Mysore J. Agric. Sci., 59 (2) : 284-291 (2025)

Identification of Drought Tolerant Tea in Bi-parental Mapping Population Based on Photosynthetic Parameters

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Received : October 2024
Accepted : December 2024

Abstract

Tea in south India is grown as a rainfed crop in the western ghats. Due to climate change, the tea growing regions in south India receive excessive rainfall during the monsoon seasons. In spite of the high rain fall with more number of wet days, absence of the summer showers leads to severe drought for a period of 90-120 days. An attempt is made to screen the F_1s developed through controlled hybridization program between UPASI-9 which is a proven drought tolerant tea clone and TRI-2024 which is a drought susceptible tea clone introduced from Sri Lanka. For identifying F_1s with drought tolerance, two important photosynthetic parameters, net photosynthetic rate (Pn) and water use efficiency (WUE) were observed for screening the progenies. Out of the 100 F_1s evaluated for drought tolerance, 28 F_1s recorded high net photosynthetic rate (Pn) ranging from 4.00 to 5.10 ((CO^2) $m^{-2}S^{-1}$) and high water use efficiency (WE) ranging from 4.00 to 4.62 (A/E) when compared to the drought susceptible parent TRI-2024.

Keywords : F1 progenies, Hybridization in tea, High photosynthetic efficiency breeding, Tea germplasm

Tea (*Camellia sinensis* L.) is cultivated in a total area of 5318305 hectares all over the world and the global production for the year 2024 was reported as 6604 million kg (Anonymous, 2024). Out of the total area of 6,19,773 hectares of tea in India 1,13,000 hectares of tea is cultivated in the western ghats in the states of Tamilnadu, Kerala and Karnataka. Annual production of tea in south India is reported as 236 million kg in the year 2023. In Tamilnadu total tea production is reported as 167.40 million kg from a total cultivated area of 63913 hectares (Anonymous, 2024). All over the world, adverse impacts of climate change are reported (Srinivasa Reddy *et al*., 2023; Krishna Murthy and Monali Raut, 2024). Due to the climate change, rain fall pattern in the tea growing areas in the western ghats is also adversely affected. The tea growing areas in south India are experiencing prolonged period of drought from end November/ mid-December to end April/ May due to the absence of summer rains in the months of February/ March to May. Since Tea is grown as a rainfed crop in Coimbatore District of Tamilnadu, Idukki districts of Kerala and Chickmangalur District of Karnataka these plantation districts experience recurring drought during the summer months (Ranjith and Ilango, 2017). Similar to south India the tea growing regions of Sri Lanka also experience drought in the months of January and February due to erratic summer rains (Damayanthi *et al*., 2017).

Though the onset of south west monsoon is more or less on-time during the first week of June, the tea growing regions in western- ghats receive excessive rainfall due to both south west and north east monsoons. In spite of the high rain fall with more number of wet days, absence of the summer rains leads to severe drought. Out of the total annual production 236 million kg of tea about 37 per cent of the crop is harvested during the drought months. Therefore, there is a need to intensify the clonal selection program to develop drought tolerant tea cultivars through breeding. Among the F_1s raised through breeding, once a single F_1 progeny is identified for drought tolerance, it can be multiplied in large number through vegetative propagation and cultivated for commercial purpose. Many researchers have reported that drought reduced tea production by 14 to 33 per cent and caused 6 to 19 per cent of plan deaths (Cheruiyot *et al*., 2010).

Botany and Plant improvement division of UPASI Tea Research Institute, during the last six decades has developed 33 tea cultivars. Out of this, only UPASI-2, UPASI-6 and UPASI-9 have been proved to be drought tolerant cultivars (Satyanarayana *et al*., 1992). All the other clones were developed for their high yield and superior quality. During the 1970s many tea clones were introduced in to south India from Sri Lanka. Some of the popular clones are TRI-2023, TRI-2024, TRI-2025, TRI-2026 and TRI-2043.

During the 80s TRI-2024 and TRI-2025 were extensively used for controlled hybridization program for developing biclonal seed stocks (Satyanarayana and Sharma, 1991). Among these F_1 population, 100 numbers of F_1s developed through breeding of UPASI-9 (Female parent) x TRI-2024 (Male parent) were maintained in the field germplasm of UPASI Tea Research Institute, Valparai, which is recognized as the 41st National Active Germplasm Site (NAGS) by NBPGR, New Delhi. The clone UPASI-9 (Female parent) is a proven drought tolerant tea cultivar (Satyanarayana *et al*., 1992) and TRI-2024 (Male parent) is a proven drought susceptible tea cultivar. These 100 F_1s were screened for their drought tolerance in the field for a period of four years.

Material and Methods

The experiment was conducted at UPASI Tea Research Institute Experimental Farm, located in Valparai, Coimbatore district, Tamil Nadu. The Experimental Farm is situated at a latitude of 10 f 15.960 f N and a longitude of 076 f 58.033 E, at an altitude of 1050 m above mean sea level, in the western ghats of South India. All the F_1 progenies were planted in the Tea Experimental Farm following a Randomized Complete Block Design (RCBD). All the 100 numbers of F_1s were monitored for the photosynthetic parameters of stomatal conductance (Gs), water use efficiency (WUE), net photosynthetic rate (Pn), transpiration rate (Tr) and number of crop shoots/ 30cm^2 during the drought seasons of December to April from 2020 to 2024 and the mean values were considered for statistical analysis. As reported by many researchers, these four months are the drought season for south India (Satyanarayana *et al*., 1992). Therefore, all the photosynthetic parameters were observed during these four months.

Gas Exchange Parameters

Gas exchange parameters were measured on the fully matured fourth leaf of the growing crop shoots using TARGAS-1 PP system. Stomatal conductance (Gs), water use efficiency (WUE), net photosynthetic rate (Pn), transpiration rate (Tr) were recorded during the peak of the drought period. Photosynthetic parameters were observed between 11.00 am to 1.00 pm during the month of February and March when the plants were under severe moisture stress. Number of crop shoots was recorded by placing a quadrat of 30cm^2 on the centre of canopy of the tea bush during the month of February and March.

Statistical Analysis

Statistical analysis was performed using Graph pad Prism version 8.0. the data were expressed as the mean values from duplicates test, along with the standard deviation (SD) of the mean. The following statistical methods were employed.

Two-way Analysis of Variance (ANOVA) : was used to evaluate the significance of differences between groups based on two independent variables. This method allows for the analysis of the interaction between the two variables, as well as main effects of each variables individually. The significance of the results was assessed at a significance level of ($P \leq 0.0001$).

Post- hoc analysis (Fisher´s least significant difference - LSD : For cases where significant differences were found ($P \leq 0.0001$) using two way Anova, Fisher´s least significant difference (LSD) test was used to perform pairwise comparisons of the means. The test helps to identify which specific groups differ from each other in terms of their mean values. The fisher LSD method is a commonly used post-hoc test when Anova indicates significant differences, controlling for type I error.

Standard Deviation (SD) : The variability with in each group was represented by the standard deviation (SD), which indicates how spread out the data points are from the mean.

RESULTS AND DISCUSSION

Differences of Photosynthetic Parameters Among the F_1 Progenies

The surviving 100 F_1s were observed for the photosynthetic parameters and number of crop shoots/ 30 cm^2 during the drought periods for four years. Significant differences were observed in Pn, Tr, Gs, WUE and number of crop shoots/30 cm^2 among the F_1s (Table 1). In all the F_1s identified for drought tolerance, the observed physiological parameters like stomatal conductance (Gs), water use efficiency (WUE), net photosynthetic rate (Pn) and transpiration rate (Tr) were high. Stomatal conductance ranged from 25-132, water use efficiency minimum 1.10 to maximum 4.62, net photosynthetic rate minimum 1.11 to maximum 5.10 and transpiration rate minimum 1.12 to maximum 4.98 (Table 1). All the F_1 progenies identified for drought tolerance were able to grow even during the moisture stress period and produced more number of crop shoots per unit area.

TABLE 1

Variance of photosynthetic parameters and number of crop shoots for the F_1 population

Parameters	Source of variance	Df	SS	MS	F Value	Mean ± SD	CV	Range
	Among the F_1s	99	136900	112158	9.044	68.51 ± 37.36	54.43	25 - 132
Gs	Error	1	2643	-	-	-	-	-
	Total	100	139543					
	Among the F_1s	99	139.4	1.408	2.229	2.88 ± 1.18	41.01	1.10 - 4.62
WUE	Error	1	2.82	-	-	-	-	-
	Total	100	141.82					
	Among the F_1s	99	148.1	1.495	1.668	2.94 ± 1.22	41.41	1.11- 5.10
Pn	Error	1	7.42	-	-	-	-	-
	Total	100	156.72					
	Among the F_1s	99	151	1.525	4.215	2.89 ± 1.23	42.47	1.12 - 4.98
Tr	Error	1	4.86	-	-	-	-	-
	Total	100	156.92					
No.of crop	Among the F_1s	99	10011	101.1	8.972	20.10 ± 10.01	49.78	06 - 37
shoots/30 cm^2	Error	1	1521	-	-	-	-	-
	Total	100	16038					

TABLE 2

Correlation coefficients among photosynthetic parameters and number of crop shoots for the F_1 population

Parameters	Gs	WUE	Pn	Tr	No.of crop shoots/30 cm^2
Gs	-	0.9088 ****	0.8898 ****	0.9249 ****	0.9071 ****
WUE	0.9088 ****	-	0.9283 ****	0.9544 ****	0.9447 ****
Pn	0.8898 ****	0.9283 ****	-	0.9349 ****	0.9222 ****
Tr	0.9249 ****	0.9544 ****	0.9349 ****	-	0.9588 ****
No.of crop shoots/30 cm^2	0.9071 ****	0.9447 ****	0.9222 ****	0.9588 ****	-

****Significant at $P < 0.0001$

Drought has become one of the serious problems in tea production in south India. Therefore, the aim of the present study was to breed tea clones with high Pn and WUE. Many tea breeders have reported that the combination of these two factors is an objective in high photosynthetic efficiency breeding (HPE) (Fang *et al*., 2008). In the present study, the differences in photosynthetic parameters are significant among F_1s (Table 1). In the parental combination UPASI-9 x TRI-2024 provided an opportunity to identify 28 F_1s with drought tolerance in the programme of high photosynthetic efficiency breeding (HPE) in tea in south India.

Correlation Coefficient among the Photosynthetic Parameters

Correlation analysis indicated that Pn is positively correlated with WUE and Gs ($P < 0.0001$). Significantly positive correlations were also observed between Tr and Gs, Gs and WUE and WUE and number of crop shoots/ 30 cm^2 (Table 2).

All the observed four physiological parameters stomatal conductance (Gs), water use efficiency (WUE), net photosynthetic rate (Pn) and transpiration rate (Tr) were higher in the female parent UPASI-9 and low in male parent TRI-2024 (Table 3). The drought tolerant characters of the female parent UPASI- 9 are also proved by production of more number of numbers of crop shoots during the drought period and drought susceptible characters of male parent TRI-2024 production of low number of crop shoots during the drought period (Table 3).

Clustering Analysis Based on Stomatal Conductance (Gs)

Cluster hierarchical indicated that the 100 F_1s, were classified into six groups based on stomatal conductance (Gs). Group I was characterized with high Gs and consisted of 16 F_1s. Group II contained 12 F_1s with relatively high Gs. Group III was with medium Gs, which contained 8 F_1s. Group IV contained 8 F_1s with relatively medium Gs. Group V

TABLE 3

Photosynthetic parameters and number of crops shoots of F_1s

Parents & progenies	GS	WUE	PN	TR	No. of crop shoots/ 30cm^2	Parents & progenies	GS	WUE	PN	TR	No. of crop shoots/ 30cm^2
UPASI-9	139	4.9	5.89	4.98	30	PR-50	49	2.49	2.9	2.56	12
TRI-2024	65	1.93	1.82	1.04	16	PR-51	39	1.75	1.11	1.38	09
PR-1	75	3.39	3.28	3.27	28	PR-52	127	4.31	4.19	4.72	34
PR-2	131	4.08	4.12	4.52	32	PR-53	31	1.68	1.29	1.49	07
PR-3	43	2.43	2.19	2.15	14	PR-54	43	2.38	2.55	2.32	14
PR-4	38	1.99	1.32	1.12	10	PR-55	42	2.65	2.41	2.61	11
PR-5	99	3.98	3.42	3.11	21	PR-56	87	3.12	3.29	3.44	30

Continued....

TABLE 3 Continued....

Parents & progenies	GS	WUE	PN	TR	No. of crop shoots/ 30cm^2	Parents & progenies	GS	WUE	PN	TR	No. of crop shoots/ 30cm^2
PR-6	35	1.34	1.46	1.45	09	PR-57	29	1.99	1.63	1.24	10
PR-7	48	2.12	2.48	2.54	19	PR-58	117	4.48	4.34	4.19	36
PR-8	29	1.10	1.15	1.18	06	PR-59	130	4.31	4.65	4.58	35
PR-9	66	3.42	3.00	3.41	23	PR-60	26	1.24	1.72	1.56	09
PR-10	130	4.12	4.21	4.31	34	PR-61	35	1.19	1.58	1.72	08
PR-11	55	2.58	2.59	2.67	15	PR-62	95	3.19	3.92	3.95	25
PR-12	119	4.25	4.34	4.52	31	PR-63	38	1.37	1.36	1.37	10
PR-13	53	2.34	2.64	2.49	18	PR-64	105	4.26	4.68	4.38	35
PR-14	128	4.51	4.58	4.10	35	PR-65	34	1.82	1.41	1.24	08
PR-15	57	2.13	2.47	2.98	16	PR-66	48	2.49	2.72	2.51	20
PR-16	108	4.61	4.35	4.27	32	PR-67	39	1.46	1.18	1.98	10
PR-17	123	4.34	4.92	4.76	31	PR-68	113	4.19	4.99	4.15	33
PR-18	27	1.23	1.39	1.82	10	PR-69	129	4.08	4.16	4.67	33
PR-19	85	3.35	3.32	3.35	27	PR-70	30	1.75	1.27	1.56	06
PR-20	103	4.51	4.89	4.32	34	PR-71	122	4.21	4.18	4.35	32
PR-21	42	2.75	2.59	2.51	19	PR-72	27	1.59	1.31	1.29	09
PR-22	36	1.14	1.35	1.59	09	PR-73	53	2.72	2.98	2.72	20
PR-23	64	3.29	3.37	3.54	29	PR-74	79	3.48	3.64	3.91	25
PR-24	33	1.31	1.25	1.21	08	PR-75	103	4.21	4.95	4.28	32
PR-25	58	2.49	2.82	2.46	20	PR-76	29	1.21	1.75	1.35	10
PR-26	127	4.24	4.71	4.98	36	PR-77	51	2.67	2.34	2.31	19
PR-27	55	2.38	2.13	2.72	11	PR-78	126	4.54	4.82	4.58	31
PR-28	28	1.36	1.39	1.38	07	PR-79	28	1.42	1.99	1.47	09
PR-29	79	3.02	3.58	3.72	24	PR-80	57	2.13	2.72	2.57	18
PR-30	121	4.48	4.36	4.27	33	PR-81	25	1.61	1.99	1.24	09
PR-31	42	2.59	2.32	2.51	16	PR-82	119	4.12	4.21	4.31	31
PR-32	119	4.60	4.72	4.95	35	PR-83	28	1.54	1.42	1.82	10
PR-33	25	1.29	1.58	1.57	10	PR-84	92	3.05	3.49	3.84	24
PR-34	49	2.68	2.4	2.64	15	PR-85	30	1.72	1.37	1.75	08
PR-35	50	2.72	2.47	2.33	13	PR-86	132	4.62	5.10	4.95	37
PR-36	100	3.07	3.11	3.21	29	PR-87	34	1.91	1.54	1.69	09
PR-37	53	2.41	2.64	2.19	11	PR-88	60	2.71	2.51	2.14	14
PR-38	30	1.58	1.72	1.64	10	PR-89	65	3.59	3.31	3.11	24
PR-39	128	4.26	4.58	4.61	31	PR-90	32	1.33	1.28	1.31	10
PR-40	48	2.56	2.14	2.25	17	PR-91	97	3.80	3.81	3.98	21
PR-41	37	1.49	1.67	1.99	07	PR-92	107	4.30	4.00	4.97	34
PR-42	120	4.33	4.55	4.75	31	PR-93	37	1.38	1.72	2.13	15
PR-43	60	2.81	2.41	2.39	13	PR-94	56	2.31	2.11	1.22	07
PR-44	75	3.23	3.42	3.24	26	PR-95	84	3.92	3.67	3.64	30
PR-45	56	2.99	2.28	2.48	19	PR-96	130	4.00	4.79	4.13	37
PR-46	125	4.18	4.27	4.33	32	PR-97	38	1.46	1.64	1.38	09
PR-47	57	2.81	2.64	2.37	18	PR-98	63	3.64	3.46	3.28	23
PR-48	51	2.72	2.41	2.49	16	PR-99	31	1.58	1.33	1.35	08
PR-49	128	4.16	4.22	4.91	31	PR-100	120	4.46	4.51	4.61	32

PR: Progeny number, Gs: Stomatal conductance (mmol (H_20) m^{-2} S^{-1}), WUE: Water use efficiency (A/E), Pn: Net photosynthetic rate [(Co_2) m^{-2} S^{-1}], Tr: Transpiration rate (mmol (H_20) m^{-2} S^{-1}), No.of crop shoots: Number of crop shoots/30 cm ^{2}

TABLE 4

Clustering analysis based on photosynthetic parameters and number of crop shoots for the F_1 population

Parameters	Group	Progeny number	No.of. Progenies	Frequency (%)	mean ± SD	Range
GS	I	2,10,14,17,26,30,39,46,49,52,59,69,71,78,86,96	16	16	126.63 ± 4.21a	121- 132
	II	12,16,20,32,42,58,64,68,75,82,92,100	12	12	115.92 ± 4.16b	103- 120
	III	5,19,36,56,62,84,91,95	8	8	92.00 ± 4.10c	84-100
	IV	1,9,23,29,44,74,89,98	8	8	70.60 ± 3.95 d	63-79
	V	3,7,11,13,15,21,25,27,31,34,35,37,40,43,45,47, 48,50,54,55,66,73,77,80,88,94	26	26	54.19 ± 3.83e	42-58
	VI	4,6,8,18,22,24,28,33,38,41,51,53,57,60,61,63, 65,67,70,72,76,79,81,83, 85,87,90,93,97,99	30	30	31.57 ± 3.76 f	25- 39
WUE	I	2,10,12,14,16,17,20,26,30,32,39,42,46,49,52,58, 59,64,68,69,71,75,78,82,86,92,96,100	28	28	4.41 ± 0.30a	4.00- 4.62
	II	1,5,9,19,23,29,36,44,56,62,74,84,89,91,95,98	16	16	3.41 ± 0.26 b	3.02- 3.98
	III	3,7,11,13,15,21,25,27,31,34,35,37,40,43,45,47, 48,50,54,55,66,73,77,80,88,94	40	40	2.54 ± 0.24c	2.13- 2.99
	IV	4,6,8,18,22,24,28,33,38,41,51,53,57,60,61,63, 65,67,70,72,76,79,81,83, 85,87,90,93,97,99	30	30	1.47 ± 0.22 d	1.10- 1.99
PN	I	2,10,12,14,16,17,20,26,30,32,39,42,46,49,52, 58,59,64,68,69,71,75,78,82,86,92,96,100	28	28	4.49 ± 0.28 a	4.00- 5.10
	II	1,5,9,19,23,29,36,44,56,62,74,84,89,91,95,98	16	163.48 ± 0.25 b3.00-3.92		
	III	3,7,11,13,15,21,25,27,31,34,35,37,40,43,45,47, 48,50,54,55,66,73,77,80,88,94	40	40	2.49 ± 0.23c	2.11- 2.98
	IV	4,6,8,18,22,24,28,33,38,41,51,53,57,60,61,63, 65,67,70,72,76,79,81,83, 85,87,90,93,97,99	30	30	1.46 ± 0.22d	1.11- 1.99
TR	I	2,10,12,14,16,17,20,26,30,32,39,42,46,49,52, 58,59,64,68,69,71,75,78,82,86,92,96,100	28	28	4.51 ± 0.27 a	4.10-4.98
	II	1,5,9,19,23,29,36,44,56,62,74,84,89,91,95,98	16	16	3.48 ± 0.26b	3.11-3.95
	III	3,7,11,13,15,21,25,27,31,34,35,37,40,43,45,47, 48,50,54,55,66,73,77,80,88,94	40	40	2.43 ± 0.22c	2.13-2.99
	IV	4,6,8,18,22,24,28,33,38,41,51,53,57,60,61,63,65, 67,70,72,76,79,81,83, 85,87,90,93,97,99	30	30	1.47 ± 0.18d	1.12-1.98
No.of crop shoots /30cm^2	I	2,10,12,14,16,17,20,26,30,32,39,42,46,49,52,58, 59,64,68,69,71,75,78,82,86,92,96,100	28	28	33.07 ± 2.11a	31-37
	II	1,5,9,19,23,29,36,44,56,62,74,84,89,91,95,98	16	16	25.56 ± 1.89b	21- 30
	III	3,7,11,13,15,21,25,27,31,34,35,37,40,43,45,47, 48,50,54,55,66,73,77,80,88,94	40	40	15.88 ± 1.75c	11 – 20
	IV	4,6,8,18,22,24,28,33,38,41,51,53,57,60,61,63,65, 67,70,72,76,79,81,83, 85,87,90,93,97,99	30	30	8.73 ± 1.18d	06- 10

was categorized into low Gs, which contained 26 F_1s and Group VI contained 30 F_1s with relatively low Gs (Table 4).

Clustering Analysis Based on Water use Efficiency (WUE)

All the 100 F_1s, were classified into four groups based on their water use efficiency (WUE). Group I had a high WUE, which included 28 F_1s. Group II had a relatively high WUE, which contained 16 F_1s. Group III was medium in WUE, which contained 40 F_1s and Group IV (30 F_1s) had the lowest WUE value (Table 4).

Clustering Analysis Based on Net Photosynthetic Rate (Pn)

On the basis of Photosynthetic rate (Pn), the 100 F_1s, were classified into four groups. Group I was high in Pn, which contained 28 F_1s. Group II was relatively high in Pn, which contained 16 F_1s. Group III was medium in Pn, which contained 40 F_1s and Group IV (30 F_1s) had the lowest Pn value (Table 4).

Clustering Analysis Based on Transpiration Rate (Tr)

According to Transpiration Rate (Tr), four groups were categorized, consisting of 28,16,40 and 30 F_1s, respectively. Group I had the highest Pn rate. Group II contained a relatively high photosynthetic rate. Group III was categorized into medium Pn and Group IV was categorized into low photosynthetic rate (Table 4).

Clustering Analysis Based on Number of Crop Shoots/30 cm²

Based on the number of crop shoots/ 30 cm², the 100 F1s, were classified into four groups. Group I, which was characterized by a high number of crop shoots/ 30 cm², consisted of 28 F_1s. Group II, which had a relatively high number of crop shoots per 30 cm², consisted of 16 F_1s. Group III, which had a medium number of crop shoots per 30 cm², consisted of 40 F_1s. The other 30 F_1s constituted Group IV with a low number of crop shoots/30 cm² (Table 4).

Luo *et al*., (1995) reported that the biomass of tea plant had a significantly positive correlation with Pn. Researchers in Sri Lanka have developed new tea accessions based on the photosynthetic rate, transpiration rate, stomatal conductance, relative water content and total soluble sugar content (Damayanthi *et al*., 2017). Similarly, reports are also available as high WUE is the basic of drought resistance in other crops (Zhu *et al*., 2005). Based on the clustering analysis of Gs, WUE, Pn, Tr and number of crops shoots/ 30 cm² given in (Table 4), all the 100 F_1s, developed through controlled hybridization involving the parental combination of UPASI-9 x TRI-2024 were classified as drought tolerant, relatively drought tolerant, intermediate and

TABLE 5

F_1s identified for drought tolerance, intermediate and drought susceptible based on net photosynthetic rate (Pn), water use efficiency (WUE) and number of crop shoots

Characters	Total number of F_1s	Progeny number	Frequency (%)
Drought tolerant	28	2,10,12,14,16,17,20,26,30,32,39,42,46,49,52,58,59,64,68,69,71,75, 78,82,86,92,96,100	28
Relatively drought tolerant	16	1,5,9,19,23,29,36,44,56,62,74,84,89,91,95,98	16
Intermediate	40	3,7,11,13,15,21,25,27,31,34,35,37,40,43,45,47,48,50,54,55,66,73, 77,80,88,94	40
Drought susceptible	30	4,6,8,18,22,24,28,33,38,41,51,53,57,60,61,63,65,67,70,72,76,79, 81,83, 85,87,90,93,97,99	30
Total	100	-	100

drought susceptible (Table 5). For identifying F_1s with drought tolerance, two important photosynthetic parameters net photosynthetic rate (Pn) and water use efficiency (WUE) were taken as the basis. A total of 28 F_1s (28%) were identified for drought tolerance followed by 16 (16%) for relatively drought tolerant, 40 (40%) as intermediate and 30 (30%) as drought susceptible (Table 5).

Though the tea growing regions in the western ghats receive very high rainfall of up to 500 to 600 cm in a year, irregular distribution within a year cause moisture stress leading to significant crop loss (Karunarathne *et al*., 1999). Damayanthi *et al*., (2017) have reported that for tea in addition to adaptation measures to over come the adverse impacts of drought, planting drought tolerant cultivar is important. The tea breeders have highlighted the importance of selection and breeding to develop genotypes to withstand the impacts of drought conditions and also to maintain productivity during the drought months (Damayanthi *et al*., 2017).

An attempt was made to develop F_1s for drought tolerance through controlled hybridization programme involving the drought susceptible clone TRI-2024 which was introduced from Sri Lanka. A total of 28 F_1s were identified to be drought tolerant based on the two photosynthetic parameters Pn and WUE as well as the production of number of crop shoots during the drought season. The reported controlled hybridization programme was also the first attempt in south India to develop high photosynthetic efficiency breeding in tea (HPE) involving a tea clone introduced from Sri Lanka. All the 28 drought tolerant F_1s are individually multiplied through vegetative propagation in large numbers and planted in the field separately for further screening for their quality.

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