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SCREENING OF GROUNDNUT GENOTYPES FOR HIGH WATER USE EFFICIENCY AND TEMPERATURE TOLERANCE

M. BABITHA, P. SUDHAKAR, P. LATHA, P.V. REDDY* AND R.P. VASANTHI

Department of Plant Physiology, Regional Agricultural Research Station, ANGRAU, Tirupati-517502

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SUMMARY

An experiment was conducted during post rainy season of 2001-02 at Regional Agricultural Research Station, Tirupati with 111 spanish and 110 virginia groundnut genotypes. The genotypes were screened for moisture stress and high temperature tolerance and were classified into 3 groups, viz. low, medium and high for SPAD chlorophyll meter reading (SCMR), SLA, chlorophyll fluorescence ratio and membrane injury. Majority of the spanish genotypes had medium SCMR (45-50) and SLA (125-150), while most of the virginias had high SCMR (>50) and medium SLA (125-150). Majority of the spanish and virginia genotypes screened had high membrane injury of >60%. Significant variation was observed between the genotypes for SCMR, SLA, chlorophyll fluorescence ratio and membrane injury. Spanish genotype TIR-21 showed less reduction in F_v/F_m ratio when exposed to temperatures of 45^{0}C (1.13% reduction) and 55^{0}C (22% reduction), while virginia genotype TIR-34 maintained high F_v/F_m ratio at temperature > 50^{0}C. Genotypes TIR-20 and JAL-31 showed a higher reduction of 84 and 82% respectively in F_v/F_m ratio when exposed to 55^{0}C. Spanish genotype JAL-07 had a low membrane injury (37%). Incidentally, it also maintained high SCMR (52) and low SLA (101.6cm^2 g^{-1}), indicating that it can tolerate both water deficit and high temperature. However, this genotype showed more reduction (62%) in F_v/F_m ratio at 55^{0}C. Virginia groundnut CSMG84-1 showed low membrane injury (34%). Thus the genotypes TIR-21, TIR-34, JAL-07 and CSMG 84-1 are better for higher temperatures and hence can be recommended for the specified situation in order to increase the yield potential under high temperature conditions.

***Key words*: Chlorophyll fluorescence ratio, groundnut, membrane injury, SPAD chlorophyll meter reading, specific leaf area, temperature tolerance**

INTRODUCTION

Groundnut is an important oilseed crop of the semi-arid tropics with average yield of around 0.8 t ha^{-1} which is far below its potential yield of 7 t ha^{-1} (ICRISAT, 1993). Drought, a complex combination of stresses involving both moisture stress and high temperature, is a major constraint in groundnut production (ICRISAT 1994). Identification of genotypes that have a greater ability to use limited water and tolerate high temperatures is thereby important to enhance productivity of the crop. Water-use efficieny (W) is an important trait, which can contribute to productivity when water resources are scarce. While potentially useful, W cannot be easily exploited because of practical difficulties involved in measurement. Recent studies have identified indirect surrogate measurements, specific leaf area (SLA) and soil plant analysis development (SPAD) chlorophyll meter reading (SCMR), which are associated with water use efficiency, particularly in groundnut (Wright *et al.* 1994).

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* Corresponding author

Improvement in high temperature tolerance is considered vital for yield improvement in many regions and cropping systems. Further, high temperature tolerance will be necessary if the frequency of hot weather increases in the future because of global climatic change (Schneider 1989). This change, coupled with an increase in carbon dioxide concentration, may substantially increase the need for high temperature tolerant genotypes throughout the world (Hall 1992). Identification of reliable physiological traits for selection of high temperature tolerant genotypes by utilizing the existing variability among cultivars is therefore, important.

Wide ranges of photosynthetic responses have been reported in response to a concomitant increase in temperature and carbon dioxide (Coleman & Bazzaz 1992). Oxygen evolution and chlorophyll fluorescence are greatly altered by high temperature and widely used as indicators of high temperature injury to the photosynthetic apparatus (Bar-Tsur *et al.* 1985). A conductivity test based on the thermo stability of the plasmalemma has been used to estimate high temperature tolerance in bean (*Phaseolus vulgaris* L.) and other crops (Chaisompongpan *et al.* 1990). The potential of a genotype or species to acclimate to moderately high temperature, thereby reducing high temperature injury (Alexandrov 1964), is an important factor in determining plant performance in high temperature environments. Little research has been done on high temperature tolerance in groundnut. Therefore, a study was conducted during post-rainy season, 2001-02 to screen groundnut germplasm for high temperature tolerance.

MATERIALS AND METHODS

The present experiment was conducted in a replicated trial (in rows of 10 m. length) during post rainy season of 2001-02 at Regional Agricultural Research Station, Tirupati with 111 Spanish and 110 Virginia groundnut genotypes. Virginia genotypes, which are long duration types, were sown ten days earlier to Spanish genotypes.

Chlorophyll fluorescence ratio: Chlorophyll fluorescence was measured at 60 DAS. The procedure used to measure chlorophyll fluorescence characteristics was similar to that of Smillie and Hetherington (1990). For each main unit and replicate, four leaflets of the second fully expanded leaf from the top of the main axis were detached and evenly distributed among four cap tubes containing 1ml. of distilled water. Four more leaflets from each of the additional plants were detached and distributed among the four tubes. One tube was designated for each of the three different high temperature treatments (45°C, 50°C and 55°C). The tube, which was not heated, was treated as control. The tubes were capped and placed in water baths maintained at selected temperatures for 5 min. After the high temperature treatment, leaves were dark adapted for 30 min. at room temperature. Chlorophyll fluorescence was recorded with a fluorescence measurement system (Handy PEA, Hansatech Electronics Ltd., UK). Fiber optic cables connected to a Bjorkman lamp were used to send actinic light and saturating light pulses. The equipment detected fluorescence signal at 695nm. and the output was read on a computer. Initial (F_0) and maximum (F_m) fluorescence values were recorded. Variable fluorescence (F_v) was derived by subtracting F_0 from F_m. Ratio of F_v to F_m was calculated to determine the degree of thermo inhibition (Havaux 1993).

Electrolyte leakage test to measure cell membrane thermostability (MT): Cell membrane thermostability was measured using the procedure described by Martineau *et al*. (1979). Each assay sample consisted of two sets of twelve-leaf discs cut with a 1.2cm. diameter punch from twelve leaflets from the fully expanded leaves at the uppermost two nodes of each plant. Before each assay, the two paired sets of leaf discs were placed into two separate test tubes and washed thoroughly with atleast four changes of distilled water to remove exogenous electrolytes and electrolytes released from cut cells at the periphery of the discs. The excess water was removed from the tubes, and the tubes covered with plastic film. One set of discs was then incubated for 15min at 55^0C in a temperature-controlled water bath while the other set was maintained at room temperature (control). The justification for temperature of 55^0C being used in this study for assessing acclimation to high temperature stress is based on previous studies which suggested that high temperature stress of 54^0C in groundnut (Srinivasan *et al.* 1996) is most appropriate to distinguish genotypes within each crop on the basis of membrane injury in the leaf tissue. After the temperature treatment, the incubated tubes were quickly cooled to room temperature before adding distilled water to both sets of tubes. The tubes were then placed in an incubator for 18hrs at 10^{0}C to allow leakage of electrolytes from the discs. The tubes were then brought back to room temperature, inverted several times to mix the contents, and an initial measurement of solution conductance made using an electrical conductivity meter (CM 180, ELICO, India), after which the tubes were covered with aluminum foil and autoclaved at 120^{0}C for 10min. to kill the leaf tissues. The autoclaved tubes were cooled to room temperature, the contents mixed thoroughly, and a second conductance measurement taken. Membrane thermostability was expressed as relative injury (RI) from the following calculation:

$$\mathrm{RI}\ (\%) = [1-(1-(T_i/T_f))/(1-(C_i/C_f))]\ \mathrm{x}100$$

T and C refer to the conductances of the treatment and control solutions, respectively, and the subscripts i and f to initial and final conductance, respectively. The ratio of initial to final conductance (T_i/T_f) is a relative measure of electrolyte leakage caused by elevated temperatures, and consequently a measure of the extent of damage to cellular membranes; it should reflect the injury to the cell membrane at the elevated temperature.

Specific leaf area (SLA) and SPAD chlorophyll meter reading (SCMR): Observations on SPAD Chlorophyll Meter Reading (SCMR) and SLA were recorded on the second fully expanded leaf from the apex on the main axis. SCMR was recorded with Minolta 502 SPAD Chlorophyll Meter. SLA was calculated from the measured values of leaf area (using LI-COR-3100 leaf area meter) and leaf dry weight and expressed as cm^2 g^{-1}.

RESULTS AND DISCUSSION

Spanish (111) and virginia (110) groundnut genotypes screened for moisture stress and high temperature tolerance using SCMR, SLA, chlorophyll fluorescence ratio and cell membrane thermostability (Table 1a and 1b). The genotypes were classified into 3 groups, viz. low, medium and high for SCMR, SLA, chlorophyll fluorescence ratio and membrane injury % (Table 2). Majority of the spanish genotypes had medium SCMR (45-50) and SLA (125-150), while most of the virginias had high SCMR (>50) and medium SLA (125-150). Majority of the genotypes screened (both spanish and virginias) had high membrane injury of >60%. Significant variation was observed between the genotypes for all the parameters tested (Table 1). Genotypic variation for water use efficiency traits (Reddy *et al*. 2003) and high temperature tolerance (Talwar *et al*. 1999) has been reported in diverse groundnut genotypes. This shows the possibility of selection of superior genotypes under water stress and high temperature environments. Selection of best genotypes for high water use efficieny and temperature tolerance was done based on the mean values of the genotypes (Table 3). The results of top five ranked genotypes for SCMR, SLA, chlorophyll fluorescence ratio and membrane injury are given in Table 4.

Chlorophyll fluorescence ratio: Exposure of groundnut genotypes to high temperature stress of 45 to 55^{0}C caused a depression of quantum efficiency as indicated by a reduction in F_v/F_m (Fig.1). High temperature stress of 50^{0}C for 5min. was sufficient to cause 50% thermoinhibition as indicated by the decrease in F_v/F_m ratio. The justification for temperatures of 45^{0}C or above being used in this study for assessing acclimation to high temperature stress is based on previous studies, which suggested that high temperature stress of 50^{0}C in cabbage (*Brassica oleracea* L.) (Hossain *et al*. 1995) and 54^{0}C in groundnut (Srinivasan *et al*. 1996)

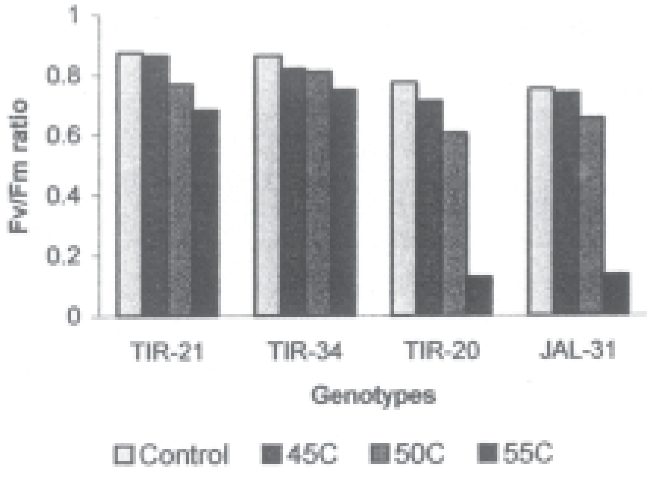

Fig. 1. Chlorophyll fluorescence ratio (Fv/Fm) in groundnut genotypes as influenced by high temperatures

Table 1a. SPAD chlorophyll meter reading (SCMR), specific leaf area (SLA), relative injury (RI) and chlorophyll fluorescence ratio in Spanish groundnut germplasm

Germplasm	SCMR	SLA	RI	Chlorophyll fluorescence ratio			
				Control	45^0C	50^0C	55^0C
ICGV 86031	45.6	125.0	85.1	0.8345	0.7623	0.5382	0.2765
JUG-09	44.8	140.7	85.9	0.8045	0.7819	0.4592	0.2886
JUG-42	42.6	111.2	88.7	0.8259	0.7658	0.4701	0.3602
TIR-18	48.1	128.0	80.9	0.8024	0.7225	0.5335	0.3176
JAL-42	46.1	122.4	85.6	0.8174	0.7348	0.5290	0.2667
TIR-16	45.2	141.3	84.0	0.8172	0.7367	0.6884	0.2574
JAL-41	46.8	127.2	67.2	0.8045	0.7796	0.6188	0.4266
TIR-17	48.3	123.9	76.4	0.8150	0.7798	0.5690	0.3230
JAL-09	46.7	126.9	80.0	0.7762	0.7288	0.5871	0.5549
JAL-20	47.5	105.4	82.3	0.8213	0.6461	0.6453	0.3930
TIR-42	46.9	133.5	85.6	0.7844	0.7683	0.5842	0.2338
JUG-41	48.7	126.5	79.3	0.7934	0.7814	0.6215	0.3546
TIR-15	48.5	121.7	65.1	0.7287	0.7196	0.6567	0.2346
JUG-38	49.1	120.4	61.1	0.7875	0.7478	0.6167	0.2886
ICR-19	46.4	135.3	49.7	0.8280	0.7680	0.6853	0.2117
JAL-08	46.7	111.1	53.1	0.8068	0.6766	0.4892	0.1593
ICR-41	46.7	120.4	44.2	0.8126	0.7946	0.7372	0.2172
JAL-38	49.9	124.5	50.5	0.8422	0.8249	0.6484	0.2737
JUG-20	49.5	124.9	53.9	0.8069	0.7906	0.7598	0.3786
JAL-07	52.0	101.6	37.1	0.8305	0.8116	0.6953	0.3147
TIR-14	46.7	109.8	42.1	0.8350	0.7822	0.6624	0.3436
JAL-37	47.9	104.9	47.4	0.7736	0.6775	0.4213	0.2100
JUG-21	44.8	140.5	48.9	0.7381	0.7242	0.6498	0.3611
JUG-37	48.7	145.5	74.9	0.8205	0.7916	0.6220	0.4144
JAL-19	48.5	121.7	73.6	0.7260	0.5533	0.4855	0.1412
ICR-09	48.2	141.2	69.7	0.8120	0.7678	0.6053	0.3871
JUG-39	45.8	145.0	64.1	0.8365	0.8005	0.6854	0.3234
JUG-40	46.4	134.4	74.5	0.8148	0.7208	0.5804	0.4505
JUG-07	48.3	116.5	72.8	0.8471	0.7935	0.6487	0.4098
TIR-41	47.2	122.1	63.7	0.8103	0.7374	0.6632	0.3817
ICR-38	46.4	146.6	66.2	0.8199	0.7706	0.6891	0.4272
JUG-08	44.6	143.8	71.8	0.8194	0.7177	0.6170	0.2461
ICR-08	46.6	104.2	79.0	0.8391	0.7637	0.5459	0.3769
ICR-37	45.4	145.6	67.7	0.8234	0.7703	0.6737	0.2530
ICR-42	49.9	142.4	93.9	0.8298	0.7827	0.6720	0.2582
ICR-40	46.7	142.9	93.3	0.8288	0.7220	0.5754	0.1846
TIR-40	47.0	149.9	90.8	0.8318	0.7818	0.6135	0.2670
ICR-20	47.7	138.5	91.7	0.8386	0.7676	0.5936	0.2119
TIR-39	47.9	166.4	91.3	0.8266	0.8092	0.5900	0.3463

Germplasm	SCMR	SLA	RI	Chlorophyll fluorescence ratio			
				Control	45^{0}C	50^{0}C	55^{0}C
ICR-39	44.2	117.7	90.7	0.8382	0.8191	0.6260	0.2737
TIR-13	47.3	131.9	91.6	0.8176	0.7793	0.6048	0.2252
JAL-40	46.3	108.2	89.6	0.8138	0.7163	0.5745	0.1416
TIR-37	45.5	133.1	83.9	0.8162	0.7347	0.6897	0.4448
ICR-07	46.3	121.2	86.7	0.8108	0.7555	0.6732	0.3186
JUG-19	49.0	121.4	92.4	0.8116	0.7700	0.5369	0.2913
ICR-21	48.1	112.2	84.4	0.8092	0.6859	0.5548	0.2860
JAL-39	46.7	108.9	90.8	0.7056	0.4923	0.4739	0.1924
JAL-21	45.6	154.2	92.0	0.8192	0.6876	0.6646	0.3168
TIR-38	44.1	128.9	84.1	0.8174	0.7718	0.6656	0.3502
TAG 24	43.0	161.0	87.2	0.8244	0.7356	0.5542	0.3794
TCGP-6	45.5	126.5	81.4	0.8334	0.7505	0.6628	0.2269
ICGV 86325	50.2	155.4	75.3	0.8242	0.7919	0.4876	0.2398
ICGV 91123	43.0	144.6	86.0	0.8322	0.8158	0.6097	0.3833
ICGV 92206	47.5	147.6	78.8	0.8334	0.7906	0.5395	0.3031
ICGV 86015	47.3	165.9	65.9	0.8456	0.8357	0.5647	0.2465
ICG 7791	40.6	166.2	68.6	0.8640	0.8128	0.4777	0.3740
ICG 7216	48.1	145.7	88.7	0.8382	0.8045	0.5367	0.3825
ICG 7416	50.7	178.8	70.3	0.8272	0.8170	0.5480	0.2289
ICG 11987	49.9	139.0	79.1	0.8308	0.8072	0.5098	0.2551
CHICO	43.6	157.3	82.7	0.8580	0.8258	0.6876	0.4743
TCGP-6	48.3	130.9	77.1	0.8771	0.8160	0.6686	0.2189
ICG 9930	41.6	162.2	82.5	0.8227	0.7823	0.6029	0.3383
55-437	45.1	140.8	80.9	0.8440	0.8293	0.6357	0.4704
VRI Gn 5	51.5	136.6	76.9	0.8377	0.7672	0.6564	0.3133
VG 9514	43.8	156.8	83.3	0.8771	0.8545	0.6678	0.3257
VG 9513	44.7	138.2	81.9	0.8245	0.8065	0.7093	0.4650
VG 9521	44.8	146.9	75.2	0.8504	0.8351	0.7439	0.4234
R 8808	44.5	156.1	77.3	0.8636	0.8452	0.7593	0.4806
JL 220	43.4	169.6	82.1	0.6840	0.5853	0.5350	0.1363
JAL-46	42.9	169.8	83.6	0.8137	0.7790	0.7080	0.4591
JAL-43	42.1	159.2	83.9	0.8355	0.8225	0.7862	0.4779
JAL-47	44.1	153.4	89.6	0.8253	0.7345	0.6324	0.3618
JAL-45	43.9	151.4	88.9	0.8251	0.8090	0.7221	0.3193
JAL-12	42.4	161.1	93.7	0.8049	0.7928	0.7576	0.4389
JAL-44	42.8	157.5	88.4	0.8199	0.7701	0.6837	0.5134
JAL-24	45.1	158.9	81.5	0.8332	0.8224	0.7115	0.5633
JAL-22	45.2	150.2	84.7	0.8282	0.8176	0.6481	0.5149
JAL-48	44.3	165.4	81.7	0.7042	0.5729	0.4580	0.1477
JAL-11	43.0	151.2	86.5	0.8490	0.8209	0.7771	0.5573
JAL-10	46.3	151.9	83.5	0.8248	0.8119	0.5844	0.2901

Germplasm	SCMR	SLA	RI	Chlorophyll fluorescence ratio			
				Control	45^{0}C	50^{0}C	55^{0}C
JAL-23	43.1	184.5	83.3	0.7963	0.7750	0.5383	0.3976
GG 2	47.6	160.4	82.3	0.8290	0.8133	0.6650	0.5200
JUG-43	53.4	135.9	85.4	0.8556	0.8368	0.5739	0.3631
JUG-24	50.9	167.8	82.7	0.8667	0.8475	0.7104	0.3825
JUG-11	42.6	160.5	90.6	0.8508	0.8410	0.6451	0.4125
JUG-22	48.4	136.2	88.7	0.8353	0.8168	0.6631	0.3542
JUG-46	44.3	159.4	86.8	0.8286	0.8184	0.6034	0.4046
JUG-48	45.6	167.7	75.2	0.8502	0.8176	0.5831	0.3156
JUG-44	51.2	134.0	85.6	0.8315	0.8218	0.5714	0.3020
JUG-12	47.4	152.6	83.1	0.8362	0.8188	0.6896	0.3262
JUG-47	49.9	146.2	89.5	0.8705	0.8326	0.6996	0.3738
JUG-45	50.5	139.2	66.1	0.8437	0.8286	0.7363	0.5740
JUG-10	46.5	155.8	84.1	0.8453	0.8294	0.7705	0.6037
JUG-23	49.6	152.1	84.1	0.8598	0.8422	0.7925	0.5233
K-134	46.4	138.3	81.5	0.8488	0.8306	0.7994	0.5570
TIR-44	44.1	163.0	86.6	0.8538	0.8316	0.7684	0.4854
TIR-43	47.8	146.3	83.9	0.8394	0.8246	0.7385	0.5249
TIR-48	47.9	130.8	80.8	0.8244	0.8118	0.6202	0.4615
TIR-21	47.2	156.4	86.6	0.8747	0.8648	0.7689	0.6814
TIR-24	49.9	155.2	79.2	0.7900	0.6750	0.5694	0.2105
TIR-45	48.2	137.0	84.1	0.7270	0.6351	0.5572	0.1539
TIR-22	47.8	149.0	79.9	0.7964	0.7076	0.5566	0.1739
TIR-23	48.4	153.3	84.2	0.7580	0.6676	0.5916	0.2026
TIR-20	42.6	185.4	80.4	0.7740	0.7116	0.6043	0.1269
TIR-46	47.3	148.5	72.8	0.7169	0.7082	0.4486	0.1541
TIR-47	47.0	152.4	79.6	0.7307	0.6739	0.4627	0.1298
TIR-19	48.4	147.5	81.8	0.7573	0.5982	0.4803	0.1293
TCGP-5	44.2	145.8	81.3	0.6981	0.5890	0.3357	0.1768
TCGP-7	47.5	144.5	84.6	0.7660	0.5139	0.4658	0.1321
TCGP-10	48.5	129.4	79.1	0.7232	0.6293	0.4741	0.1557
ICGS-76	53.4	130.1	81.2	0.8388	0.8176	0.4133	0.2204
Mean	**46.7**	**141.4**	**78.8**	**0.8113**	**0.7666**	**0.6172**	**0.3309**
SEm	0.483	5.135	2.647	0.0071	0.0075	0.0081	0.0072
CD (5%)	1.345*	14.3*	7.376*	0.0198*	0.0209*	0.0225*	0.0202*
CV (%)	1.8	6.3	7.2	1.5	1.7	2.3	3.8

Table 1b. SPAD chlorophyll meter reading (SCMR), specific leaf area (SLA), relative injury (RI) and chlorophyll fluorescence ratio in virginia groundnut germplasm

Germplasm	SCMR	SLA	RI	Chlorophyll fluorescence ratio			
				Control	45^{0}C	50^{0}C	55^{0}C
TIR-32	52.6	127.8	71.0	0.8456	0.8101	0.4440	0.3189
TIR-09	52.5	130.7	63.7	0.8273	0.8043	0.4469	0.2572
JAL-02	50.2	124.2	73.4	0.8487	0.8296	0.4600	0.3663
JUG-29	47.4	140.4	73.5	0.8664	0.6365	0.3656	0.3375
JUG-01	51.3	125.7	73.7	0.8521	0.8255	0.4639	0.3379
JAL-29	52.9	134.0	80.3	0.8415	0.8276	0.3443	0.3359
ICR-15	52.8	133.3	76.6	0.8616	0.8418	0.5594	0.3617
TIR-12	52.0	132.2	79.3	0.8458	0.7675	0.3596	0.3173
JAL-13	50.1	132.1	80.8	0.8312	0.8077	0.3685	0.2497
TIR-11	51.8	125.2	78.9	0.8498	0.8286	0.3466	0.3307
JUG-14	50.1	123.2	78.2	0.8353	0.8012	0.7415	0.5500
TIR-33	50.9	133.9	78.7	0.8225	0.8049	0.7280	0.5543
JUG-26	50.1	117.4	69.9	0.8447	0.8276	0.7780	0.5369
TIR-34	52.9	135.6	72.4	0.8629	0.8197	0.7748	0.5985
ICR-01	53.9	117.5	86.2	0.8435	0.8156	0.7790	0.5392
JUG-28	50.3	123.6	72.7	0.8318	0.8197	0.7611	0.5334
ICR-30	51.8	110.3	74.4	0.8515	0.8271	0.742	0.5550
TIR-07	53.8	121.5	66.9	0.8123	0.6156	0.3859	0.3796
TIR-10	52.0	120.4	67.7	0.8579	0.8469	0.6932	0.3787
ICR-13	50.2	117.8	73.3	0.8365	0.7452	0.6896	0.5193
JAL-15	55.3	110.4	65.0	0.8562	0.6985	0.4256	0.3758
JUG-02	50.7	118.7	72.3	0.8214	0.7459	0.6596	0.3763
ICR-14	51.4	121.1	78.2	0.8426	0.7529	0.6125	0.3798
JAL-28	53.7	132.1	80.1	0.8145	0.7459	0.6189	0.2689
JAL-27	50.2	131.3	73.6	0.8242	0.6985	0.5896	0.3748
JAL-03	49.7	134.2	77.2	0.8147	0.6935	0.3858	0.3769
JAL-26	54.2	121.0	64.6	0.8369	0.8236	0.7698	0.3789
JAL-25	54.2	121.0	62.2	0.8523	0.6584	0.5987	0.3789
JAL-30	56.9	117.3	64.6	0.8254	0.8456	0.6256	0.2658
JUG-27	49.2	134.9	40.1	0.8369	0.7985	0.6895	0.5198
TIR-08	52.0	133.6	50.0	0.8254	0.7123	0.6156	0.4698
TIR-31	53.5	134.5	41.8	0.8456	0.7712	0.6352	0.2658
JAL-14	54.1	125.4	37.3	0.8425	0.6728	0.5389	0.5299
JUG-15	52.3	120.8	40.1	0.8397	0.7126	0.5314	0.5299
ICR-28	50.6	128.2	45.8	0.8365	0.7456	0.5394	0.3789
JAL-01	52.9	131.2	40.7	0.8365	0.7352	0.3869	0.3798
TIR-35	50.1	135.4	45.6	0.8512	0.7456	0.4593	0.2456
ICR-26	49.3	134.9	52.3	0.8479	0.8523	0.6589	0.2689
ICR-25	52.3	140.1	69.1	0.8547	0.7985	0.4896	0.3758

Germplasm	SCMR	SLA	RI	Chlorophyll fluorescence ratio			
				Control	45^{0}C	50^{0}C	55^{0}C
JUG-30	52.4	125.4	51.7	0.8254	0.7458	0.6893	0.5183
JUG-03	50.2	124.3	50.5	0.8479	0.7932	0.5789	0.3787
TIR-36	52.6	131.8	50.3	0.8478	0.7589	0.6893	0.5149
ICR-02	52.6	136.9	60.0	0.8541	0.8536	0.7592	0.5391
ICR-29	53.0	142.8	53.3	0.8125	0.8095	0.7587	0.2458
JUG-13	50.4	121.8	60.9	0.8369	0.7125	0.4156	0.3789
ICR-27	51.8	143.4	40.7	0.8412	0.7456	0.6986	0.4684
JUG-25	51.1	130.6	37.1	0.8152	0.7931	0.5871	0.3793
ICR-03	49.7	133.7	40.1	0.8269	0.8169	0.6598	0.3760
CSMG84-1	49.0	139.8	34.4	0.8316	0.7467	0.6423	0.2535
ICGS-44	49.3	126.0	37.1	0.7344	0.7232	0.6316	0.2429
TIR-28	45.1	144.5	44.7	0.7597	0.7287	0.5686	0.1657
TIR-30	45.1	144.9	41.0	0.7618	0.7426	0.5631	0.2463
TIR-04	43.3	146.2	43.0	0.7562	0.7480	0.6243	0.2482
JUG-31	50.2	129.4	55.9	0.7480	0.7172	0.6458	0.1602
JUG-16	49.7	141.0	47.1	0.7527	0.7271	0.5806	0.2600
JAL-35	48.4	156.5	49.4	0.7601	0.7308	0.6383	0.2258
ICR-32	41.8	156.5	60.8	0.7693	0.7327	0.5544	0.3287
JUG-35	49.0	137.5	41.5	0.8362	0.7507	0.6553	0.1814
JAL-04	49.3	141.3	60.1	0.7398	0.7271	0.5615	0.1488
ICR-33	50.4	141.1	76.3	0.7576	0.7443	0.6372	0.2238
JAL-17	48.6	134.2	85.3	0.8547	0.7533	0.6497	0.1690
JUG-06	47.9	141.2	80.8	0.7483	0.7234	0.5406	0.2732
JAL-31	48.3	139.5	83.1	0.7511	0.7375	0.6518	0.1348
ICR-05	48.8	124.1	80.7	0.7774	0.7426	0.6501	0.1650
JUG-18	45.1	134.8	77.6	0.7601	0.7345	0.5642	0.2676
JUG-32	48.2	134.0	78.7	0.7452	0.7377	0.4600	0.1353
TIR-03	50.6	132.7	79.7	0.8590	0.7398	0.4125	0.1624
ICR-35	49.5	139.5	77.3	0.8578	0.7398	0.4132	0.1635
JUG-17	48.9	140.9	75.9	0.8295	0.7456	0.5138	0.2662
ICR-17	50.1	126.3	82.6	0.7125	0.6458	0.4349	0.1957
TIR-27	50.7	126.8	73.5	0.7896	0.6158	0.5398	0.1883
JUG-36	50.6	135.4	74.9	0.7458	0.6987	0.5202	0.3894
TIR-05	48.5	122.5	79.1	0.7458	0.6589	0.5450	0.3980
JUG-04	49.3	129.8	75.7	0.8556	0.7985	0.6491	0.4015
TIR-02	50.1	143.9	71.9	0.8534	0.8158	0.7896	0.2226
JAL-16	49.2	142.9	77.6	0.8236	0.7985	0.5562	0.2313
TIR-06	47.6	154.1	74.5	0.7125	0.7123	0.5073	0.4024
ICR-04	44.6	144.9	72.3	0.7125	0.6125	0.5168	0.1835
ICR-34	48.2	140.3	77.4	0.7458	0.6589	0.5599	0.2667
TIR-01	47.1	126.5	76.0	0.7458	0.6458	0.5698	0.3857

Germplasm	SCMR	SLA	RI	Chlorophyll fluorescence ratio			
				Control	45^{0}C	50^{0}C	55^{0}C
JAL-32	51.3	138.5	77.8	0.8501	0.789	0.6687	0.1668
JUG-34	50.4	156.5	70.5	0.8236	0.7985	0.5042	0.2479
TIR-26	53.8	136.8	74.6	0.8589	0.7567	0.6088	0.398
ICR-18	50.9	144.1	71.6	0.7125	0.7123	0.5272	0.2118
JUG-05	51.7	136.6	70.9	0.8459	0.8456	0.5973	0.2302
JAL-34	50.6	151.2	75.9	0.7125	0.6589	0.5764	0.2339
ICR-06	50.6	133.0	79.3	0.7125	0.6458	0.5065	0.2524
ICR-36	50.2	143.5	72.7	0.8567	0.7985	0.5956	0.2135
ICR-31	49.4	144.4	78.5	0.8545	0.8398	0.5815	0.2446
JAL-36	50.5	152.5	40.1	0.7458	0.7152	0.5375	0.2257
JAL-06	46.4	135.0	41.6	0.8236	0.7458	0.5248	0.1668
JAL-18	49.6	136.2	40.6	0.7126	0.6525	0.5963	0.1517
JAL-33	49.0	143.1	60.3	0.7152	0.6458	0.5933	0.208
TIR-25	47.4	156.5	69.8	0.8523	0.7985	0.5807	0.4091
TIR-29	47.1	133.8	40.2	0.7125	0.6325	0.5442	0.374
JAL-05	48.8	139.4	60.2	0.8269	0.7458	0.6418	0.2302
JUG-33	47.5	142.7	43.2	0.8501	0.8125	0.7051	0.2412
ICR-16	48.3	145.6	49.9	0.7458	0.6985	0.5294	0.3853
ICR-48	50.5	141.9	41.0	0.8446	0.8271	0.6440	0.2466
ICR-44	49.3	138.3	37.2	0.8295	0.8012	0.7370	0.2728
ICR-22	49.6	131.5	40.5	0.8163	0.8012	0.6679	0.2835
ICR-47	47.6	140.0	37.4	0.8328	0.8197	0.7552	0.2290
ICR-24	48.2	139.2	37.7	0.8543	0.8271	0.7268	0.2520
ICR-45	49.3	134.1	42.2	0.8625	0.8560	0.6649	0.3643
ICR-46	45.4	143.8	40.8	0.8246	0.8123	0.7379	0.2164
ICR-11	48.8	140.6	90.2	0.8488	0.8234	0.6465	0.1617
ICR-43	45.1	136.5	77.9	0.8422	0.7428	0.6502	0.1807
ICR-12	49.1	126.2	73.3	0.8131	0.8012	0.6440	0.2089
ICR-23	51.1	133.4	77.0	0.8391	0.8271	0.7417	0.2351
ICR-10	49.1	130.8	80.8	0.8406	0.8341	0.6593	0.3563
Mean	**50.0**	**134.3**	**63.4**	**0.8124**	**0.7577**	**0.5887**	**0.3167**
SEm	0.774	3.854	2.457	0.0169	0.0154	0.0192	0.0162
CD (5%)	2.155*	10.7*	6.847*	0.0473*	0.0431*	0.0538*	0.0453*
CV (%)	2.7	5.0	7.7	3.6	3.4	5.4	8.8

Table 2. Range observed in groundnut genotypes for SCMR, SLA, membrane injury (%) and chlorophyll fluorescence ratio

Trait	Range	Spanish	Virginia
SCMR	Low (<45)	30	2
	Medium (45-50)	72	47
	High (>50)	9	61
SLA (cm^2 g^{-1})	Low (100-125)	24	20
	Medium (125-150)	49	83
	High (>150)	38	7
Membrane injury (%)	Low (30-40)	1	7
	Medium (40-60)	8	32
	High (>60)	102	71
Chlorophyll fluorescence	Low (<0.3)	46	58
ratio (55^{0}C)	Medium (0.3-0.5)	53	38
	High (>0.5)	12	14

are most appropriate to distinguish genotypes within each crop on the basis of membrane injury in the leaf tissue. Many studies have demonstrated abrupt decrease in PS II photochemistry above a threshold temperature (Havaux *et al*. 1996, Talwar *et al*. 1999). The per cent change in F_o and F_v/F_m with increasing level of heat stress over their respective control indicates that F_o increased and F_v/F_m (ratio of variable to maximum fluorescence) decreased with increasing level of heat stress.

Spanish genotype TIR-21 showed less reduction in F_v/F_m ratio when exposed to temperatures of 45^{0}C (1.13% reduction) and 55^{0}C (22% reduction), while virginia genotype TIR-34 maintained high F_v/F_m ratio at temperature > 50^{0}C. Thermal adaptation of PSII is a key factor for the acclimation to high temperature (Talwar *et al*. 1999). Havaux (1993) confirmed the thermal plasticity of PSII *in vivo* by demonstrating that the brief exposure of potato (*Solanum tuberosum* L.) leaves to moderately elevated temperature induced noticeable increase in the heat tolerance of PSII. Previously, Weis (1981) reported that the thylakoid membrane is a primary temperature sensor, which starts the process of temperature adaptation in plants. Havaux *et al.* (1996) suggested that thermal adaptation to mild heat stress involves the stabilization of permeability properties of the thylakoid membrane, which is protected by de-epoxidization of xanthophyll in potato leaves. Spanish genotype TIR-20 and Virginia genotype JAL-31 showed a higher reduction of 84 and 82% respectively in F_v/F_m ratio when exposed to 55^{0}C.

Membrane injury: Spanish genotype JAL-07 had a low membrane injury (37%). Incidentally, it also maintained high SCMR (52) and low SLA (101.6cm^2 g^{-1}), indicating that it can tolerate both water deficit and high temperature. However, this genotype showed more reduction (62%) in F_v/F_m ratio at 55^{0}C. This confirms the view that the photosynthetic apparatus in groundnut is more sensitive than plasmalemma integrity to high temperature stress (Chaisompongpan *et al*. 1990, Talwar *et al.* 1999). Virginia groundnut CSMG84-1 showed low membrane injury (34%).

This study concludes that genotypic differences in water use efficiency and heat tolerance exist among groundnut genotypes, which are detectable by SLA, SCMR, chlorophyll fluorescence or membrane

Table 3. Mean and range of SCMR, SLA, membrane injury (%) and chlorophyll fluorescence ratio of 111 spanish and 110 virginia groundnut genotypes during post-rainy season, 2001-02

Parameter	Spanish		Virginia	
	Mean	Range	Mean	Range
SCMR	46.7	40.6-53.4	50.0	41.8-56.9
SLA	141.4	101.6-185.4	134.3	110.3-156.5
Membrane injury (%)	78.8	37.1-93.9	63.4	34.4-90.2
Chlorophyll fluorescence ratio (55^{0}C)	0.3309	0.0831-0.6814	0.3167	0.1348-0.7485

Table 4. Top five ranked genotypes for SCMR, SLA, membrane injury (%) and chlorophyll fluorescence ratio of 111 spanish and 110 virginia groundnut genotypes grown during post-rainy season, 2001-02, Tirupati

Spanish	
High SCMR	JUG-43, JAL-07, ICGS-76, VRI Gn 5, JUG-44
Low SLA	JAL-07, ICR-08, JAL-37, JAL-20, JAL-40
Low membrane injury	JAL-07, TIR-14, ICR-41, JAL-37, JUG-21
High chlorophyll fluorescence ratio (55^0C)	TIR-21, JUG-10, JUG-45, JAL-24, JAL-11
Virginia	
High SCMR	JAL-30, JAL-15, JAL-26, JAL-25, JAL-14
Low SLA	ICR-30, JAL-15, JAL-30, JUG-26, ICR-01
Low membrane injury	CSMG 84-1, ICGS-44, JUG-25, ICR-44, JAL-14
High chlorophyll fluorescence ratio (55^0C)	TIR-34, ICR-30, TIR-33, JUG-14, ICR-01

thermostability. Hence these parameters may be used as practical tools for identifying water use efficient and high temperature-tolerant genotypes. The groundnut genotypes identified from this study may be used as good donor sources for developing drought and high heat tolerant genotypes. However, the relative injury test and chlorophyll fluorescence techniques identified different heat-tolerant cultivars. Further studies are required to relate the performance of heat-tolerant genotypes identified by these in-vitro methods to field performance in hot environments.

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