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Research Article

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Influence of Trichoderma on Photosynthesis and Drymatter Partitioning in Sunflower

Ramyasri Yemineni[1*], S. Narender Reddy[2], P. Lakshmamma[3], B. Lavanya[4], B. Santhosh[5] and T. Dayakar Reddy[6]

[1,2,4,5]Department of Crop Physiology and [6]Department of Genetics and Plant Breeding, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad-500030.

[3]ICAR-Indian Institute of Oilseed Research, Rajendranagar, Hyderabad-500030

*Corresponding Author E-mail: ramyasriyemineni87@gmail.com

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ABSTRACT

Trichoderma species are commonly used as bio-control agents against phytopathogenic fungi and some isolates are able to improve plant growth. In this study, effects of 9 Trichoderma strains in sunflower on photosynthesis, dry matter partitioning were examined. Plant height, number of leaves, days to 50% flowering, days to physiological maturity, Total Dry Matter, Photosynthetic Rate, SPAD Chlorophyll Meter Readings (SCMR), Leaf Area Index, Crop Growth Rate (CGR), Net Assimilation Rate (NAR), diameter of head, head weight, number of filled seed per head, 100 seed weight, seed yield and Harvest Index were studied by the application of Trichoderma strains.

Key words: *Trichoderma species, TDM, Photosynthetic Rate, SCMR, CGR and NAR.*

INTRODUCTION

Trichoderma spp. colonize plant roots and establish symbiotic relationships with a wide range of host plants. As a consequence, plant growth and performance is enhanced[13]. *Trichoderma spp.* are being employed widely in agriculture both for disease control and yield increases[5], even under axenic conditions[16]. Recently *Trichoderma* spp. are suggested as Plant Growth Promoting Fungi (PGPF) due to their ability to produce siderophores, phosphate-solubilizing enzymes, and phytohormones[3]. *Trichoderma spp.* are rhizosphere components i.e. able to colonize the roots and thus promote plant growth[10]. They may also exert several other mechanisms such as tolerance to stress through enhanced root and plant development[15]. *Trichoderma* spp. colonize plant roots and establish symbiotic relationships with a wide range of host plants. As a consequence, plant growth and performance is enhanced[13].

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The present study had been investigated to study the effect of *Trichoderma starins* on morphological and Physiological characters in sunflower.

MATERIAL AND METHODS

The experiment was conducted during R*abi* 2014-15 at Student Farm, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad. Nine *Trichoderma* strains namely, *Trichoderma harzianum*- Th 4d, *Trichoderma asperellum*-TaS1, *Trichoderma asperellum*-Tv5, *Trichoderma sps*-Ta DOR 673, *Trichoderma koningii*, *Trichoderma asperellum*- Ta DOR 7316, *Trichoderma* virens, *Trichoderma asperellum*-$N_{13,}$ *Trichoderma hamatum* were used along with a control.

Leaf area was measured by using LI-3100 leaf area meter (LI COR-Lincon, Nebraska, USA). Using the leaf area, LAI was calculated by using the following formula.

$$LAI = \frac{\text{Leaf Area}}{\text{Ground Area}}$$

$$\text{Crop Growth Rate} = (W_2-W_1) / (t_2-t_1) \times (1/P)$$

Where W_1 and W_2 are total dry weight of plant at times t_1 and t_2 and P is the land area.

$$NAR= \{(W_2-W_1)/ (t_2-t_1)\} \text{ X } \{(Log_eA_2-Log_eA_1)/ (A_2-A_1)\}$$

Where W_1 and W_2 are total plant dry weights at times t_1 and t_2, Log_eA_1 and Log_eA_2 are the natural logs of leaf area A_1 and A_2 at times t_1 and $t_{2.}$

$$RGR= (Log_eW_2-Log_eW_1) / (t_2-t_1)$$

Where Log_eW_1 and log_eW_2 are the natural log values of total dry weights at time t_1 and t_2

RESULTS AND DISCUSSION

Morphological parameters:

Growth in terms of plant height was increased rapidly up to 75 DAS in all the genotypes. Maximum plant height was recorded in *Trichoderma asperellum* –TaS1 (132.6 cm) followed by *Trichoderma* sps.Ta DOR 673(130.8 cm) and minimum plant height was recorded in *Trichoderma koningii*.(105.8 cm) (Table 1.). Increase in plant height by the inoculation of *Trichoderma harzianum* was also reported by Kucuk in wheat[8] and Mukopadhyay and Pan in radish[11].

The number of leaves per plant was significantly different among the treatments. Gradual increase was found for number of leaves up to 75 DAS there after declined up to 90 days (Table 2.).

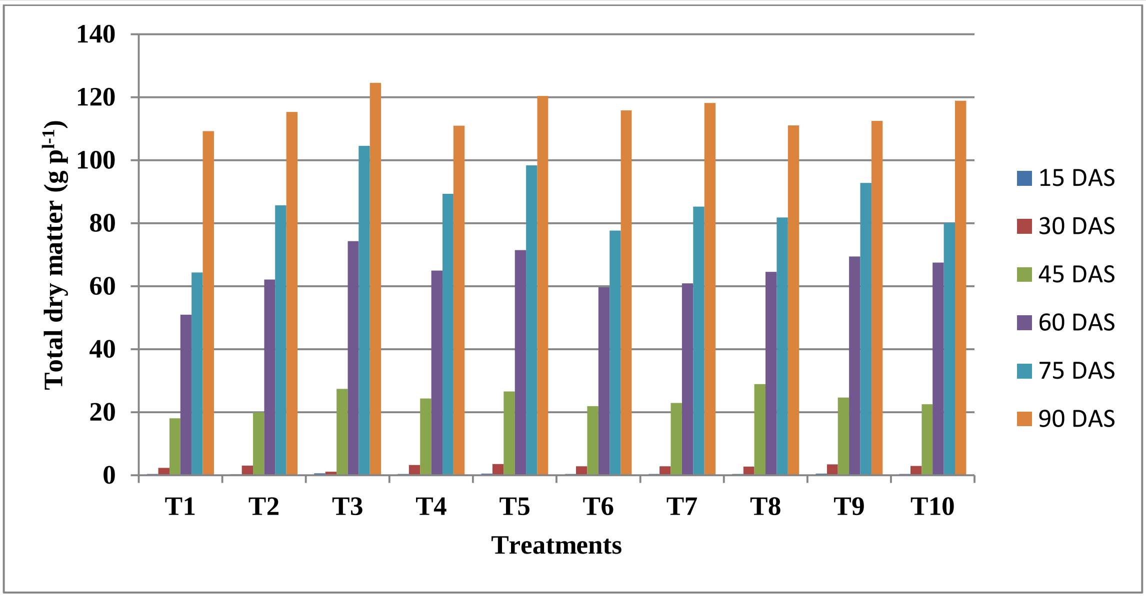
The size of photosynthetic surface in terms of number of leaves per plant was found significantly different in all the treatments (Table 3.). *Tichoderma* supplies more amount of nutrients to the plants and helps in increasing the number of leaves.

At harvest stage lowest number of leaves was found in untreated plants. Similar results for number of leaves were also reported by Khair *et al*.[7] in bean plants. The highest number of days taken for 50% flowering was recorded in T3-*Trichoderma asperellum*-TaS1 (64) followed by T5-*Trichoderma* sps-Ta DOR 673(62). The increase in the time taken for days to 50% flowering was due to sufficient availability of nutrients (Table 3.).

Trichoderma asperellum –TaS1 took maximum no of days to reach the maturity (94 days) where as minimum days to reach maturity was observed in control plants (88) (Table 3.). Similar results were also reported by Nagaraju *et al*.[12].

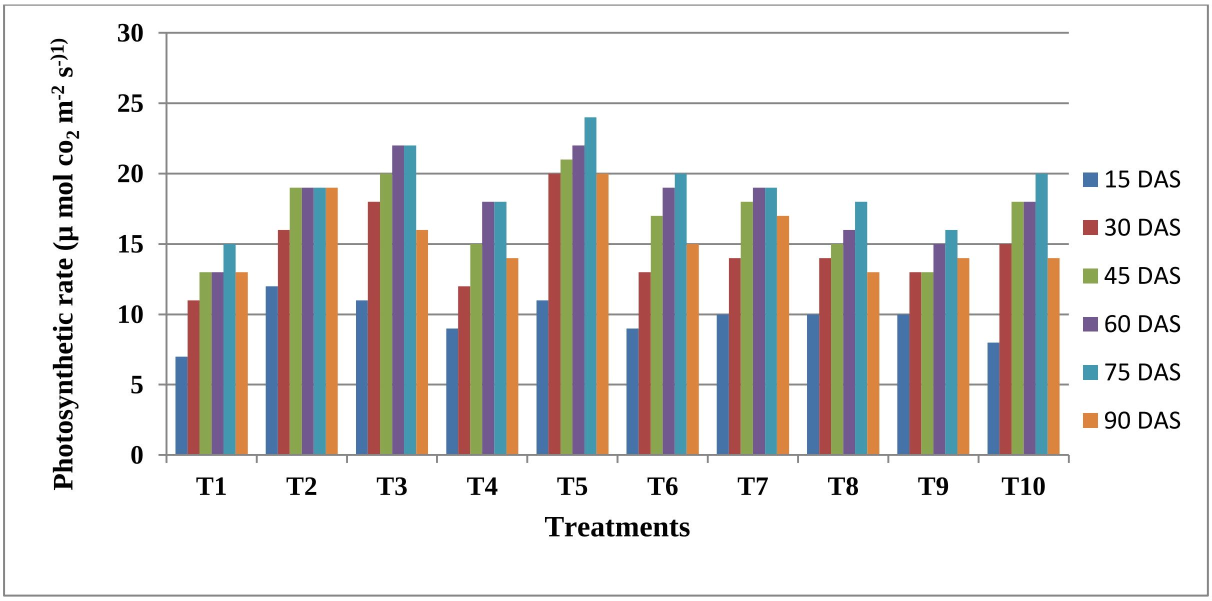
PHYSIOLOGICAL PARAMETERS

Highest dry matter was recorded in *Trichoderma asperellum* –TaS1 (124.5 g pl^{-1}) followed by *Trichoderma sps* –Ta DOR 673 with (120 g pl^{-1}) at 90 DAS. Lowest dry matter was observed in control plants (109.2 g pl^{-1}) (Table 4.).



Graph 1: Total dry matter (g plant^{-1}) in sunflower as influenced by *Trichoderma* strains during *rabi* season

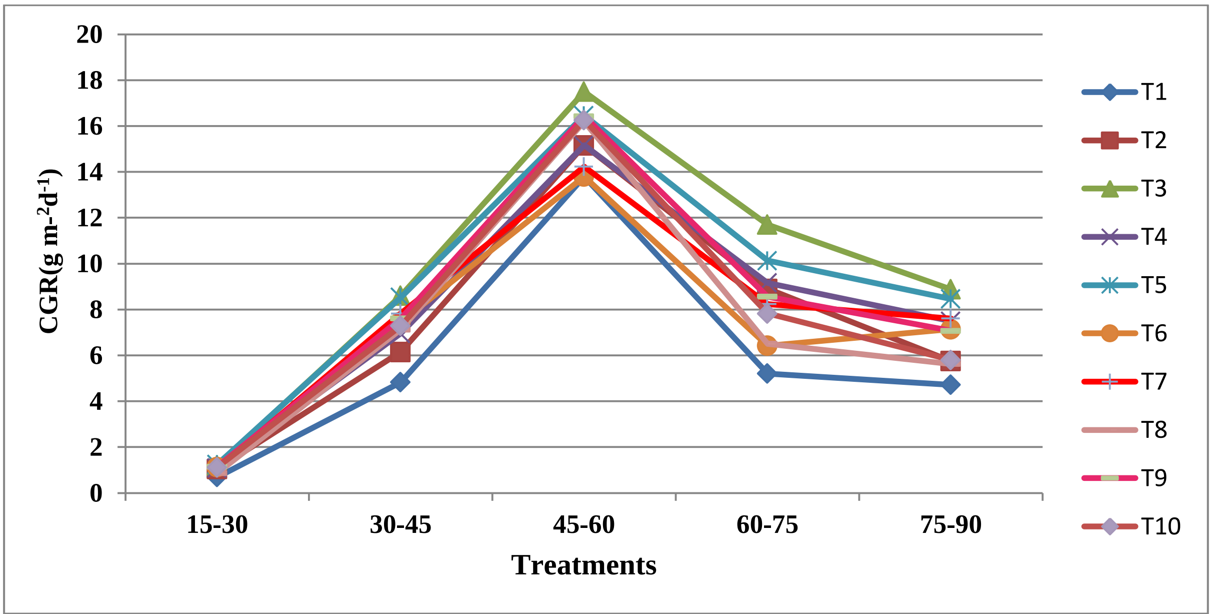
Significant difference for photosynthetic rate was observed among the treatments at 45, 60, 75 and 90 DAS. *Trichoderma sps*-Ta DOR 673(24 µ moles CO_2 m^{-2} s^{-1}) followed by *Trichoderma asperellum*-TaS1 (22 µ moles CO_2 m^{-2} s^{-1}) recorded highest photosynthetic rate at 75 DAS (Table 5) & (Graph 2.). The photosynthetic rate was increasing due to the increase in leaf area of plants, better root development and root penetration in to soil might have helped in increased nutrient uptake and increased chlorophyll content as observed in SCMR values. These results are in agreement with Vargas *et al.*[14], John *et al.*[6]. Maximum SPAD values were recorded in *Trichoderma asperellum*-TaS1 throughout the crop growth period except at 15 DAS (Table 6.). This confirm the views of Entesari *et al.*[4], Badda *et al.*[1], Lo and Lin[9].



Graph 2: Photosynthetic rate (µ moles CO_2 $m^{-2}s^{-1}$) of sunflower as influenced by *Trichoderma* strains in *rabi* season

Highest LAI was recorded in *Trichoderma asperellum*-TaS1 (7.6) followed *Trichoderma sps*-Ta DOR 673(7.4) at 60 DAS. Minimum LAI of 6.1 was observed in control treatment at 60 DAS (Table 7.). Leaf area index was increasing due to the increase in number of leaves per plant under the influence of sufficient nutrient uptake in treated plants as compared to control. Similar results were obtained in tomato by Bharti *et al.*[2], Lo and Lin *et al.*[9].

Highest crop growth rate was recorded in *Trichoderma asperellum*-TaS1 (17.50 g $m^{-2}day^{-1}$) followed by *Trichoderma sps*-Ta DOR 673(16.46 g $m^{-2}day^{-1}$) at 45-60 DAS. Lowest CGR value was recorded in control plants (13.80 g m^{-2}day-^{1}) at 45-60 DAS (Table 8.) & (Graph 3.). The increase in the diameter of head may be attributed to increase in leaf area index and increased photosynthetic activity leading to more translocation of photosynthates from source to sink at flower bud initiation stage. The results are in accordance with findings of Nagaraju *et al.*[12] in sunflower crop with the application of *Trichoderma* strains.



Graph 3: Crop growth rate (g $m^{-2}d^{-1}$) in sunflower as influenced by *Trichoderma* strains in R*abi* season

Highest NAR value was recorded in *Trichoderma sps*-Ta DOR 673(0.905 mg $cm^{-2}d^{-1}$) followed by *Trichoderma asperellum*-TaS1 (0.850 mg $cm^{-2}d^{-1}$) at 45-60 DAS (Table 9.).

Yield and Yield Components:

Among the treatments *Trichoderma asperellum* –TaS1 showed higher head dry weight (83.89 g) followed by *Trichoderma asperellum*-N13 (82.16g). Lowest head weight was recorded by *Trichoderma hamatum* (71.83g) (Table 10.).

Increase in number of filled seed per capitulum can be attributed to higher pollen fertility, increased fertilization, increase in effective leaf area, rate of photosynthesis and increased translocation assimilates in to head to increase the formation of seeds. Higher 100 seed weight was recorded in *Trichoderma asperellum* TaS1 (5.91) followed by *Trichoderma* sps –Ta DOR 673 (5.65) where as lowest 100 seed wt of 4.62 g recorded in control (Table 11.). Similar increase in 100 seed weight with *Trichoderma* was also reported by Nagaraju *et al.*[12]. Highest harvest index value was observed in *Trichoderma asperellum* –TaS1 (30.48 %) followed by *Trichoderma* sps –Ta DOR 673(30.0 %) (Table11.).

Table 1: Plant height (cm) of sunflower as influenced by *Trichoderma* strains during *Rabi* season

Treatments	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
T1-Untreated control	13.2	18.8	44.3	84.1	108.2	120.2
T2-*Trichoderma harzianum*-Th 4d	12.7	21.3	46.6	88.7	116.9	117.5
T3-*Trichoderma asperellum*-TaS1	18.1	23.6	65.0	104.5	132.2	132.6
T4-*Trichoderma asperellum*-Tv5	13.9	23.6	56.1	97.7	119.8	120.1
T5-*Trichoderma* sps-Ta DOR 673	17.4	26.4	61.1	102.3	130.4	130.8
T6-*Trichoderma koningii*	16.9	23.3	49.2	85.9	105.3	105.8
T7-*Trichoderma asperellum*-Ta DOR 7316	16.1	24.1	52.2	92.0	115.1	118.0
T8-*Trichoderma virens*	16.6	23.4	56.9	88.6	107.0	112.9
T9-*Trichoderma asperellum*-N13	17.1	24.9	56.5	92.9	105.7	105.9
T10-*Trichoderma hamatum*	16.5	28.0	56.6	94.5	119.4	122.6
SE(m)±	0.78	0.84	1.4	2.77	2.76	0.96
CD(p=0.05)	1.64	2.51	4.39	5.83	8.21	2.88

Table 2: Number of leaves plant $^{-1}$ in sunflower as influenced by *Trichoderma* strains during *Rabi* season

Treatments	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
T1-Untreated control	9	12	13	17	18	14
T2-*Trichoderma harzianum*-Th 4d	10	14	15	19	21	17
T3-*Trichoderma asperellum*-TaS1	12	14	20	23	25	20
T4-*Trichoderma asperellum*-Tv5	8	14	16	18	21	16
T5-*Trichoderma* sps-Ta DOR 673	11	13	17	22	23	18
T6-*Trichoderma koningii*	7	16	16	20	22	15
T7-*Trichoderma asperellum*-Ta DOR 7316	7	13	14	19	21	18
T8-*Trichoderma virens*	7	11	15	17	20	18
T9-*Trichoderma asperellum*-N13	8	14	16	19	22	17
T10-*Trichoderma hamatum*	10	16	17	21	20	15
SE(m)±	0.6	0.7	0.7	0.68	0.74	0.6
CD(p=0.05)	1.8	2.3	2.3	2.06	2.2	2.07

Table 3: Days to 50% flowering and days to physiological maturity in sunflower as influenced by *Trichoderma* strains during *Rabi* season

Treatments	Days to 50% flowering	Days to maturity
T1-Untreated control	59	88
T2-*Trichoderma harzianum*-Th 4d	61	91
T3-*Trichoderma asperellum*-TaS1	64	94
T4-*Trichoderma asperellum*-Tv5	61	92
T5-*Trichoderma* sps-Ta DOR 673	62	93
T6-*Trichoderma koningii*	60	91
T7-*Trichoderma asperellum*-Ta DOR7316	59	92
T8-*Trichoderma virens*	60	90
T9-*Trichoderma asperellum*-N13	61	92
T10-*Trichoderma hamatum*	60	90
SE(m)±	0.81	1.18
CD(p=0.05)	2.42	3.53

Table 4: Total dry matter (g plant^{-1}) in sunflower as influenced by *Trichoderma* strains during *Rabi* season

Treatments	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
T1-Untreated control	0.38	2.29	18.05	50.96	64.36	109.2
T2-*Trichoderma harzianum*-Th 4d	0.32	3.03	19.87	62.05	85.70	115.3
T3-*Trichoderma asperellum*-TaS1	0.57	1.07	27.38	74.25	104.54	124.5
T4-*Trichoderma asperellum*-Tv5	0.37	3.25	24.36	64.94	89.27	110.9
T5-*Trichoderma* sps-Ta DOR 673	0.48	3.54	26.54	71.45	98.36	120.4
T6-*Trichoderma koningii*	0.33	2.81	21.87	59.62	77.63	115.8
T7-*Trichoderma asperellum*-Ta DOR7316	0.34	2.78	22.90	60.90	85.27	118.1
T8-*Trichoderma* virens	0.39	2.76	28.87	64.54	81.82	111.0
T9-*Trichoderma asperellum*-N13	0.44	3.47	24.65	69.45	92.72	112.5
T10-*Trichoderma hamatum*	0.42	2.96	22.54	67.45	80.09	118.9
SE(m)±	0.44	0.14	1.27	1.72	1.40	1.14
CD(p=0.05)	0.13	0.42	3.82	5.31	4.20	3.41

Table 5: Photosynthetic rate (µ moles CO_2 m^{-2}s^{-1}) of sunflower as influenced by *Trichoderma* strains in *Rabi* season

Treatments	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
T1-Untreated control	7	11	13	13	15	13
T2-*Trichoderma harzianum*-Th 4d	12	16	19	19	19	19
T3-*Trichoderma asperellum*-TaS1	11	18	20	22	22	16
T4-*Trichoderma asperellum*-Tv5	9	12	15	18	18	14
T5-*Trichoderma* sps-Ta DOR 673	11	20	21	22	24	20
T6-*Trichoderma koningii*	9	13	17	19	20	15
T7-*Trichoderma asperellum*-Ta DOR7316	10	14	18	19	19	17
T8-*Trichoderma virens*	10	14	15	16	18	13
T9-*Trichoderma asperellum*-N13	10	13	13	15	16	14
T10-*Trichoderma hamatum*	8	15	18	18	20	14
SE(m)±	0.54	0.6	0.9	1.14	1.19	0.92
CD(p=0.05)	1.62	1.91	2.79	3.42	3.58	2.78

Table 6: SPAD chlorophyll meter readings (SCMR) of sunflower as influenced by *Trichoderma* strains in *Rabi* season

Treatments	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
T1-Untreated control	29.38	30.34	29.77	37.19	33.33	28.15
T2-*Trichoderma harzianum*-Th 4d	24.89	21.18	31.21	35.85	34.77	28.37
T3-*Trichoderma asperellum*-TaS1	36.18	38.08	35.39	38.68	37.72	31.71
T4-*Trichoderma asperellum*-Tv5	35.17	36.35	33.14	35.86	34.18	25.57
T5-*Trichoderma* sps-Ta DOR 673	39.24	35.89	34.67	37.24	37.49	27.91
T6-*Trichoderma koningii*	35.21	37.66	32.69	35.00	37.44	26.54
T7-*Trichoderma asperellum*-Ta DOR 7316	32.54	36.86	32.19	36.25	35.98	25.19
T8-*Trichoderma virens*	31.85	34.71	34.48	37.64	36.22	27.16
T9-*Trichoderma asperellum*-N13	31.54	35.61	34.44	36.00	36.54	23.81
T10-*Trichoderma hamatum*	30.54	34.13	33.33	38.19	37.01	27.20
SE(m)±	1.21	1.11	0.99	0.71	0.90	1.05
CD(p=0.05)	2.98	5.56	5.11	2.12	2.69	3.12

Table 7: Leaf area index (LAI) in sunflower as influenced by *Trichoderma* strains in *Rabi* season

Treatments	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
T1-Untreated control	0.04	1.2	5.0	6.1	5.3	3.0
T2-*Trichoderma harzianum*-Th 4d	0.06	1.3	5.2	6.5	5.9	3.4
T3-*Trichoderma asperellum*-TaS1	0.08	2.0	6.9	7.6	6.6	4.5
T4-*Trichoderma asperellum*-Tv5	0.07	1.5	5.9	6.5	5.3	4.0
T5-*Trichoderma* sps-Ta DOR 673	0.08	1.8	6.1	7.4	6.3	4.1
T6-*Trichoderma koningii*	0.05	1.3	5.7	6.8	5.6	3.6
T7-*Trichoderma asperellum*-Ta DOR7316	0.03	1.3	5.2	6.5	5.7	4.0
T8-*Trichoderma* virens	0.06	1.4	5.6	6.8	6.0	3.8
T9-*Trichoderma asperellum*-N13	0.07	1.8	5.8	6.2	5.9	4.1
T10-*Trichoderma hamatum*	0.03	1.4	5.2	6.3	5.9	3.7
SE(m)±	0.010	0.153	0.06	0.08	0.22	0.17
CD(p=0.05)	0.030	0.458	0.20	0.22	0.668	0.057

Table 8: Crop growth rate (g $m^{-2}d^{-1}$) in sunflower as influenced by *Trichoderma* strains in *Rabi* season

Treatments	15-30 DAS	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS
T1-Untreated control	0.70	4.83	13.80	5.21	4.72
T2-*Trichoderma harzianum*-Th 4d	1.05	6.15	15.16	8.90	5.75
T3-*Trichoderma asperellum*-TaS1	1.21	8.60	17.50	11.79	8.88
T4-*Trichoderma asperellum*-Tv5	1.09	6.96	15.16	9.16	7.49
T5-*Trichoderma* sps-Ta DOR 673	1.25	8.53	16.46	10.13	8.46
T6-*Trichoderma koningii*	1.14	7.46	13.80	6.42	7.14
T7-*Trichoderma asperellum*-Ta DOR 7316	1.08	7.83	14.23	8.24	7.61
T8-*Trichoderma virens*	0.87	7.13	16.20	6.51	5.63
T9-*Trichoderma asperellum*-N13	1.15	7.61	16.43	8.56	7.07
T10-*Trichoderma hamatum*	1.12	7.29	16.26	7.83	5.80
SE(m)±	0.03	0.38	1.05	0.66	0.22
CD(p=0.05)	0.10	1.14	3.14	2.04	0.66

Table 9: Net assimilation rate (mg $cm^{-2}d^{-1}$) of sunflower as influenced by *Trichoderma* strains during *Rabi* season

Treatments	15-30 DAS	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS
T1-Untreated control	0.567	0.597	0.731	0.647	0.347
T2-*Trichoderma harzianum*-Th 4d	0.577	0.653	0.773	0.712	0.410
T3-*Trichoderma asperellum*-TaS1	0.610	0.716	0.850	0.776	0.423
T4-*Trichoderma asperellum*-Tv5	0.443	0.671	0.751	0.751	0.393
T5-*Trichoderma* sps-Ta DOR 673	0.680	0.782	0.905	0.834	0.583
T6-*Trichoderma koningii*	0.550	0.648	0.723	0.735	0.393
T7-*Trichoderma asperellum*-TaDOR7316	0.510	0.651	0.757	0.739	0.413
T8-*Trichoderma virens*	0.433	0.629	0.807	0.712	0.407
T9-*Trichoderma asperellum*-N13	0.570	0.690	0.843	0.764	0.413
T10-*Trichoderma hamatum*	0.467	0.657	0.773	0.767	0.320
SE(m)±	0.029	0.016	0.018	0.019	0.017
CD(p=0.05)	0.086	0.049	0.055	0.062	0.052

Table 10: Diameter of head (cm), head weight (g), no of filled seed head^{-1} in sunflower as influenced by *Trichoderma* species during *Rabi* season

Treatments	Diameter of head (cm)	Head weight (g)	No of filled seed head
T1-Untreated control	16.6	74.41	467
T2-*Trichoderma harzianum*-Th 4d	16.6	73.78	536
T3-*Trichoderma asperellum*-TaS1	17.7	83.89	638
T4-*Trichoderma asperellum*-Tv5	16.5	74.69	541
T5-*Trichoderma* sps-Ta DOR 673	17.6	82.16	585
T6-*Trichoderma koningii*	16.3	75.61	594
T7-*Trichoderma asperellum*-TaDOR7316	16.1	72.57	557
T8-*Trichoderma virens*	17.3	76.67	566
T9-*Trichoderma asperellum*-N13	16.4	78.15	636
T10-*Trichoderma hamatum*	16.9	71.83	548
SE(m)±	0.14	2.052	2.33
CD(p=0.05)	0.44	4.652	6.98

Table 11: 100 seed weight (g), seed yield, harvest index (%) in sunflower as influenced by *Trichoderma* strains during *Rabi* season

Treatments	100 Seed wt (g)	Seed yield (g plant^{-1})	Harvest index (%)
T1-Untreated control	4.62	29.9	27.43
T2-*Trichoderma harzianum*-Th 4d	5.39	32.8	28.52
T3-*Trichoderma asperellum*-TaS1	5.93	37.8	30.48
T4-*Trichoderma asperellum*-Tv5	5.44	32.9	29.90
T5-*Trichoderma* sps-Ta DOR 673	5.61	36.0	30.00
T6-*Trichoderma koningii*	4.70	34.0	29.56
T7-*Trichoderma asperellum*-Ta DOR 7316	5.08	33.3	28.24
T8-*Trichoderma virens*	4.96	32.5	29.27
T9-*Trichoderma asperellum*-N13	5.34	32.7	29.19
T10-*Trichoderma hamatum*	5.33	34.7	29.40
SE(m)±	0.257	0.83	1.54
CD(p=0.05)	8.531	2.51	NS

CONCLUSION

The highest seed yield values in *Trichoderma* treatment can be attributed to the cumulative effect of the yield components viz., more head diameter, more no of filled seed per head, more 100 seed weight all these factors are in turn due to increased nutrient uptake by the roots, increased SCMR values, photosynthetic rate and translocation of more photosynthates in to seeds. Based on performance of morpho physiological parameters, out of the nine *Trichoderma* strains studied, two strains viz., *Trichoderma asperellum* –TaS1, *Trichoderma* sps-Ta DOR 673 were found to be better strains and have shown good plant growth and photosynthesis finally showed increased yields in sunflower.

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