d
Level of significance	*	*	*
CV%	6.83	9.27	11.53

Means bearing same letter(s) in a column do not differ significantly at 5% level of probability; *=significant at 5% level of probability

different treatments to strawberry plants (Table 6). Maximum K was estimated in T_6 (73.33 mg/100g) treatment which was statistically similar to T_7 (66.67 mg/100g). Control fruits had minimum amount of K (32.67 mg/100g). Fruits obtained from T_6 treatment contained maximum amount of Ca (11.87 mg/100g) and Mg (36.67 mg/100g). Statistically similar to the highest Ca content was noticed in T_7 treatment and statistically uniform Mg content was recorded in T_4 and T_7 treatments. Control fruits exhibited minimum Ca (5.96 mg/100g) and Mg (15.33 mg/100g) content. The present findings are in line with the findings of Karlidag *et al*. (2011) who reported that the quality of strawberry fruits depends on environment, genetic factors and plant nutrition status. Ansari *et al*. (2018) also noticed similar observations.

Conclusion

In conclusion the result of the present study revealed that the treatment T_6 (Vermicompost @162g/pot + AMF @ 162g/pot) was found better for achieving not only growth and yield levels of the fruit but also its quality parameters. Among the organic sources, vermicompost is a good source of nutrients but its combination with arbuscular mycorrhizal fungi provides the superior growth, yield and rich quality fruits of strawberry.

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