Original Research Article

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

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 T_8 (TA 41 – 80ml/15 L) & T_7 (TA41– 70ml/15L) which shows highest values 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 (T_0) and (T_8).

Key words: Strawberry, TA41, growth, yield, quality, *Trichoderma asperelloides*

INTRODUCTION

Thestrawberry(*Fragaria*×*ananassa*Duch.)hasgainedprominenceasafruitofglobalimportance **(Zeist and Resende 2019).** The garden strawberry (*Fragaria* × *ananassa*) is acrossbetweenthewildstrawberries*Fragariavirginiana*and*Fragariachiloensis.*Theancestryof the current hybrid species can be traced back to the Americas. Nonetheless, the currenthybrid species was cultivated in Europe using imported specimens and then introduced to theUnited States in the latter half of the 18th century **(Hernández-Martnez *et al*. 2023).** Astrawberry is an aggregated fruit that develops from receptacle tissue. Multiple ovariesdevelop on a single receptacle to produce achene's fruits witha single seed.Accordingto**Flachowsky*etal.*(2011),**theenlargedreceptaclecontainingachenesisconsidered a berry, but is commonly referred to as a 'fruit' in a horticultural sense. Strawberryplants are perennial, herbaceous and of low stature. Typically, strawberry flowers have fivewhite petals. Strawberry plants are capable of vegetative propagation through the productionofrunners(stolons),whichtrailabove-groundandcanestablishnew,clonaldaughterplantsattheirnodes**(Davis*et al.*2007).**

Thereareday-neutralandshort-dayvarietiesofstrawberriesbasedontheirphotoperiodicresponse. SweetCharlie,acultivarwith aday-neutralphotoperiod,hasdarkredberries with dark green and semi-glossy leaves. It possesses specific characteristics in itscompositionthatappealtoconsumers,suchasitsintensebrightredcolour,characteristicodour,soft textureand slightly acidicflavour**(Gabriel*et al.* 2019)**.

It is a temperate-zone crop that can also be found in the subtropics and grows at analtitude of 3000 m above mean sea level. In India, 14,000 MT of strawberries are producedannually in an area of 3000 ha **(NHB 2022, 17-19).** Maharashtra, Punjab, Haryana, the HimachalPradeshhills,Jammu&Kashmir,Uttarakhand,UttarPradesh,Rajasthan,andWestBengal arethe main strawberry-growing states in India. In Himachal Pradesh, it is cultivated in Sirmour,Kullu, Kangra, Solan and Shimla districts, covering 40 ha and producing210MTannually**(NHB2022).**Theplantsthrivedattemperaturesbetween15and35°C,with floweringoccurringbest at14℃ to 18°C**(RaniandAhmad2012).**Itthrivesbestinsoilthatrangesin pH from 5.7to 6.5 and issandy loam to loamy.

TheBiocontrolagent*Trichoderma*isprevalentinalmostalltypesofsoilsbutnaturallytheir population is too low in soil that they are not very effective in action. There are twoimportantspeciesof*Trichodermaharzianum*and*Trichodermaviride*,which are known as

bio-control agent. *Trichoderma* is used as a successful bio-controlagentstosuppresssoil-bornepathogens.Itinducesdefenseresponsesandsystemicresistance

in addition to control of plant pathogens by spraying plants above the ground of soil **(Freeman, *etal.*, 2004** and **Alfano, *et al*., 2007).** *Trichoderma* is very effective in controlling diseasesandhence increasestheyield of fruitcrops.

MATERIALSANDMETHODS

Thisexperimentwaslaidout fromAugust2023toMarch2024atHorticultureResearchFarm,DepartmentofHorticulture,Naini AgriculturalInstitute,SamHigginbottomUniversity of Agriculture, Technology and Sciences, Prayagraj (U.P.). The horticultureresearchfarmissituatedat25^{0}39”42”Nlatitude,81^{0}67”56”Elongitudeandatanaltitudeof 98 m above mean sea level. The treatment consisted of T_0 - (RDN) + Control (WaterSpary) N, P, K (100:50:50 Kg/h), T_1 - TA41- 10ml /15L, T_2 - TA41- 20ml /15L, T_3 - TA41-30ml/15L,T_4-TA41-40ml/15L,T_5-TA41-50ml/15L,T_6-TA41-60ml/15L,T_7-TA41-70ml /15L, T_8 - TA41- 80ml /15L. The experiment was laid out in a Randomized BlockDesign with 9 treatments and replicated thrice. Data recorded on different aspects of fruitcrops, *viz.*, growth and yield were subjected to statistical analysis by analysis of variancemethod.(**GomezandGomez,1984)**andeconomicdata analysismathematicalmethod.

RESULTS AND DISCUSSIONPLANTSTANDSAND GROWTH

Numberof leaves plant^{-1}

Thedatanumberofleavesplant^{-1}ofstrawberryasinfluencedby*Trichodermaasperelloides*(TA41)are summarizedinTablenumber1.

Thedatarevealsthatthenumberofleavesplant^{-1}ofstrawberryincreasedsignificantlyby the application of *Trichodermaasperelloides*(TA41) essence under experiment over thecontrol. 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 undercontrol.Further,theinteractioneffectof*Trichodermaasperelloides*(TA41)totheamountof waterrequired for foliar spray significantly influenced thenumber ofleaves plant^{-1}.

The maximum number of leaves plant^{-1} in treatment in *Trichodermaasperelloides*(TA41)was closelyobserved by**Sharma*etal*.(2016).** Higher levelsofsugar dueto*Trichodermaasperelloides*application might be explained by an increase

in P^H contentwhich are synthesizedfrom sugar**Kumar(2010).**

Plantspreadcm(East–West)

ThedataPlantspreadE-W(cm)ofstrawberryasinfluencedby*Trichodermaasperelloides*aresummarized in Tablenumber1

The data reveals that the Plant spread E-W (cm)of strawberry increased significantlyby the application of *Trichodermaasperelloides*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 *Trichodermaasperelloides*to the amount of water requiredsignificantly influenced thePlant spread E-W(cm).

The maximum plant spread in treatment in *Trichodermaasperelloides*was closelyobserved by **Sharma *et al.* (2016b).** Higher levels of sugar due to *Trichodermaasperelloides*application might be explained by an increase in P^H content which is synthesized from sugar**Mandal*et al.*, (2021).**

Plantspread(cm)N-S

ThedataplantspreadN-S(cm)ofstrawberryasinfluencedby*Trichodermaasperelloides*aresummarized in Tablenumber1

Thedatarevealsthattheplantspread N-S(cm)ofstrawberryincreasedsignificantlybythe application of *Trichodermaasperelloides*essence under experiment over the control. Themaximum plant spread E-W (cm) of (31.31 cm) was recorded with treatments 8 (TA41-80ML/15L)in120DATrecorded,whiletheminimum(23.39cm)wasrecordedundercontrol.Further, the interaction effect of *Trichodermaasperelloides*on the amount of water requiredforfoliarspray significantly influenced theplant spread N-S (cm).

The maximum plant spread in treatment in *Trichodermaasperelloides*was closelyobserved by **Mandal *et al.*, (2021).** Higher levels of sugar due to *Trichodermaasperelloides*application might be explained by an increase in P^H content which is synthesized from sugar**Kumar*et al.*, (2018).**

YIELDATTRIBUTES

Fruit length (mm)

ThedataFruitlength(mm)ofstrawberryasinfluencedby*Trichodermaasperelloides*aresummarizedin Table number2

ThedatarevealsthattheFruitlength(mm)ofstrawberryincreasedsignificantlybytheapplication of *Trichodermaasperelloides*essence under the experiment over the control. Themaximum Fruit length (mm) of (55.46) was recorded with treatment 9 (TA41-80ml/L) isrecorded, while the minimum (37.98) was recorded under control. Further, the interactioneffectof*Trichodermaasperelloides*totheamountofwaterrequiredforfoliarspraysignific antly influencedthe Fruit length (mm).

Themaximumincreaseinfruitlength(mm)followingthe useof*Trichodermaasperelloides*might be due to its effect on cell division and cell elongation. *Trichodermaasperelloide*sis also reported to promote growth by increasing the plasticity of the cell wall followedby hydrolysis of starch into sugar which reduces cell wall potential, resulting in the entry ofwaterinto the cell and causing itselongation **Kumar (2010).**

Fruit width (mm)

ThedataFruitwidth(mm)ofstrawberryasinfluencedby*Trichodermaasperelloides* aresummarizedinTable number2.

ThedatarevealsthattheFruitwidth(mm) ofstrawberryincreasedsignificantlybytheapplication of *Trichodermaasperelloides*essence under experiment over the control. Themaximum Fruit width (mm) of (38.89) was recorded with treatments 9 (TA41-80ml/15L) inrecorded, while the minimum (30.42) was recorded under control. Further, the interactioneffectof*Trichodermaasperelloides*totheamountorwaterrequiredforfoliarspraysignific antlyinfluencedthe Fruit width(mm).

The maximum increase in fruit width following the use of *Trichodermaasperelloides*mightbe duetoitseffectoncelldivisionandcellelongation. Thebeneficialeffectof*Trichodermaasperelloides*on fruit set and reducing fruit drop might be due to the higheravailabilityofphotosynthates.Thesechemicalsarealsoassociatedwithhormonemetabolism

whichpromotesthe synthesisofauxin,Theseresultsconformwith**Abdelmoaty*etal*.,(2022).**

Freshweight offruit(g)

ThedataFruitweightoffruit(g)ofstrawberryasinfluencedby*Trichodermaasperelloides*aresummarizedinTable number2.

The data reveals that the Fruit weight of fruit (g) of strawberry increased significantlyby the application of *Trichodermaasperelloides*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)inrecorded,whiletheminimum(13.49g)wasrecordedundercontrol.Further,theinteractioneffectof*Trichodermaasperelloides*totheamountorwaterrequiredforfoliarspraysignificantlyinfluencedthe Fruit weight of fruit(g).

The maximum Increase in fruit weight following use of *Trichodermaasperelloides*mightbeduetoitseffectincelldivisionandcellelongation.*Trichodermaasperelloides*isalsoreported to promote growth by increasing plasticity of cell wall followed by hydrolysis ofstarch into sugar which reduces cell wall potential, resulting in the entry of water into the celland causing its elongation**Abdelmoaty*et al.*, (2022).**

Numberof fruitplant^{-1}

ThedataNumberoffruitplant^{-1}ofstrawberryasinfluencedby*Trichodermaasperelloides*aresummarizedinTable number2

The data reveals that the Number of fruit plant^{-1} of strawberry increased significantlyby the application of *Trichodermaasperelloides*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, theinteractioneffectof*Trichodermaasperelloides*totheamountorwaterrequiredforfoliarspraysignificantlyinfluencedthe Numberoffruitplant^{-1}.

The increaseinnumberoffruitsperplantwiththeuseof*Trichodermaasperelloides*mightbe due to fact that benzyl adenine causes the production of large number of fruits with rapidelongation of peduncle, leading to full development of flower buds having all reproductivepartsfunctionalwhichincreasesthefruitsetandnumberofberriesperplant.Itcouldalso

bedue to the fact that *Trichodermaasperelloides*application accelerates the development ofdifferentiatedinflorescence.**Mandal*et al.*, (2021).**

Fruit yieldplant^{-1}

ThedataFruityieldplant ofstrawberryasinfluencedby*Trichodermaasperelloides* aresummarized in Tablenumber2

Thedatareveals thattheFruityieldplant of strawberryincreased significantly the applicationof*Trichodermaasperelloides*essenceunderexperimentoverthecontrol.The maximumFruityieldplant of(682.91)wasrecordedwithtreatment9(TA41-80ml/15L)in recorded, while the minimum (118.70) was recorded under control. Further, the interactioneffectof*Trichodermaasperelloides*totheamountofwaterrequired in foliarspray

significantly influencedthe Fruit yield plant.

Themaximumincreaseinfruityield/plantfollowinguseof*Trichodermaasperelloides*might beduetoitseffectincelldivisionandcellelongation.Thebeneficialeffectof*Trichodermaasperelloid es*on fruit set and reducing fruit drop might be due to the higheravailability of photosynthates. These chemicals are also associated with hormone metabolismwhich promotes synthesis of auxin, These results are in conformity with **Abdelmoaty*et al.*,(2022).**

Fruit yield/hac(q)

ThedataFruityield/ha(q)ofstrawberryasinfluencedby*Trichodermaasperelloides* aresummarized in Tablenumber2.

The data reveals that the Fruit yield/ha (q) of strawberry increased significantly by theapplication of *Trichodermaasperelloides*essence under experiment over the control. Themaximum Fruit yield/ha (q) of (61.46) was recorded with treatment 9 (TA-80ml/15L) isrecorded, while the minimum (10.68) was recorded under control. Further, the interactioneffectof*Trichodermaasperelloides*totheamountofwaterrequiredinfoliarspraysignifica ntlyinfluencedthe Fruit yield/ha (q).

Themaximumincreaseinfruityield/plantfollowing theuseof*Trichodermaasperelloides*mightbeduetoitseffectincelldivisionandcellelongation.Theb eneficialeffectof*Trichodermaasperelloides*onfruitsetandreducingfruitdropmightbeduetothehig her

availability of photosynthates. These chemicals are also associated with hormone metabolismwhichpromotessynthesisofauxin,Theseresultsareinconformitywith**Mandal*etal.*,(2 021)**

QUALITYPARAMETER

TSS°Brix

The data TSS °Brix of strawberry as influenced by *Trichodermaasperelloides*aresummarizedinTable number 3

Thedatarevealsthat theTSS°Brix ofstrawberry increased significantlybytheapplication of *Trichodermaasperelloides*essence under experiment over the control. Themaximum 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*Trichodermaasperelloides*to the amount of water required for foliar spray significantlyinfluencedtheTSS°Brix.

Maximum TSS in treatment- *Trichodermaasperelloides*might be attributed to the rapidmobilization of sugars and other soluble solids to developing fruits **Mandal *et al*., (2021).** Itmaybebecause *Trichodermaasperelloides*increasespalatabilityoffruitbyinfluencing theblendof TSS,total sugar,vitaminC and juicecontent as observedby, **Sharma *et al.* (2016b)**

Titratableacidity

ThedataTitratableacidityofstrawberryasinfluencedby*Trichodermaasperelloides* aresummarized in Tablenumber3.

The data reveals that the Titratable acidity of strawberry increased significantly by theapplication of *Trichodermaasperelloides*essence under experiment over the control. TheminimumTitratableacidityof(1.96)wasrecordedwithtreatment9(TA-80ml/L)isrecorded,while the maximum (1.12) was recorded under control. Further, the interaction effect of*Trichodermaasperelloides*to the amount of water required for foliar spray significantlyinfluencedtheTitratable acidity.

Theinteractioneffectof*Trichodermaasperelloides*significantlyinfluencedthetitrableacidity percent in strawberry. **Kumar (2010)** reported the promontory effect of *Trichodermaasperelloides*onqualityparametersinguava.Thedecreaseinacidityin*Trichodermaasperelloides*treated plants might be due to their better utilization in respiration and rapidmetabolictransformation oforganic acids into sugars**Sharma *et al*. (2016b).**

VitaminC(mg/100ml)

Thedataon VitaminC(mg/100ml)ofstrawberryasinfluencedby*Trichodermaasperelloides*aresummarized in Table number 3.

The data reveals that the Vitamin C (mg/100 ml) of strawberry increased significantlyby the application of *Trichodermaasperelloides*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, theinteractioneffectof*Trichodermaasperelloides*totheamountorwaterrequiredforfoliarspraysignificantlyinfluencedthe Vitamin C(mg/100 ml).

The maximum Vitamin C content in the treatment of *Trichodermaasperelloides*was closelyobserved by **Kumar (2010).** Higher levels of sugar due to *Trichoderma* application might beexplained behind the increase in ascorbic acid content which is synthesized from sugar **BhupeshChandraKabdwal*et al*.(2018).**

ECONOMICS

Thedataonthe economicsofstrawberryasinfluencedbygrowthregulatoraresummarizedin Table number4

Thedatarevealsthattheeconomicsof strawberryincreasedsignificantlywith theapplication of growth regulators underexperimentation overthe control.

Themaximumcostofcultivation(154000Rs.)wasrecordedwithtreatments9(TA41-80ml /15L)while the minimum costofcultivation (74000Rs.)was recorded undercontrol.

Themaximumgrossreturn(860472 Rs.)wasrecordedwith treatments9 (TA41-80ml /15L) while theminimum grossreturn(149558Rs.)wasrecorded under control.

Themaximumnetreturn(706472Rs.)wasrecorded intreatments9(TA41-80ml /15L) while theminimum netreturn(75558Rs.) wasrecorded undercontrol.

The maximum B:C ratio (4.59) was recorded in treatments 9 (TA41- 80ml /15L)whilethe minimum B:C ratio(1.02) was recordedundercontrol.

CONCLUSION

Based on the results of the present study, it is concluded that, overall treatment T8(TA41-80ml/15L)performedbestintermsofgrowth,yieldandqualityofthestrawberrywasalsoobtained from this treatment.

ThemaximumbenefitcostratiowasobservedinT8(TA41-80ml/15L)followedbyT7(TA41-

60ml/15L)whiletheminimumbenefitcostratiowasobservedinT0(Control).

Table1Effectofapplicationof*Trichodermaasperelloides*ongrowthofstrawberry

Treatment	**Treatmentcombinations**	**Numbersof**	PlantSpread	**PlantSpread**
Symbol		**leaves/plan t 120DAT**	**E-W(cm) 120D AT**	**N-S(cm) 120DAT**
T0	(RDN)+Control(Water Spary)N,P,K(100:50:5 0Kg/h)	25.41	27.39	23.39
T1	TA41-10ml/15L	27.33	28.31	24.31
T2	TA41-20ml/15L	28.08	29.35	25.35
T3	TA41-30ml/15L	28.36	30.62	26.62
T4	TA41-40ml/15L	29.33	31.29	27.29
T5	TA41-50ml/15L	29.48	32.22	28.22
T6	TA41-60ml/15L	30.60	33.49	29.49

T7	TA41-70ml/15L	30.08	34.06	30.06
T8	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

Table2Effectofapplicationof*Trichodermaasperelloides*onyieldofstrawberry

Treatment Symbol	Treatmentcombinations	Fruitlength (mm)	Fruitwidth (mm)	Fruitweight(g)	Number offruitplant^{-1}	Fruityield plant (g)	Fruityield/hac (q)
T_0	(RDN)+Control(WaterSpary)N,P,K(100:50:50Kg/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

Table3Effectofapplicationof*Trichodermaasperelloides*onqualityofstrawberry

Treatment Symbol	Treatmentcombinations	TSS°Brix	Titratableacidity	VitaminC (mg/100ml)
T_0	(RDN)+Control(WaterSpary)N,P,K(100:50:50Kg/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

Table4Effectofapplicationof*Trichodermaasperelloides*oneconomicsofstrawberry

Treatment Symbol	TreatmentCombination	Cost of cultivation/ha	Gross Return/ha	Net Return/ha	B:C Ratio
T0	(RDN)+Control(WaterSpary)N,P,K(100:50:50Kg/h)	74000	149558	75558	1.02
T1	TA41-10ml/15L	84000	195242	111242	1.32
T2	TA41-20ml/15L	94000	256560	162560	1.73
T3	TA41-30ml/15L	104000	326077	222077	2.14
T4	TA41-40ml/15L	114000	385333	271333	2.38
T5	TA41-50ml/15L	124000	483196	359196	2.90
T6	TA41-60ml/15L	134000	577613	443613	3.31
T7	TA41-70ml/15L	144000	785613	641613	4.46
T8	TA41-80ml/15L	154000	860472	706472	4.59

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