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Study of effect of different shading factors on photo synthetically active radiation (PAR) (µ mol m^{-2} s^{-1}), transpiration rate and stomatal conductance rate of tomato plant under Shadenet house condition

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Abstract
The studies was performed by conducting the field experiments under different shadenets at the Instructional Farm of Department of Irrigation and Drainage Engineering, Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, Mahatma Phule Krishi Vidyapeeth, Rahuri during *rabi* seasons of 2013-14. Result shows that photosynthetically active radiation decreased with increase in shading levels. Maximum PAR was found in open field (0 shadenet) as compared to other shades. Treatment wise mean PAR values were near about similar over the season in both years under same shade. The transpiration rate and stomatal conductance rate of tomato plant increased with the advancement of age of crop during both the years. During the year 2013-14 average transpiration rate and average stomatal conductance rate was found maximum due to T_1(75% x 0.95 ETc) *i.e.*, (6.82 m mol m^{-2} s^{-1}) and (0.61 m mol m^{-2} s^{-1}) .During the year 2014-15 average transpiration rate and average stomatal conductance rate was found maximum due toT_1 (75% x 0.95 ETc) i.e. (7.37 m mol m^{-2} s^{-1}) and (0.74 m mol m^{-2} s^{-1}).

Keywords: Shading percentages, photo synthetically active radiation, transpiration rate and stomatal conductance

1. Introduction
Tomato (*Solanum lycopersicum* L.) belongs to the family Solanaceae is one of the most popular and nutritious vegetable crops all over the world**.** It is easy to grow as compared to peppers and cucumbers, and fruit yield can be very high under protection. Demand for tomatoes is usually strong due to vine-ripe nature and general overall high level of eating quality. There are two main types of tomato *viz*. (i) determinate or 'bush' tomato, and (ii) indeterminate or 'vine' tomato. Determinate cultivars are used mainly for processed food while indeterminate cultivars have been largely developed for greenhouse systems. Tomato is a warm season plant. It can withstand with severe frost conditions. Temperature and light intensity affect germination, vegetative growth, fruit set, pigmentation and nutritive value of this fruits. The night temperature is the critical factor in fruit setting with the optimum range of 16 °C to 22 °C. fruits fail to set at 12 °C or below. (Ramesh 2010) [7]

Farmers in arid/ semi-arid regions of the world use shade nets in protective cultivation on a large scale. The role of shade net in achieving higher productivity through modified micro climate, protection against the adverse climatic condition, insects and pest attacks has been quoted by many scientists. However, very limited research is available on the effect of colored nets and its shading on its water requirement.

Shade net house is a framed structure made of materials such as GI pipes, angle iron, wood or bamboo. It is covered with plastics net which are made of 100% polyethylene thread with specialized UV treatment having different shading percentages. It provides partially controlled atmosphere and environment by reducing light intensity and effective heat during day time to crops grown under it. It promotes seasonal and off-seasonal cultivation round the year. Shading nets are used in tropical and subtropical countries for vegetable production. The need of protected cultivation since last 10 years has been dramatically increased.

The various cause are reduced weed pressure, moisture conservation, reduction of certain insect pests, higher crop yields, and more efficient use of soil nutrients. (Manisha Jagadale 2018) [6]

Stomata are tiny openings or valves distributed on leaf surfaces that allow for gas exchange, where water vapor leaves the plant and CO_2 enters. Special cells called guard cells control stomatal opening and closing. Many studies have shown a direct effect of CO_2 and temperature on stomatal conductance. As temperature increases, stomatal apertures open to allow evaporative cooling through the release of water vapor. When stomatal pores open, the supply of CO_2 available for the photosynthetic enzymes is increased.

This study evaluated the effects of shade level on photo synthetically active radiation (PAR) (µ mol m^{-2} s^{-1}), transpiration rate and stomatal conductance rate of tomato plant under shadenet house condition.

2. Materials and Methods

The field experiment was conducted at the Instructional Farm of Department of Irrigation and Drainage Engineering, Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, Mahatma Phule Krishi Vidyapeeth, Rahuri during the period from November 2013 to May 2014. Geographically the farm lies at 74^0 38' 00" E longitudes and 19^0 20' 00" N latitude at 557 m above the mean sea levels in the central campus of Mahatma Phule Krishi Vidyapeeth, Rahuri.

2.1 Experimental Details

An experiment was conducted under this investigation. The details are as follow. The experiment under different shadenet houses of 75%, 50%, 35% with open field condition i.e. (Zero percent shadenet house).

2.1.1 Layout of experiment

The experiments were laid out with sixteen treatments arranged in a different shadenet house. The length and width of each treatment plot was 4.5 m x 1 m under shadenet houses . A space of 0.5 m was provided between two treatments as a buffer strip to avoid lateral movement of water from treatment to treatment.

2.1.2 Agronomical Details of the Crop

Sr. No.	Particulars	Specification
1.	Crop	Tomato (*Solanum lycopersicum* L.)
2.	Variety	Hy. Phule Raja
3.	Transplanting date (First Trial)	25- Nov-2013
4.	Transplanting date (Second Trial)	01- Dec-2014
5.	Duration of the crop	160 -180 days
6.	Plastic mulch	Silver-black mulches of 25-micron thickness
7.	Recommended fertilizer dose (N:P:K)	300:150:150 kg ha^{-1}

2.1.3Treatment Details

This experiment was carried out in split plot design with sixteen treatments based on different combinations of the shading percentages and irrigation levels.

Sr. No.	Factor A: Shading percentage	Factor B: Irrigation levels
1.	S_1 = 75% shading	I_1 = 0.95 ETc
2.	S_2 = 50% shading	I_2 = 0.75 ETc
3.	S_3 = 35% shading	I_3 = 0.55 ETc
4.	S_4 = 0% shading *i.e.* (Open field)	I_4 = 0.35 ETc

Table 1: Crop duration of tomato observed under shadenet houses.

Sr. No.	Experiment	2013-14	2014-15
		Crop duration, days	
1.	S_1 = 75% shadenet house	172	209
2.	S_2 = 50% shadenet house	167	197
3.	S_3 = 35% shadenet house	161	192
4.	S_4= 0% shadenet house *i.e.* (Open field)	155	170

2.2 Photo synthetically active radiation (PAR) (µ mol m^{-2} s^{-1})

The photosynthetically active radiation (PAR) were measured at 30,60,90,120 and 150 DAT on a clear sky in between 12.00 pm to 1.00 pm with the LI 191SA Line Quantum sensor (Li-cor make) at an interval of 30 days. The incident PAR was measured 1 feet above the canopy by line quantum sensor facing toward the sky. The transmitted PAR was measured by placing the line quantum sensor at ground level facing upwards. Reflected PAR by soil and mulch measured at ½ to 1 feet above the ground by facing line quantum sensor towards the mulch and soil. The reflected PAR by canopy + mulch and soil was measured by holding line quantum sensor above the canopy facing toward the canopy. The absorbed photosynthetically active radiation (APAR) calculated by using following formula given by (Daughtry *et al.*,1992) [3].

$$APAR = [(Io + Rs) - (Tc + Rc)]$$

APAR = [(Intercepted + Reflected from soil) − (Transmitted + Reflected from canopy)]

2.3 Transpirtion rate and stomatal conductance rate of tomato plant

Transpiration rate and stomatal conductance rate of tomato crop under shadenet houses from the observation plant were measured at 30, 60, 90, 120 and 150 DAT with the help of Portable photosynthesis system (LI-6400).

3. Results and Discussion

3.1 PAR (Photosynthetically Active Radiation) (µ mol m^{-2} s^{-1}) under Shadenet Houses

Data pertaining to mean photosynthetically active radiation (PAR) as influenced by the different treatments at 30, 60, 90, 120 and 150 days after transplanting for the year 2013 and 2014 are presented graphically in Fig. 1. Photosynthetically active radiation decreased with increase in shading levels. Maximum PAR was found in open field (0 shadenet) as compared to other shades. Treatment wise mean PAR values were near about similar over the season in both years under same shade. Similar results were reported by Carlos and Perez (2013) [2].

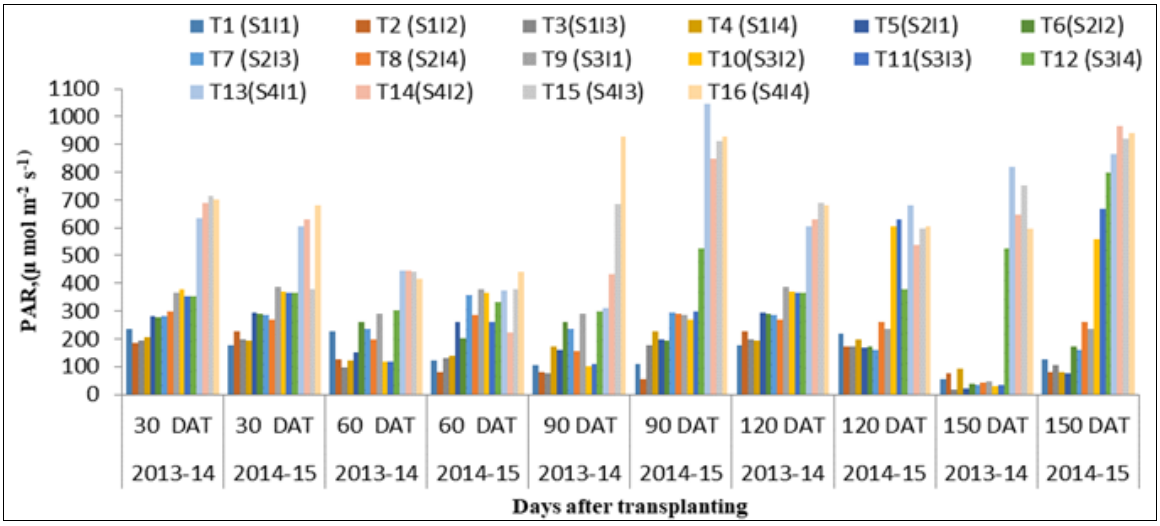

Fig 1: Photosynthetically active radiation recorded at different days of observation under shadenet houses

3.2 Transpiration Rate and Stomatal Conductance Rate of Tomato Plant under Shadenet Houses

Data pertaining to transpiration rate and stomatal conductance rate of tomato plant at 30 DAP, 60 DAP, 90 DAP, 120 DAP and 150 DAP as influenced by the different treatment under different shadenet house for the year 2013 and 2014 are presented in Tables 2 to 5 and graphically depicted in Figs. 2 to 5 respectively. Transpiration rate and stomatal conductance rate of tomato crop depends upon evaporative demand and somatal opening and closing. The data show that the transpiration rate and stomatal conductance rate of tomato plant increased with the advancement of age of crop during both the years. During the year 2013-14 average transpiration rate and average stomatal conductance rate was found maximum due to T_1(75% x 0.95 ETc) *i.e.*, (6.82 m mol m^{-2} s^{-1}) Table (2)and (0.61 m mol m^{-2} s^{-1}) Table (4). During the year 2014-15 average transpiration rate and average stomatal conductance rate was found maximum due toT_1 (75% x 0.95 ETc) i.e. (7.37 m mol m^{-2} s^{-1}) Table (3) and (0.74 m mol m^{-2} s^{-1}) Table (5).Transpiration rate and stomatal conductance rate decreased with decreasing shading levels during both the years. Similar results were reported by Carlos and Perez (2013) [2].

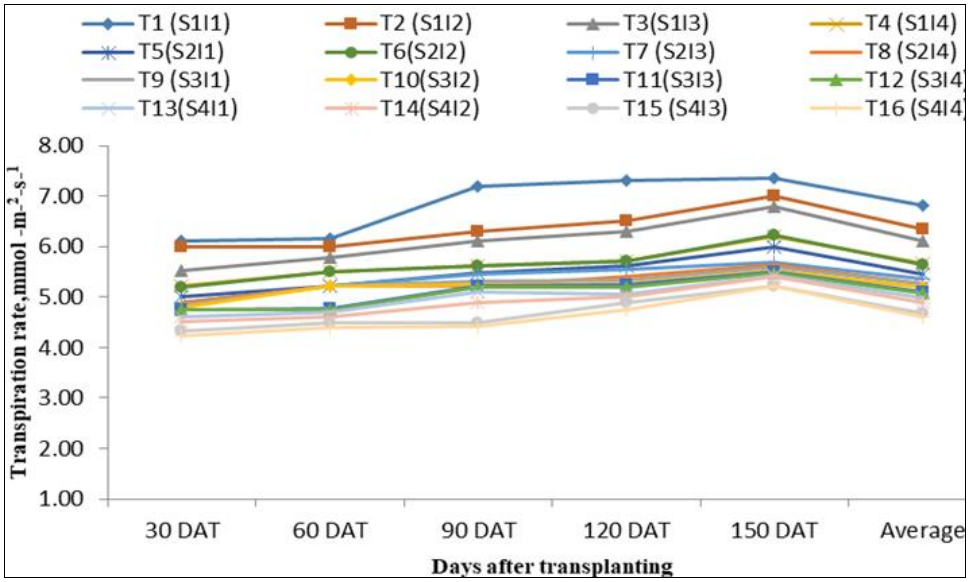

Fig 2: Transpiration rate of tomato plant recorded at different days of observation under shadenet houses (2013-14)

Table 2: Transpiration rate (m mol m^{-2} s^{-1}) of tomato plant recorded at different days under different shadenet house for the year 2013-14

Treatments	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	Average
T_1 (75% x 0.95 ETc)	6.10	6.15	7.20	7.30	7.35	6.82
T_2(75% x 0.75 ETc)	5.99	6.00	6.30	6.50	7.00	6.36
T_3(75% x 0.55 ETc)	5.53	5.78	6.10	6.30	6.80	6.10
T_4 (75% x 0.35 ETc)	5.23	5.50	5.63	5.71	6.20	5.65
T_5(50% x 0.95 ETc)	5.00	5.22	5.47	5.62	5.99	5.46
T_6(50% x 0.75 ETc)	5.20	5.50	5.62	5.71	6.23	5.65
T_7 (50% x 0.55 ETc)	4.89	5.23	5.45	5.55	5.69	5.36
T_8 (50% x 0.35 ETc)	4.88	5.21	5.23	5.41	5.64	5.27
T_9 (35% x 0.95 ETc)	4.84	5.23	5.32	5.34	5.60	5.27
T_{10} (35% x 0.75 ETc)	4.80	5.21	5.24	5.26	5.52	5.21

T_{11} (35% x 0.55 ETc)	4.76	4.78	5.21	5.24	5.51	5.10
T_{12} (35% x 0.35 ETc)	4.74	4.75	5.20	5.19	5.48	5.07
T_{13} (0% x 0.95 ETc)	4.62	4.70	5.10	5.06	5.42	4.98
T_{14} (0% x 0.75 ETc)	4.52	4.60	4.90	5.00	5.41	4.89
T_{15} (0% x 0.55 ETc)	4.32	4.50	4.50	4.90	5.23	4.69
T_{16} (0% x 0.35 ETc)	4.23	4.40	4.41	4.76	5.21	4.60

Table 3: Transpiration rate (m mol m^{-2} s^{-1}) of tomato plant recorded at different days under different shadenet house for the year 2014-15

Treatments	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	Average
T_1 (75% x 0.95 ETc)	7.23	7.25	7.28	7.52	7.55	7.37
T_2(75% x 0.75 ETc)	6.23	6.53	6.75	6.79	7.02	6.66
T_3(75% x 0.55 ETc)	6.20	6.45	6.50	6.70	6.80	6.53
T_4 (75% x 0.35 ETc)	5.65	5.42	5.47	5.63	6.52	5.74
T_5(50% x 0.95 ETc)	5.62	5.40	5.41	5.49	5.51	5.49
T_6(50% x 0.75 ETc)	5.52	5.34	5.37	5.42	5.47	5.42
T_7 (50% x 0.55 ETc)	5.24	5.26	5.32	5.40	5.42	5.33
T_8 (50% x 0.35 ETc)	5.21	5.25	5.30	5.37	5.40	5.31
T_9 (35% x 0.95 ETc)	5.15	5.23	5.24	5.30	5.35	5.25
T_{10} (35% x 0.75 ETc)	5.00	5.20	5.23	5.28	5.32	5.21
T_{11} (35% x 0.55 ETc)	4.78	5.12	5.00	5.10	5.12	5.02
T_{12} (35% x 0.35 ETc)	4.74	4.76	4.86	5.05	5.10	4.90
T_{13} (0% x 0.95 ETc)	4.56	4.60	4.74	5.00	5.02	4.78
T_{14} (0% x 0.75 ETc)	4.23	4.52	4.62	4.76	4.77	4.58
T_{15} (0% x 0.55 ETc)	4.20	4.41	4.52	4.70	4.72	4.51
T_{16} (0% x 0.35 ETc)	4.21	4.23	4.50	4.53	4.55	4.40

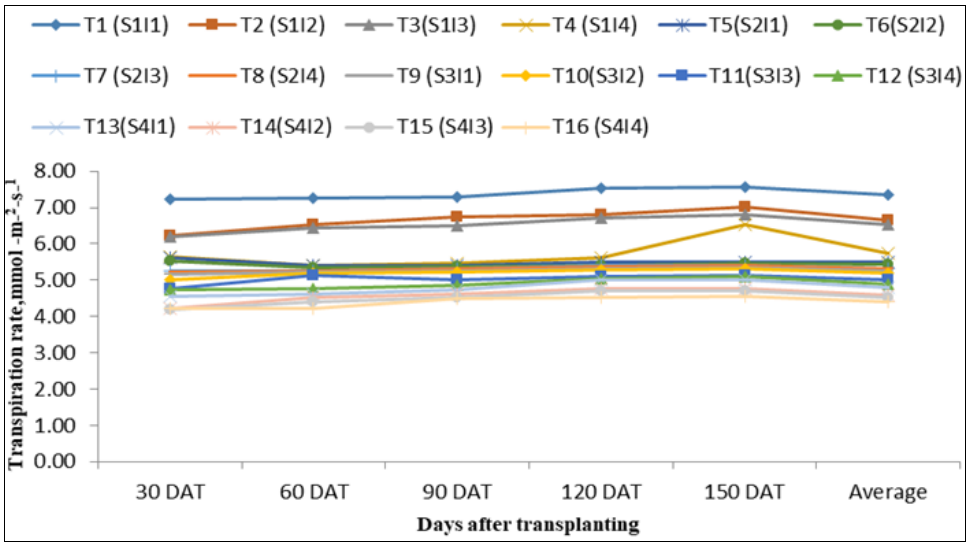

Fig 3: Transpiration rate of tomato plant recorded at different days of observation under shadenet houses (2014-15)

Table 4: Stomatal conductance rate (m mol m^{-2} s^{-1}) of tomato plant recorded at different days under different shadenet house for the year 2013-14

Treatments	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	Average
T_1 (75% x 0.95 ETc)	0.59	0.60	0.62	0.67	0.57	0.61
T_2(75% x 0.75 ETc)	0.55	0.56	0.59	0.60	0.54	0.57
T_3(75% x 0.55 ETc)	0.52	0.54	0.56	0.59	0.53	0.55
T_4 (75% x 0.35 ETc)	0.50	0.52	0.54	0.55	0.52	0.53
T_5(50% x 0.95 ETc)	0.48	0.50	0.51	0.52	0.52	0.51
T_6(50% x 0.75 ETc)	0.43	0.48	0.50	0.49	0.51	0.48
T_7 (50% x 0.55 ETc)	0.42	0.44	0.47	0.48	0.50	0.46
T_8 (50% x 0.35 ETc)	0.41	0.41	0.44	0.45	0.48	0.44
T_9 (35% x 0.95 ETc)	0.40	0.39	0.42	0.43	0.47	0.42
T_{10} (35% x 0.75 ETc)	0.39	0.40	0.41	0.42	0.44	0.41
T_{11} (35% x 0.55 ETc)	0.37	0.38	0.39	0.41	0.42	0.39
T_{12} (35% x 0.35 ETc)	0.35	0.37	0.37	0.38	0.40	0.37
T_{13} (0% x 0.95 ETc)	0.34	0.35	0.35	0.37	0.39	0.36
T_{14} (0% x 0.75 ETc)	0.32	0.35	0.36	0.34	0.35	0.34
T_{15} (0% x 0.55 ETc)	0.30	0.34	0.35	0.37	0.32	0.34
T_{16} (0% x 0.35 ETc)	0.38	0.30	0.34	0.34	0.33	0.34

Table 5: Stomatal conductance rate (m mol m^{-2} s^{-1})of tomato plant recorded at different days under different shadenet house for the year 2014-15

Treatments	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	Average
T_1 (75% x 0.95 ETc)	0.74	0.72	0.75	0.77	0.70	0.74
T_2(75% x 0.75 ETc)	0.71	0.72	0.73	0.74	0.71	0.72
T_3(75% x 0.55 ETc)	0.69	0.71	0.72	0.72	0.70	0.71
T_4 (75% x 0.35 ETc)	0.65	0.70	0.71	0.71	0.69	0.69
T_5(50% x 0.95 ETc)	0.64	0.69	0.70	0.70	0.65	0.68
T_6(50% x 0.75 ETc)	0.64	0.68	0.68	0.67	0.64	0.66
T_7 (50% x 0.55 ETc)	0.62	0.63	0.65	0.66	0.63	0.64
T_8 (50% x 0.35 ETc)	0.60	0.61	0.62	0.63	0.62	0.62
T_9 (35% x 0.95 ETc)	0.58	0.59	0.60	0.60	0.61	0.60
T_{10} (35% x 0.75 ETc)	0.55	0.58	0.58	0.59	0.57	0.57
T_{11} (35% x 0.55 ETc)	0.53	0.54	0.55	0.56	0.58	0.55
T_{12} (35% x 0.35 ETc)	0.52	0.54	0.54	0.55	0.56	0.54
T_{13} (0% x 0.95 ETc)	0.50	0.52	0.53	0.53	0.54	0.52
T_{14} (0% x 0.75 ETc)	0.48	0.49	0.50	0.51	0.52	0.50
T_{15} (0% x 0.55 ETc)	0.48	0.50	0.49	0.50	0.51	0.50
T_{16} (0% x 0.35 ETc)	0.46	0.48	0.49	0.49	0.50	0.48

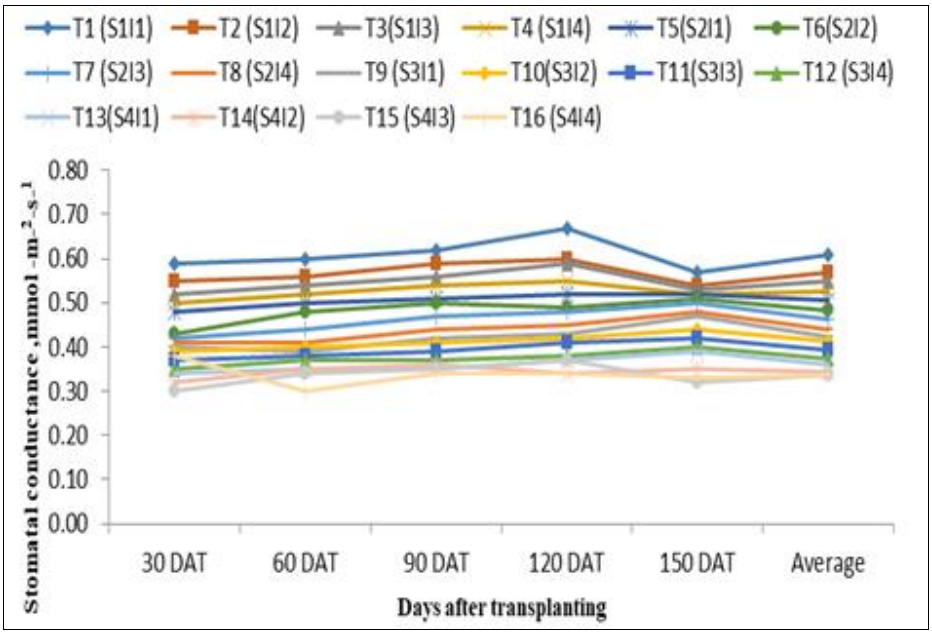

Fig 4: Stomatal conductance rate of tomato plant recorded at different days of observation under shadenet houses (2013-14)

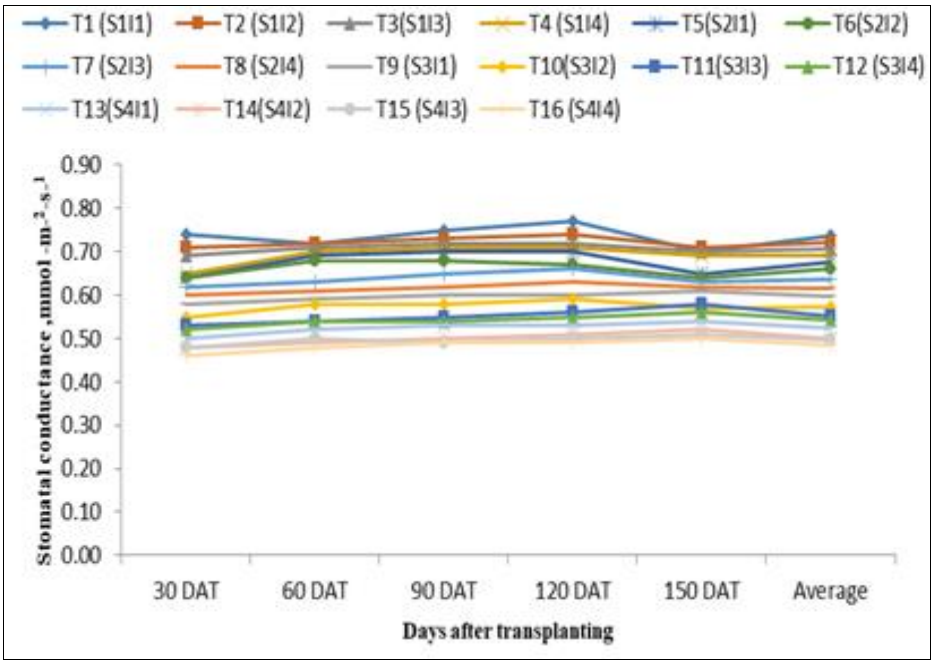

Fig 5: Stomatal conductance rate of tomato plant recorded at different days of observation under shadenet houses (2014-15)

4. Conclusions

The experiments were conducted to know the effects of shade level on photo synthetically active radiation (PAR) (µ mol m^{-2} s^{-1}), transpiration rate and stomatal conductance rate of tomato plant under shadenet house condition.

Photosynthetically active radiation decreased with increase in shading levels. Maximum PAR was found in open field (0 shadenet) as compared to other shades.

During the year 2013-14 average transpiration rate and average stomatal conductance rate was found maximum due to T_1(75% x 0.95 ETc) *i.e.,* (6.82 m mol m^{-2} s^{-1}) and (0.61 m mol m^{-2} s^{-1}) During the year 2014-15 average transpiration rate and average stomatal conductance rate was found maximum due toT_1 (75% x 0.95 ETc) i.e. (7.37 m mol m^{-2} s^{-1}) and (0.74 m mol m^{-2} s^{-1}).Transpiration rate and stomatal conductance rate decreased with decreasing shading levels during both the years.

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