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Evaluation of groundcovers under solar panels for weed control

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Abstract
The study was conducted to identify the best groundcover for growing under the solar panels for effective weed control. The experiment was laid out in Factorial randomized block design with two factors and three replications. Groundcovers were planted in plots of size 2.0 m ×1.8 m and one plot is left as a control in the experimental area. The study revealed that among the different groundcovers evaluated *Sphagneticola trilobata* (Singapore daisy) registered a greater weed control and the weed count number in the experimental plots at 120 days after planting in the open condition (3.54) and under solar panels (3.37) respectively. It is imperative from the results that the species *Sphagneticola trilobata, Lantana sellowiana, Setcreasea purpurea* may be recommended for the management of weeds. The results are in relation with the plant spread values and the highest plant spread at 120 days after planting in the East-West (197cm) and (189.30 cm) was recorded by *Sphagneticola trilobata* in open and under panel conditions. The same treatment records the North-South spread (147.67cm) and (149.44cm) in open field and under panels at 120 days after planting. The physiological parameters recorded at 120 days after planting also reveals that the (T_1) records the highest value than the other treatments and are highly suitable for growing in both the environments with greater weed control.

Keywords: Evaluation, groundcovers, solar panels, weed control

Introduction
Groundcovers are the plants that grow over the ground protects the top soil from erosion by wind and water and weed growth. Often the term 'ground cover' is used to refer the plants which are used in the place of weeds and those which improve the appearance of the land area. Groundcovers serve the aesthetic purpose and lend beauty to the landscapes by their beautifully coloured flowers and attractive foliages. Apart from beauty, they also aid economic importance added low cost of establishment and maintenance enables ground covers an important place in the landscape areas. Ground covers also possess the therapeutic value and in the urban landscapes, ground covers provide a cooling effect to overcome the heat sinks thereby lowering the air and soil temperature.

Growing of groundcovers improves the soil structure by preventing soil compaction and soil loss by erosion and also the leaching of nutrients from the soil surface. Added they are also used as a green manure plants to improve the soil fertility. Due to their aesthetic appeal ground covers are grown along the roadside and in the landscape settings such as airports and city boundaries. Shooshtarian *et al*., (2010) [3] revealed that in the areas of warm and dry climatic conditions with low precipitation rate lawn demands more water and minerals whereas the groundcovers require less maintenance than the lawns and they also enable to overcome the monotonous green view caused by the turf grasses. Some of the commonly grown groundcovers are *Medicago sativa, Hedera helix, Lonicera japonica, Lantana sellowiana, Mentha spp., Vinca rosea, Chlorophytum comosum* and *Juniperous spp.*In this study nine groundcovers was selected for growing under the panels and in open conditions and the experiment was carried out for a period of 120 days.

Ross *et al*., (2009) describes, weeds are the plants which are grown out of a place that are competitive, persistent, pernicious in nature and negatively interfere with crop growth and human activity. During manipulation some species are controlled easily while others thrive since they have a better acclimatization to the particular environment and their virtues are also not discovered (Emerson *et al*., 2012). Some important characters which made them difficult to eradicate are long term survival, wide adaptation for spread, rapid establishment and the presence of reproductive structures containing seeds. It has also been reported that in plant kingdom about 3% of the population (approximately 8000 species) are regarded as weeds, as they reduces the yield of the main crop by competing for water, light and space. Added they are also harmful to human beings and animals.

A photovoltaic system is designed to supply usable solar energy by means of photovoltaic. Several components in photovoltaic's include the solar panels to absorb the sunlight and convert to electricity, solar inverter to change the electric current from DC to AC, as well as mounting, cabling and other electrical accessories to set up a working system. Such systems can be installed on the building's roof, façade or on ground. For commercial electricity generation the photo voltaic modules are installed on the ground areas of larger acre and the areas should be free of obstacles to prevent the shade over the modules.

The electricity generated from the photovoltaic systems had a wider application in supplying electricity for household, rural development and agricultural applications, Tele - communications and Signage.

As the agri-voltaic systems is considered the photovoltaic modules are installed at certain heights from the ground level *i.e*., about 2 m from the ground level. Due to this larger area under the panels is left fallow which promotes more weed growth and also it aids shelter for snakes, insects, reptiles and venomous animals. The following list of weed species were found in the experimental area (*Acalypha indica, Tribulus terrestris, Abutilon indicum, Tephrosia purpurea, Cenchrus ciliaris, Achyranthes aspera*) Management of weeds includes mechanical, chemical and biological methods. The place where the panels are installed, use of manual labour involves more time consumption, high cost and also it is tedious to clean the existing weed population under the panels. Chemical weedicide spray causes residual effect in the soil which is harmful to the environment and the spray molecules may cause markings over the panel surface. If weeder is used for weeding taller plants can be eradicated whereas some stones may struck and hit the panels thereby creating hotspots and damage on the panels which needs to be replaced. In order to overcome this constraint, biological method of weed control using the cover crops is suggested. These crops may suppress the weed growth by direct competition or by the production of some inhibiting substances (Mark Schonbeck, 2015)

Materials and Methods

The present study was conducted at Vedaah 30 MW Solar PV power plant, Agaram village, Dindigul, Tamil Nadu (2018-2019). Experiment was laid down in Factorial Randomized block design with 2 factors and 3 replications. First Factor consists of 10 treatments which represents nine groundcovers and a control whereas second factor contains two treatments which denotes the growing environment and the objective of the study is used to identify the best groundcover which is suitable for growing in the open field and under solar panels to improve the panel efficiency, weed control and to reduce the soiling levels over the photovoltaic modules.

Factor 1

Treatments	Groundcovers
F_1T_1	*Sphagneticola trilobata*
F_1T_2	*Callisia repens*
F_1T_3	*Setcreasea purpurea*
F_1T_4	*Aptenia cordifolia*
F_1T_5	*Lantana sellowiana*
F_1T_6	*Tradescantia flumiensis zebrine*
F_1T_7	*Plectranthus prostratus*
F_1T_8	*Hemigraphis colorata*
F_1T_9	*Stylosanthes hamata*
F_1T_{10}	Control

Factor 2

Levels	Growing Environment
F_2T_1	Under panels (Class A type,310 Watts)
F_2T_2	Open field

Plot size of 2 m × 1.8 m was laid both in open field as well as under panels. The plants are planted at 30 cm ×30 cm spacing and one plot is made as a control to check the weed growth. Initially well decomposed farmyard manure was applied as a basal dose and foliar spray with 19-19-19 @1g/l of water was given to the plants. Observations on morphological, physiological parameters and weed count are taken at 30 days interval.

Results and Discussion

In this study groundcovers are grown in two different conditions, open field and under solar panels. The result obtained on plant morphological, physiological characters and weed count are discussed below

Weed count

The data obtained on weed count at 30 days interval is presented in Table: 1. It indicated that the plot planted with the groundcover (*Sphagneticola trilobata*) recorded the least weed count number (7.16,6.80,6.02,3.54) at 30,60,90 and 120 days after planting in open field conditions. While the same groundcover *Sphagneticola trilobata* grown under the solar panels recorded the weed count number (6.02, 5.2, 4.38, 3.37) at 30 days interval from planting. This is because the *Sphagneticola* plants exhibit an allelopathic effect that has a potential to prevent the weed growth and acts as a good competitor for water and nutrients thereby reducing their availability for the weeds which drastically reduces the weed population. The result obtained are in conformation with the findings of Hernandez-Aro *et al.*(2016) that the roots and leaves of Wedelia plants produces the allelochemicals that exert an allelopathic effect over the weed plants thereby preventing the germination and also suppress the spread of other plants. The highest value on weed count number (7.75, 7.53, 6.92, 5.34) and (6.16,5.20,4.53,3.81) at open field and under the solar panels was recorded in the control plots (T_{10}).This is because the control plots remains empty without any groundcovers and it promotes the growth of weeds to a greater extent than compared to all the other treatments.

Morphological characters

Plant spread

The data on plant spread in the East-West direction is presented in the Table: 2. The highest groundcover spread (29cm, 103.80 cm, 167 cm, 197 cm) at 30 days interval was recorded in T_1 under open condition and (27.54cm, 113.93 cm,138.89 cm and 189.30 cm) at 30,60,90 and 120 days after planting under the solar panels.

The result on North-South spread of the plants are tabulated in the Table: 3 and it was found that T_1(*Sphagneticola trilobata*) registered highest plant spread (26.90 cm,114.90 cm,137.29 cm,147.67 cm) and (26.72 cm,98.29 cm,133.89 cm,149.44 cm) at 30 days interval in both open field and under solar panels respectively. The increased spread was achieved due to the trailing and mat forming ability of the species which produces runner shoots that extends to a greater extent and shows a dense canopy cover that drastically controls the weed population and the results in relation with the findings of Thaman, (1999) who reported that Wedelia an invasive species with greater environmental tolerance showing vigrous vegetative as well as reproductive characters. The least spread in plant spread in open field (10.14cm,26.88 cm,33.20 and under solar panels (6.16 cm,15.49 cm,25.17 cm,28.20 cm) was registered in (T_9).The plant shows more erect and upright growth which resulted in the least spread of the plants.

Plant coverage

Time taken for 50% and 100% coverage of the plants are presented in Table: 4. The results indicates that the minimum days for coverage (65 and 70days) in the open field and under solar panels was achieved in T_1 which is followed by the T_2 which recorded (80 and 75 days) for coverage in both the conditions. The micro climate prevailed was highly suitable for the growth of *Sphagneticola trilobata* which resulted in the faster coverage of the plants and also the adaptability nature of the T_1 plants are superior than compared with other groundcovers, that had enable them to attain the vigorous growth in a shorter period of time. The above results are in confirmation with the findings of Quigley *et al*., (2003) who evaluated the growth of ground covers and concluded that the combined growth of fast and slow growing ground covers under shade produced lesser number of weeds than compared with the open field conditions. The treatment *Tradescantia flumiensis zebrina* had registered the maximum days for coverage in the open field (120 days) and under solar panels (110 days).Habit and habitat influences the coverage of the plants. Zebrina species is not able to tolerate the direct sunlight as the plants highly prefer the shaded conditions and takes long time for coverage.

Physiological characters

Leaf area

The leaf area of different groundcovers grown in open field and under solar panels is presented in Table: 5. the leaf area had shown a significant difference among the nine different groundcovers. The highest leaf area of 32.88, 47.53, 50.81 and 54.81 cm^2 was recorded in T_3 at 30, 60, 90 and 120 days after planting while the same treatment recorded the highest leaf area of 27.05, 38.64, 43.36, 51.65 cm^2 under the solar panels. It is found that the plants grown in open condition showed higher leaf area because of the increased metabolic activity and assimilate production by the leaves. Increased leaf area is an important key factor whose surface promotes the process of photosynthesis in plants and dense canopy cover was attained that affects the incoming sunlight towards the soil surface and inhibits the growth of the weeds. The results obtained are in confirmation with the findings of Pierson *et al*., (1990) who observed that leaf morphology and photosynthetic rate of the grass sp., (*Bromus tectorum*) grown in the sunlight and shade and recorded more prominent leaf characters in sunlight than the plants grown under shade. The lowest leaf area of 1.34 and 1.23 cm^2 at 120 days after planting in the open field and under solar panels was recorded in T_2.

Total Chlorophyll content

The data on total chlorophyll content was presented in the Table: 6. *Sphagneticola trilobata* (T_1) had recorded the highest chlorophyll content of 1.92 mg g^{-1} in the open condition at 120 days after planting and recorded 1.96 mg g^{-1} of total chlorophyll under solar panels. This is because the leaves under low light intensities possess elongated internodal growth for trapping the sunlight and utilizes it effectively for their growth and also the increase in chlorophyll b occurs in the shade condition which increases the pigment content and colour of the leaves. Added the higher chlorophyll of the leaves promotes the photosynthesis and metabolic activities of the plant which improves the plant health and make them the suppressor of weed growth. The above result are in relation with the findings of Mark (1997) in *Kalmia latifolia* plants grown in shade produced dark colour leaves and improved growth because of their increased chlorophyll content. The lowest chlorophyll content was registered in *Hemigraphis colorata* as it produces more anthocyanin and in the open field total chlorophyll was 1.01 mg g^{-1} and under the solar panels it recorded the chlorophyll content of 1.25 mg g^{-1}.

Proline content

The data obtained on the proline content of the different groundcovers are presented in Table:7. Among the different groundcovers the highest proline content of 1.56 mg g^{-1} was recorded in the leaves of *Sphagneticola trilobata* grown in the open field and in the plants under the shade the (T_1) recorded the highest proline content of 1.48 mg g^{-1}. Proline is a heterocyclic amino acid produced by the plants inorder to meet the physiological stress conditions. Due to the accumulation of high proline content in the leaves of *Sphagneticola trilobata* osmotic regulation was attained and enabled the plants to withstand high temperatures and drought thereby protecting the cell wall components and also lowered the rate of dehydration from the leaf surface. Added field level resistance towards the pest and disease was also attained by the plants. The result obtained was in relation with the findings of Da Man *et al*., (2011) who had studied the drought tolerance ability Tall fescue grass and found that during the drought stress conditions there was a decline in quality of turf grasses, relative water content but increase in proline and ABA content resulted in changes of phyto hormones and improved the drought tolerance nature of tall fescues grasses. The lowest proline content of 0.26 mg g^{-1} and 0.20 mg g^{-1} was observed in T_6 in open field and under solar panels respectively.

Soluble protein

The data obtained on the soluble protein content are presented in Table: 8. There is a significant difference in the protein content of the groundcovers. Among the different groundcovers *Sphagneticola trilobata* (T_1) recorded the highest protein content of 75 mg $g^{-1}$and 73 mg g^{-1} in the open field and under solar panels respectively. The protein content increases the RuBisCO enzyme in the stroma of the chloroplast which improves CO_2 fixation during photosynthesis. Due to the higher protein content, green leaves of *Sphagneticola trilobata* remains good with the outstanding performance in their morphological characters throughout the cropping period are positively correlated with the retention of nutrients, chlorophyll content, energy generation and photosynthesis of the plants than the other groundcovers. The findings are in relation with the studies of Colla *et al*. (2017) [5] found that the bio stimulant action of protein hydrolysates enhances the nutrient availability to the plants and protects the plants to withstand biotic and abiotic stress. The groundcover zebrina had registered the lowest protein content of 35 mg g^{-1} and 40 mg g^{-1} under solar panels and open field respectively.

Nitrate reductase activity

The data on the nitrate reductase activity are tabulated in Table :9 and it is found that (T_1) recorded the highest enzyme activity 155 µg NO_2 g^{-1} hr^{-1} in the open field and under solar panels the species *Sphagneticola trilobata* registered 150 µg NO_2 g^{-1} hr^{-1}.Nitrate is the major source for N and it is a signaling molecule that influences growth and differentiation and the due to the presence of higher amount of the enzyme activity (T_1) showed increased growth than the others. Added the enzyme promotes the drought tolerance ability to the plants due to which the *Sphagneticola trilobata* plants are able to tolerate with the limited irrigation and are able to survival under the solar panels as well as in the direct sun without any loss in morphological characters. The results are in accordance with the findings of Kaiser *et al*. (2001) [6] and indicates that NR is more active in the leaves in the light than dark and promotes pathogen and stress signaling mechanism in plants. The lowest enzyme activity of 55 µg NO_2 g^{-1} hr^{-1} and 50 µg NO_2 g^{-1} hr^{-1} was observed in T_6 in both the growing conditions.

Table 1: Weed count in open field and under panels at different days after planting (no./m^2)

Ground cover	30 DAP		60 DAP		90 DAP		120 DAP	
	Open Field	Under Solar Panels	Open Field	Under Solar Panels	Open Field	Under Solar Panels	Open Field	Under Solar Panels
T_1 – *Sphagneticola trilobata*	7.16	6.02	6.80	5.20	6.02	4.38	3.54	3.37
T_2 - *Callisia repens*	7.34	6.15	7.15	5.18	6.42	4.54	5.17	4.16
T_3 – *Setcreasea purpurea*	7.33	6.20	7.11	5.17	6.19	4.55	4.70	3.98
T_4- *Aptenia cordifolia*	7.36	6.03	7.14	5.22	6.42	4.43	5.24	3.63
T_5- *Lantana sellowiana*	7.34	6.02	7.03	5.12	6.25	4.38	4.91	3.63
T_6- *Tradescantia flumiensis Zebrina*	7.66	6.03	7.01	5.23	6.43	4.54	5.20	3.59
T_7 – *Plectranthus prostratus*	7.67	6.05	7.02	5.22	6.26	4.54	5.21	4.10
T_8- *Hemigraphis colorata*	7.71	6.20	7.03	5.19	6.26	4.44	5.25	3.66
T_9 – *Stylosanthes hamata*	7.63	6.21	7.00	5.19	6.43	4.46	5.25	3.50
T_{10}- Control	7.75	6.16	7.53	5.31	6.92	5.08	5.34	4.50
Mean	7.49	6.10	7.08	5.20	6.36	4.53	4.98	3.81

	GC	GE	GC×GE	GC	GE	GC×GE	GC	GE	GC×GE	GC	GE	GC×GE
SE.d	0.0201	0.0366	0.0284	0.0162	0.0329	0.0229	0.0252	0.0410	0.0356	0.094	0.0794	0.0229
CD(0.05)	0.0407	0.0741	0.0576	0.0328	0.0666	0.0464	0.0510	0.0830	0.0722	0.1916	0.1608	0.0464

Table: 2: Plant spread in East-West direction at different days after planting (cm)

Ground cover	30 DAP		60 DAP		90 DAP		120 DAP	
	Open Field(F)	Under Solar Panels	Open Field	Under Solar Panels	Open Field	Under Solar Panels	Open Field	Under Solar Panels
T_1 – *Sphagneticola trilobata*	29.10	27.54	103.80	113.93	167.00	138.89	197.00	189.30
T_2 - *Callisia repens*	20.92	24.27	44.88	48.09	45.81	54.42	52.25	63.30
T_3 – *Setcreasea purpurea*	19.99	21.10	32.61	35.75	42.60	43.06	47.00	58.30
T_4- *Aptenia cordifolia*	16.94	18.91	47.40	38.17	53.51	47.17	68.60	64.30
T_5- *Lantana sellowiana*	25.07	23.21	53.61	56.95	60.20	61.61	69.89	72.50
T_6- *Tradescantia flumiensis Zebrina*	15.82	18.56	39.81	39.08	42.11	66.60	59.60	75.20
T_7 – *Plectranthus prostratus*	19.64	18.45	49.41	45.86	51.44	53.61	57.40	65.30
T_8- *Hemigraphis colorata*	13.93	20.37	31.61	40.05	43.72	38.89	50.80	43.20
T_9 – *Stylosanthes hamata*	10.14	6.16	26.88	15.49	33.20	25.17	35.80	28.20
T_{10}- Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	17.16	17.86	43	43.34	53.96	52.94	63.83	65.96

	GC	GE	GC×GE	GC	GE	GC×GE	GC	GE	GC×GE	GC	GE	GC×GE
SE.d	0.3054	0.1427	0.4320	0.7360	0.2215	1.0409	1.1247	0.2738	1.5906	1.2608	0.2899	1.7831
CD(0.05)	0.6184	0.2888	0.8745	1.490	0.4484	2.1072	2.2768	0.5543	3.2200	2.5525	0.5869	3.6098

Significant at 5% level of significance
GC-Ground cover, GE – Growing Environment

Table 3: Plant spread in North-South direction at different days after planting (cm)

Ground cover	30 DAP		60 DAP		90 DAP		120 DAP	
	Open Field	Under Solar Panels	Open Field	Under Solar Panels	Open Field	Under Solar Panels	Open Field	Under Solar Panels
T_1 – *Sphagneticola trilobata*	26.90	26.72	114.90	98.29	137.29	133.89	147.67	149.44
T_2 - *Callisia repens*	21.53	25.00	43.48	45.83	45.31	52.27	51.75	62.75
T_3 – *Setcreasea purpurea*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_4- *Aptenia cordifolia*	13.98	15.94	51.98	39.55	53.72	42.48	63.60	67.75
T_5- *Lantana sellowiana*	20.39	20.05	52.89	54.78	64.06	57.17	60.80	58.75
T_6- *Tradescantia flumiensis Zebrina*	15.13	19.62	44.11	42.56	38.50	46.47	62.40	50.00
T_7 – *Plectranthus prostratus*	21.19	16.21	46.19	43.89	48.56	50.11	59.60	64.75
T_8- *Hemigraphis colorata*	14.37	20.02	31.45	36.39	44.22	39.37	45.20	42.20
T_9 – *Stylosanthes hamata*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

T$_{10}$- Control	0.00		0.00	0.00		0.00	0.00		0.00	0.00		0.00
Mean	13.35		14.36	25.02		37.07	43.17		42.17	49.10		49.56
	GC	GE	GC*GE	GC	GE	GC*GE	GC	GE	GC*GE	GC	GE	GC*GE
SE.d	0.1924	0.1132	0.2721	0.5380	0.1893	0.7609	0.6662	0.2107	0.9421	1.0645	0.2663	1.5054
CD(0.05)	0.3896	0.2293	0.5509	1.0892	0.3834	1.5404	1.3486	0.4266	1.9072	2.1549	0.5392	3.0476

Significant at 5% level of significance
GC-Ground cover, GE – Growing Environment

Table 4: Time taken for 50% and 100% coverage of plants in open field and under panels (Days)

Ground cover	**50 % coverage**			**100% coverage**		
	Open Field		**Under Solar Panels**	**Open Field**		**Under Solar Panels**
T$_{1}$ – *Sphagneticola trilobata*	40		45	65		70
T$_{2}$ - *Callisia repens*	50		40	80		75
T$_{3}$ – *Setcreasea purpurea*	65		60	85		90
T$_{4}$- *Aptenia cordifolia*	85		90	110		120
T$_{5}$- *Lantana sellowiana*	65		70	100		95
T$_{6}$- *Tradescantia flumiensis Zebrina*	110		95	120		110
T$_{7}$ – *Plectranthus prostratus*	60		70	80		90
T$_{8}$- *Hemigraphis colorata*	90		80	105		95
T$_{9}$ – *Stylosanthes hamata*	60		75	80		90
T$_{10}$- Control	0		0	0		0
Mean	62.5		65.5	82.5		83.5
	GC	GE	GC×GE	GC	GE	GC×GE
SE.d	1.0240	0.2612	1.4482	1.3284	0.2975	1.8787
CD(0.05)	2.0730	0.5289	2.9317	2.6893	0.6024	3.8033

Significant at 5% level of significance
Ground cover, GE – Growing Environment

Table: 5: Effect of different growing environment on leaf area of different groundcovers (cm^{2})

Ground cover	**30 DAP**			**60 DAP**			**90 DAP**			**120 DAP**		
	Open Field		**Under Solar Panels**	**Open Field**		**Under Solar Panels**	**Open Field**		**Under Solar Panels**	**Open Field**		**Under Solar Panels**
T$_{1}$ – *Sphagneticola trilobata*	13.13		10.5	16.69		13.8	19.7		17.12	22.4		20.65
T$_{2}$ - *Callisia repens*	0.65		0.62	0.87		0.84	0.96		0.92	1.34		1.23
T$_{3}$ – *Setcreasea purpurea*	32.88		27.05	47.53		38.64	50.81		43.36	54.81		51.65
T$_{4}$- *Aptenia cordifolia*	5.23		4.38	7.84		6.72	10.08		8.38	13.64		12.34
T$_{5}$- *Lantana sellowiana*	3.58		3.52	6.72		6.13	8.54		7.23	10.44		8.46
T$_{6}$- *Tradescantia flumiensis Zebrina*	12.08		11.62	14.24		14.62	15.97		15.83	16.82		16.92
T$_{7}$ – *Plectranthus prostratus*	1.98		1.66	2.58		2.28	2.86		2.64	3.24		3.12
T$_{8}$- *Hemigraphis colorata*	15.93		16.89	21.52		23.28	26.44		28.72	30.84		32.64
T$_{9}$ – *Stylosanthes hamata*	0.64		0.62	0.89		0.82	1.13		1.06	1.26		1.24
T$_{10}$- Control	0		0	0		0	0		0	0		0
Mean	8.61 13.649		7.686	11.88		10.713	13.649		12.526	15.479		14.825
	GC	GE	GC×GE	GC	GE	GC×GE	GC	GE	GC×GE	GC	GE	GC×GE
SE.d	0.2010	0.1156	0.2843	0.2604	0.1317	0.3682	0.3771	0.1585	0.5333	0.1838	0.1106	0.2599
CD(0.05)	0.4070	0.2343	0.5755	0.5271	0.2667	0.7455	0.7634	0.3209	1.0796	0.3721	0.2240	0.5262

Significant at 5% level of significance
GC-Ground cover, GE – Growing Environment

Table 6: Effect of different growing conditions of different groundcovers on total chlorophyll content (mg g^{-1})

Groundcovers	**Open environment**		**Under Solar panels**
T$_{1}$ – *Sphagneticola trilobata*	1.92		1.96
T$_{2}$ - *Callisia repens*	1.25		1.38
T$_{3}$ – *Setcreasea purpurea*	1.38		1.45
T$_{4}$- *Aptenia cordifolia*	1.47		1.57
T$_{5}$- *Lantana sellowiana*	1.76		1.84
T$_{6}$- *Tradescantia flumiensis Zebrina*	1.33		1.43
T$_{7}$ – *Plectranthus prostratus*	1.65		1.71
T$_{8}$- *Hemigraphis colorata*	1.01		1.25
T$_{9}$ – *Stylosanthes hamata*	1.54		1.68
T$_{10}$- Control	0		0
Mean	1.33		1.43
	GC	GE	GC × GE
SE.d	0.0196	0.0361	0.0277
CD (0.05)	0.0396	0.0731	0.0561

Significant at 5% level of significance
GC-Ground cover, GE – Growing Environment

Table 7: Effect of different growing environment of different groundcovers on proline content (mg g^{-1})

Groundcovers	Open environment		Under solar panels
T_1 – Sphagneticola trilobata	1.56		1.48
T_2 - Callisia repens	0.40		0.24
T_3 – Setcreasea purpurea	1.04		0.84
T_4- Aptenia cordifolia	0.58		0.36
T_5- Lantana sellowiana	1.32		1.02
T_6- Tradescantia flumiensis Zebrina	0.26		0.20
T_7 – Plectranthus prostratus	0.76		0.48
T_8- Hemigraphis colorata	0.32		0.56
T_9 – Stylosanthes hamata	0.88		0.72
T_{10}- Control	0		0
Mean	0.712		0.590
	GC	GE	GC × GE
SE.d	0.0107	0.0268	0.0152
CD (0.05)	0.0218	0.0542	0.0308

Significant at 5% level of significance
GC-Ground cover, GE – Growing Environment

Table 8: Effect of different growing environment of different groundcovers on soluble protein content (mg g^{-1})

Groundcovers	Open environment		Under solar panels
T_1 – Sphagneticola trilobata	75		73
T_2 - Callisia repens	40		35
T_3 – Setcreasea purpurea	66		62
T_4- Aptenia cordifolia	55		41
T_5- Lantana sellowiana	70		69
T_6- Tradescantia flumiensis Zebrina	33		30
T_7 – Plectranthus prostratus	48		57
T_8- Hemigraphis colorata	50		53
T_9 – Stylosanthes hamata	59		45
T_{10}- Control	0		0
Mean	49.6		46.5
	GC	**GE**	**GC × GE**
SE.d	0.8550	0.2387	1.2092
CD (0.05)	1.7309	0.4833	2.4479

Significant at 5% level of significance
GC-Ground cover, GE – Growing Environment

Table 9: Effect of different growing environment of different groundcovers on nitrate reductase activity (µg NO_2 g^{-1} hr^{-1})

Groundcovers	Open environment		Under solar panels
T_1 – Sphagneticola trilobata	155		150
T_2 - Callisia repens	95		80
T_3 – Setcreasea purpurea	115		110
T_4- Aptenia cordifolia	85		60
T_5- Lantana sellowiana	130		125
T_6- Tradescantia flumiensis Zebrina	55		50
T_7 – Plectranthus prostratus	75		70
T_8- Hemigraphis colorata	65		105
T_9 – Stylosanthes hamata	105		90
T_{10}- Control	0		0
Mean	88		84
	GC	GE	GC × GE
SE.d	0.0012	0.0092	0.0018
CD (0.05)	0.0026	0.0187	0.0036

Significant at 5% level of significance
GC-Ground cover, GE – Growing environment

Conclusion

The results revealed that among the nine different groundcovers grown under the solar panels and in open field condition, (T_1) *Sphagneticola trilobata* is highly suitable for growing in both the environmental conditions and the morphological, physiological parameters recorded during the study period reveals that the alleopathic nature and dense coverage with increased aesthetic appeal made by the plants had decreased the weed population to a greater extent and the use of groundcovers for weed control in the solar farms has a greater potential in terms of environmental safety and reducing the labour requirements. Added the dense canopy cover and the root system of the crops reduce the soil erosion to some extent thereby reducing the soiling level over the photovoltaic modules. Apart from the above benefits growing of crops under the solar panels produces a cooling effect because of the evaporation by the crops and lowers the high temperature of the modules during the peak summer months and will improve the efficiency of the solar panels.

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