



Effect of *Trichoderma asperelloides* (TA41) on Production and Quality of Strawberry (*Fragaria ananassa*) c.v. Winter Dawn

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was conducted at the Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj. Prayagraj during the session 2023 - 2024. The experiment was laid out in randomized block design with three replications, and the study consists of nine treatment combinations including control by using different Effect of *Trichoderma asperelloides* (TA41) on production and quality of strawberry. The best treatment was T8 (TA 41 – 80ml/15 L) & T7 (TA 41 – 70 ml/15 L) which shows highest values

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in all the parameters viz., number of leaf/plant (30.72), plant spread N-S (cm) (31.31 cm), plant spread E-W (cm) (35.31 cm), Days taken to first flower initiation (22.29), Days taken to initiation of fruit set (29.07), Days taken to first harvest (54.02), Days taken to final harvest (91.53), Number of pickings (10.98), Fruit length (mm) (55.46 mm), Fruit width (38.89 mm), Fresh weight (g) (40.36), Number of fruit/plant (16.92), Fruit yield/plant (g) (682.91), Fruit yield/ha. (61.46 q), TSS (11.55 brix), Vitamin C (52.76 mg/100g), Acidity (1.96 %). All the treatments were significantly superior in their growth, flowering, fruit yield and quality of strawberry over control (T0) and (T8).

Keywords: Strawberry; TA 41; growth; yield; quality; *Trichoderma asperelloides*.

1. INTRODUCTION

The strawberry (*Fragaria x ananassa* Duch.) has gained prominence as a fruit of global importance [1]. The garden strawberry (*Fragaria x ananassa*) is a cross between the wild strawberries *Fragaria virginiana* and *Fragaria chiloensis*. The ancestry of the current hybrid species can be traced back to the Americas. Nonetheless, the current hybrid species was cultivated in Europe using imported specimens and then introduced to the United States in the latter half of the 18th century [2]. A strawberry is an aggregated fruit that develops from receptacle tissue. Multiple ovaries develop on a single receptacle to produce achene's fruits with a single seed. According to Flachowsky et al. [3] the enlarged receptacle containing achenes is considered a berry, but is commonly referred to as a 'fruit' in a horticultural sense. Strawberry plants are perennial, herbaceous and of low stature. Typically, strawberry flowers have five white petals. Strawberry plants are capable of vegetative propagation through the production of runners (stolons), which trail above-ground and can establish new, clonal daughter plants at their nodes [4].

There are day-neutral and short-day varieties of strawberries based on their photoperiodic response. Sweet Charlie, a cultivar with a day-neutral photoperiod, has dark red berries with dark green and semi-glossy leaves. It possesses specific characteristics in its composition that appeal to consumers, such as its intense bright red colour, characteristic odour, soft texture and slightly acidic flavour [5].

It is a temperate-zone crop that can also be found in the subtropics and grows at an altitude of 3000 m above mean sea level. In India, 14,000 MT of strawberries are produced annually in an area of 3000 ha [6]. Maharashtra, Punjab, Haryana, the Himachal Pradesh hills, Jammu & Kashmir, Uttarakhand, Uttar Pradesh, Rajasthan, and West Bengal are the main strawberry-

growing states in India. In Himachal Pradesh, it is cultivated in Sirmour, Kullu, Kangra, Solan and Shimla districts, covering 40 ha and producing 210 MT annually [6]. The plants thrived at temperatures between 15 and 35 °C, with flowering occurring best at 14°C to 18 °C [7]. It thrives best in soil that ranges in pH from 5.7 to 6.5 and is sandy loam to loamy.

The Biocontrol agent *Trichoderma* is prevalent in almost all types of soils but naturally their population is too low in soil that they are not very effective in action. There are two important species of *Trichoderma harzianum* and *Trichoderma viride*, which are known as bio-control agent. *Trichoderma* is used as a successful bio-control agents to suppress soil - borne pathogens. It induces defense responses and systemic resistance in addition to control of plant pathogens by spraying plants above the ground of soil [8,9]. *Trichoderma* is very effective in controlling diseases and hence increases the yield of fruit crops.

2. MATERIALS AND METHODS

This experiment was laid out from August 2023 to March 2024 at Horticulture Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.). The horticulture research farm is situated at 25° 39' 42" N latitude, 81° 67' 56" E longitude and at an altitude of 98 m above mean sea level. The treatment consisted of T0 - (RDN) + Control (Water Spary) N, P, K (100:50:50 Kg/h), T1 - TA41- 10ml /15L, T2 - TA41- 20ml /15L, T3 - TA41- 30ml /15L, T4 - TA41- 40ml /15L, T5 - TA41- 50ml /15L, T6 - TA41- 60ml /15L, T7 - TA41- 70ml /15L, T8 - TA41- 80ml /15L. The experiment was laid out in a Randomized Block Design with 9 treatments and replicated thrice. Data recorded on different aspects of fruit crops, viz., growth and yield were subjected to statistical analysis by analysis of variance method [10] and economic data analysis mathematical method.

3. RESULTS AND DISCUSSION

3.1 Plant Stands and Growth

3.1.1 Number of leaves plant-1

The data number of leaves plant⁻¹ of strawberry as influenced by *Trichoderma asperelloides* (TA41) are summarized in Table 1.

The data reveals that the number of leaves plant⁻¹ of strawberry increased significantly by the application of *Trichoderma asperelloides* (TA41) essence under experiment over the control. The maximum number of leaves plant⁻¹ of (30.72) was recorded with treatments 8 (TA41- 80ml /15L)120 DAT recorded, while the minimum (25.41) was recorded under control. Further, the interaction effect of *Trichoderma asperelloides* (TA41) to the amount of water required for foliar spray significantly influenced the number of leaves plant⁻¹.

The maximum number of leaves plant⁻¹ in treatment in *Trichoderma asperelloides* (TA41) was closely observed by Sharma et al. [11] Higher levels of sugar due to *Trichoderma asperelloides* application might be explained by an increase in P^H content which are synthesized from sugar Kumar [12].

3.1.2 Plant spread cm (East – West)

The data Plant spread E-W (cm) of strawberry as influenced by *Trichoderma asperelloides* are summarized in Table 1.

The data reveals that the Plant spread E-W (cm) of strawberry increased significantly by the application of *Trichoderma asperelloides* essence under experiment over the control. The maximum Plant spread E-W (cm) of (35.31 cm) was recorded with treatments 8 (TA41- 80ml/15l) in 120 DAT recorded, while the minimum (27.39 cm) was recorded under control. Further, the interaction effect of *Trichoderma asperelloides* to the amount of water required significantly influenced the Plant spread E-W (cm).

The maximum plant spread in treatment in *Trichoderma asperelloides* was closely observed by Sharma et al. [13]. Higher levels of sugar due to *Trichoderma asperelloides* application might be explained by an increase in P^H content which is synthesized from sugar Mandal et al. [14].

3.1.3 Plant spread (cm) N-S

The data plant spread N-S (cm) of strawberry as influenced by *Trichoderma asperelloides* are summarized in Table 1.

The data reveals that the plant spread N-S (cm) of strawberry increased significantly by the application of *Trichoderma asperelloides* essence under experiment over the control. The maximum plant spread E-W (cm) of (31.31 cm) was recorded with treatments 8 (TA41- 80ML/15L) in 120 DAT recorded, while the minimum (23.39 cm) was recorded under control. Further, the interaction effect of *Trichoderma asperelloides* on the amount of water required for foliar spray significantly influenced the plant spread N-S (cm).

Table 1. Effect of application of *Trichoderma asperelloides* on growth of strawberry

Treatment Symbol	Treatment combinations	Numbers of leaves/plant 120 DAT	Plant Spread E-W (cm) 120 DAT	Plant Spread N-S (cm) 120 DAT
T ₀	(RDN) + Control (Water Spary) N,P,K (100:50:50 Kg/h)	25.41	27.39	23.39
T ₁	TA41- 10ml /15L	27.33	28.31	24.31
T ₂	TA41- 20ml /15L	28.08	29.35	25.35
T ₃	TA41- 30ml /15L	28.36	30.62	26.62
T ₄	TA41- 40ml /15L	29.33	31.29	27.29
T ₅	TA41- 50ml /15L	29.48	32.22	28.22
T ₆	TA41- 60ml /15L	30.60	33.49	29.49
T ₇	TA41- 70ml /15L	30.08	34.06	30.06
T ₈	TA41- 80ml /15L	30.72	35.31	31.31
	F-test	S	S	S
	SEm(±)	1.22	0.91	0.91
	CD (p=0.05)	3.65	2.72	2.72

Table 2. Effect of application of *Trichoderma asperelloides* on yield of strawberry

Treatment Symbol	Treatment combinations	Fruit length (mm)	Fruit width (mm)	Fruit weight (g)	Number of fruit plant ⁻¹	Fruit yield plant ⁻¹ (g)	Fruit yield/hac (q)
T ₀	(RDN) + Control (Water Spary) N,P,K(100:50:50 Kg/h)	37.98	30.42	13.49	8.38	118.70	10.68
T ₁	TA41- 10ml /15L	39.56	31.25	16.56	9.36	154.95	13.95
T ₂	TA41- 20ml /15L	41.46	32.56	19.46	10.46	203.62	18.33
T ₃	TA41- 30ml /15L	41.98	33.18	21.85	11.84	258.79	23.29
T ₄	TA41- 40ml /15L	43.56	34.29	23.63	12.94	305.82	27.52
T ₅	TA41- 50ml /15L	45.78	35.77	27.75	13.82	383.49	34.51
T ₆	TA41- 60ml /15L	49.46	36.95	31.46	14.58	458.42	41.26
T ₇	TA41- 70ml /15L	51.31	37.98	39.56	15.76	623.50	56.12
T ₈	TA41- 80ml /15L	55.46	38.89	40.36	16.92	682.91	61.46
	F-test	S	S	S	S	S	S
	SEm(±)	1.71	1.02	0.80	0.48	14.53	1.31
	CD (p=0.05)	5.12	3.07	2.39	1.44	43.54	3.92

Table 3. Effect of application of *Trichoderma asperelloides* on quality of strawberry

Treatment Symbol	Treatment combinations	TSS °Brix	Titrateable acidity	Vitamin C (mg/100 ml)
T ₀	(RDN) + Control (Water Spary) N,P,K (100:50:50 Kg/h)	10.05	1.12	40.01
T ₁	TA41- 10ml /15L	10.18	1.23	42.13
T ₂	TA41- 20ml /15L	10.31	1.34	42.46
T ₃	TA41- 30ml /15L	10.38	1.45	44.58
T ₄	TA41- 40ml /15L	10.65	1.56	46.49
T ₅	TA41- 50ml /15L	10.88	1.67	46.56
T ₆	TA41- 60ml /15L	10.98	1.77	48.63
T ₇	TA41- 70ml /15L	11.21	1.89	49.94
T ₈	TA41- 80ml /15L	11.55	1.96	52.76
	F-test	S	S	S
	SEm(±)	0.22	0.05	1.13
	CD (p=0.05)	0.67	0.15	3.39

Table 4. Effect of application of *Trichoderma asperelloides* on economics of strawberry

Treatment Symbol	Treatment Combination	Cost of cultivation/ha	Gross Return/ha	Net Return/ha	B:C Ratio
T ₀	(RDN) + Control (Water Spary) N,P,K (100:50:50 Kg/h)	74000	149558	75558	1.02
T ₁	TA41- 10ml /15L	84000	195242	111242	1.32
T ₂	TA41- 20ml /15L	94000	256560	162560	1.73
T ₃	TA41- 30ml /15L	104000	326077	222077	2.14
T ₄	TA41- 40ml /15L	114000	385333	271333	2.38
T ₅	TA41- 50ml /15L	124000	483196	359196	2.90
T ₆	TA41- 60ml /15L	134000	577613	443613	3.31
T ₇	TA41- 70ml /15L	144000	785613	641613	4.46
T ₈	TA41- 80ml /15L	154000	860472	706472	4.59

The maximum plant spread in treatment in *Trichoderma asperelloides* was closely observed by Mandal et al. [14] Higher levels of sugar due to *Trichoderma asperelloides* application might be explained by an increase in P^H content which is synthesized from sugar Kumar et al., (2018).

3.2 Yield Attributes

3.2.1 Fruit length (mm)

The data Fruit length (mm) of strawberry as influenced by *Trichoderma asperelloides* are summarized in Table 2.

The data reveals that the Fruit length (mm) of strawberry increased significantly by the application of *Trichoderma asperelloides* essence under the experiment over the control. The maximum Fruit length (mm) of (55.46) was recorded with treatment 9 (TA41-80ml/L) is recorded, while the minimum (37.98) was recorded under control. Further, the interaction effect of *Trichoderma asperelloides* to the amount of water required for foliar spray significantly influenced the Fruit length (mm).

The maximum increase in fruit length (mm) following the use of *Trichoderma asperelloides* might be due to its effect on cell division and cell elongation. *Trichoderma asperelloides* is also reported to promote growth by increasing the plasticity of the cell wall followed by hydrolysis of starch into sugar which reduces cell wall potential, resulting in the entry of water into the cell and causing its elongation Kumar [12].

3.2.2 Fruit width (mm)

The data Fruit width (mm) of strawberry as influenced by *Trichoderma asperelloides* are summarized in Table 2.

The data reveals that the Fruit width (mm) of strawberry increased significantly by the application of *Trichoderma asperelloides* essence under experiment over the control. The maximum Fruit width (mm) of (38.89) was recorded with treatments 9 (TA41-80ml/15L) in recorded, while the minimum (30.42) was recorded under control. Further, the interaction effect of *Trichoderma asperelloides* to the amount or water required for foliar spray significantly influenced the Fruit width (mm).

The maximum increase in fruit width following the use of *Trichoderma asperelloides* might be due to its effect on cell division and cell elongation.

The beneficial effect of *Trichoderma asperelloides* on fruit set and reducing fruit drop might be due to the higher availability of photosynthates. These chemicals are also associated with hormone metabolism which promotes the synthesis of auxin, These results conform with Abdelmoaty et al. [15].

3.2.3 Fresh weight of fruit (g)

The data Fruit weight of fruit (g) of strawberry as influenced by *Trichoderma asperelloides* are summarized in Table 2.

The data reveals that the Fruit weight of fruit (g) of strawberry increased significantly by the application of *Trichoderma asperelloides* essence under experiment over the control. The maximum Fruit weight of fruit (g) of (40.36 g) was recorded with treatments 9 (TA- 80ml/15L) in recorded, while the minimum (13.49 g) was recorded under control. Further, the interaction effect of *Trichoderma asperelloides* to the amount or water required for foliar spray significantly influenced the Fruit weight of fruit (g).

The maximum Increase in fruit weight following use of *Trichoderma asperelloides* might be due to its effect in cell division and cell elongation. *Trichoderma asperelloides* is also reported to promote growth by increasing plasticity of cell wall followed by hydrolysis of starch into sugar which reduces cell wall potential, resulting in the entry of water into the cell and causing its elongation Abdelmoaty et al. [15]

3.2.4 Number of fruit plant⁻¹

The data Number of fruit plant⁻¹ of strawberry as influenced by *Trichoderma asperelloides* are summarized in Table 2.

The data reveals that the Number of fruit plant⁻¹ of strawberry increased significantly by the application of *Trichoderma asperelloides* essence under experiment over the control. The maximum Number of fruit plant⁻¹ of (16.92) was recorded with treatments 9 (TA41- 80ml/15L) in recorded, while the minimum (8.38) was recorded under control. Further, the interaction effect of *Trichoderma asperelloides* to the amount or water required for foliar spray significantly influenced the Number of fruit plant⁻¹.

The increase in number of fruits per plant with the use of *Trichoderma asperelloides* might be

due to fact that benzyl adenine causes the production of large number of fruits with rapid elongation of peduncle, leading to full development of flower buds having all reproductive parts functional which increases the fruit set and number of berries per plant. It could also be due to the fact that *Trichoderma asperelloides* application accelerates the development of differentiated inflorescence. Mandal et al. [14].

3.2.5 Fruit yield plant⁻¹

The data Fruit yield plant of strawberry as influenced by *Trichoderma asperelloides* are summarized in Table 2 The data reveals that the Fruit yield plant of strawberry increased significantly the application of *Trichoderma asperelloides* essence under experiment over the control. The maximum Fruit yield plant of (682.91) was recorded with treatment 9 (TA41-80ml/15L) in recorded, while the minimum (118.70) was recorded under control. Further, the interaction effect of *Trichoderma asperelloides* to the amount of water required in foliar spray significantly influenced the Fruit yield plant.

The maximum increase in fruit yield/plant following use of *Trichoderma asperelloides* might be due to its effect in cell division and cell elongation. The beneficial effect of *Trichoderma asperelloides* on fruit set and reducing fruit drop might be due to the higher availability of photosynthates. These chemicals are also associated with hormone metabolism which promotes synthesis of auxin, These results are in conformity with Abdelmoaty et al. [15].

3.2.6 Fruit yield/hac (q)

The data Fruit yield/ha (q) of strawberry as influenced by *Trichoderma asperelloides* are summarized in Table 2.

The data reveals that the Fruit yield/ha (q) of strawberry increased significantly by the application of *Trichoderma asperelloides* essence under experiment over the control. The maximum Fruit yield/ha (q) of (61.46) was recorded with treatment 9 (TA-80ml/15L) is recorded, while the minimum (10.68) was recorded under control. Further, the interaction effect of *Trichoderma asperelloides* to the amount of water required in foliar spray significantly influenced the Fruit yield/ha (q).

The maximum increase in fruit yield/plant following the use of *Trichoderma asperelloides* might be due to its effect in cell division and cell

elongation. The beneficial effect of *Trichoderma asperelloides* on fruit set and reducing fruit drop might be due to the higher availability of photosynthates. These chemicals are also associated with hormone metabolism which promotes synthesis of auxin, These results are in conformity with Mandal et al. [14].

3.3 Quality Parameter

3.3.1 TSS °Brix

The data TSS °Brix of strawberry as influenced by *Trichoderma asperelloides* are summarized in Table 3.

The data reveals that the TSS °Brix of strawberry increased significantly by the application of *Trichoderma asperelloides* essence under experiment over the control. The maximum TSS °Brix of (11.55) was recorded with treatment 9 (TA41-80ml/L) is recorded, while the minimum (10.05) was recorded under control. Further, the interaction effect of *Trichoderma asperelloides* to the amount of water required for foliar spray significantly influenced the TSS °Brix.

Maximum TSS in treatment- *Trichoderma asperelloides* might be attributed to the rapid mobilization of sugars and other soluble solids to developing fruits Mandal et al. [14] It may be because *Trichoderma asperelloides* increases palatability of fruit by influencing the blend of TSS, total sugar, vitamin C and juice content as observed by, Sharma et al. [13].

3.3.2 Titratable acidity

The data Titratable acidity of strawberry as influenced by *Trichoderma asperelloides* are summarized in Table 3.

The data reveals that the Titratable acidity of strawberry increased significantly by the application of *Trichoderma asperelloides* essence under experiment over the control. The minimum Titratable acidity of (1.96) was recorded with treatment 9 (TA-80ml/L) is recorded, while the maximum (1.12) was recorded under control. Further, the interaction effect of *Trichoderma asperelloides* to the amount of water required for foliar spray significantly influenced the Titratable acidity.

The interaction effect of *Trichoderma asperelloides* significantly influenced the titratable acidity percent in strawberry. Kumar [12]

reported the promontory effect of *Trichoderma asperelloides* on quality parameters in guava. The decrease in acidity in *Trichoderma asperelloides* treated plants might be due to their better utilization in respiration and rapid metabolic transformation of organic acids into sugars Sharma et al. [13].

3.3.3 Vitamin C (mg/100 ml)

The data on Vitamin C (mg/100 ml) of strawberry as influenced by *Trichoderma asperelloides* are summarized in Table 3.

The data reveals that the Vitamin C (mg/100 ml) of strawberry increased significantly by the application of *Trichoderma asperelloides* essence under experiment over the control. The maximum Vitamin C (mg/100 ml) of (52.76) was recorded with treatments 9 (TA41- 80ml/L) is recorded, while the minimum (40.01) was recorded under control. Further, the interaction effect of *Trichoderma asperelloides* to the amount or water required for foliar spray significantly influenced the Vitamin C (mg/100 ml).

The maximum Vitamin C content in the treatment of *Trichoderma asperelloides* was closely observed by Kumar [12]. Higher levels of sugar due to *Trichoderma* application might be explained behind the increase in ascorbic acid content which is synthesized from sugar Bhupesh Chandra Kabdwal et al. [16].

3.4 Economics

The data on the economics of strawberry as influenced by growth regulator are summarized in Table 4. The data reveals that the economics of strawberry increased significantly with the application of growth regulators under experimentation over the control. The maximum cost of cultivation (154000 Rs.) was recorded with treatments 9 (TA41- 80ml /15L) while the minimum cost of cultivation (74000 Rs.) was recorded under control. The maximum gross return (860472 Rs.) was recorded with treatments 9 (TA41- 80ml /15L) while the minimum gross return (149558 Rs.) was recorded under control. The maximum net return (706472 Rs.) was recorded in treatments 9 (TA41- 80ml /15L) while the minimum net return (75558 Rs.) was recorded under control. The maximum B:C ratio (4.59) was recorded in treatments 9 (TA41- 80ml /15L) while the minimum B:C ratio (1.02) was recorded under control [17-19].

4. CONCLUSION

Based on the results of the present study, it is concluded that, overall treatment T8 (TA41- 80ml /15L) performed best in terms of growth, yield and quality of the strawberry was also obtained from this treatment. The maximum benefit cost ratio was observed in T8 (TA41- 80ml /15L) followed by T7 (TA41- 60ml /15L) while the minimum benefit cost ratio was observed in T0 (Control)

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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