

## HALF SIB ANALYSIS FOR PHYSIOLOGICAL TRAITS IN COCOA

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### ABSTRACT

Cocoa (*Theobroma cacao* L.) plants are sensitive to drought and hence expansion of cultivation has been hampered due to dry spells of 3-6 months in Southern India. Efforts made to identify drought tolerance characteristics among the cocoa accessions have resulted in identification of five tolerant lines. Four high yielding trees viz., I-14 (Red axil), I-21, I-29 (Amel x Na33) and II-67 (Landas 364) were selected as female parents and crossed with drought tolerant pollen parent viz., NC 42/94 (T86/2). The F1 hybrid seedlings were planted in the field for evaluation. Field measurements on physiological parameters were made during stress and non - stress conditions.

Twenty two physiological parameters were studied in four cocoa hybrids, namely, I-14 x NC42/94, I-21 x NC 42/94, I-29 x NC 42/94 and II-67 x NC 42/94. The parameters were analyzed under non - stress and stress conditions. The characters that showed high heritability and genetic advance under stress were sugar, potassium, leaf temperature, internal CO<sub>2</sub>, water potential, lipid peroxidation, superoxide dismutase, polyphenol oxidase and acid phosphatase. The heritabilities and genetic advance of the hybrids under non-stress were high for total chlorophyll, peroxidase, polyphenol oxidase and acid phosphatase indicating that the nature of gene action varies under the control of environment. Genotypic and phenotypic correlations among the traits were also studied.

### INTRODUCTION

Cocoa (*Theobroma cacao* L.) plants are sensitive to drought and hence expansion of cultivation has been hampered because of drought periods extending up to 3-6 months in Southern India. Cocoa is grown mainly as mixed crop in arecanut and coconut plantations. Providing irrigation continuously during dry periods becomes difficult and it was found desirable to look for drought tolerant cocoa types. Efforts made to identify drought tolerant characteristics among cocoa germplasm have resulted in the identification of five tolerant lines (Balasimha, *et al.*, 1985; 1988; 1991). Some of the parents have been selected along with high yielding lines for breeding.

Half sib analysis is an important method in determining genetic parameters. Liyanage and Sakai (1961) in coconut, Bavappa and Ramchander (1967) in arecanut, Dinesh and Iyer (1993) in papaya and Dinesh and Yadav (1998) in Guava have used half-sib analysis to work out variability, heritability and correlation of characters. In the present study half sib analysis in progenies of the cocoa line NC 42/94 was taken up to determine genetic parameters.

### MATERIAL AND METHODS

Four high yielding trees viz. I-14 (Red axil), I-21, I-29 (Amel x Na33) and II-67 (Landas 364) were selected as female parents and crossed with drought tolerant parent NC 42/94 (T 86/2).

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Half sib analysis in cocoa

**Table.6. Variables showing direct and indirect effects on yield in cocoa.**

Chara	Positive effects	Negative effects
X <sub>1</sub>	X <sub>2</sub>	X <sub>13</sub> , X <sub>18</sub>
X <sub>2</sub>	nil	X <sub>3</sub> , X <sub>13</sub> , X <sub>22</sub>
X <sub>3</sub>	X <sub>2</sub> , X <sub>8</sub> , X <sub>13</sub> , X <sub>22</sub>	X <sub>4</sub> , X <sub>18</sub> , X <sub>19</sub>
X <sub>4</sub>	X <sub>2</sub> , X <sub>6</sub> , X <sub>13</sub> , X <sub>19</sub> , X <sub>23</sub>	X <sub>4</sub> , X <sub>9</sub>
X <sub>5</sub>	X <sub>6</sub> , X <sub>19</sub> , X <sub>23</sub>	X <sub>4</sub> , X <sub>13</sub>
X <sub>6</sub>	X <sub>2</sub> , X <sub>4</sub> , X <sub>13</sub> , X <sub>21</sub>	X <sub>6</sub> , X <sub>11</sub> , X <sub>19</sub> , X <sub>23</sub>
X <sub>7</sub>	X <sub>2</sub>	X <sub>7</sub> , X <sub>19</sub>
X <sub>8</sub>	X <sub>3</sub> , X <sub>8</sub> , X <sub>13</sub> , X <sub>19</sub> , X <sub>22</sub>	X <sub>4</sub> , X <sub>18</sub>
X <sub>9</sub>	X <sub>9</sub> , X <sub>17</sub> , X <sub>18</sub> , X <sub>20</sub>	X <sub>4</sub> , X <sub>9</sub> , X <sub>18</sub>
X <sub>10</sub>	X <sub>2</sub> , X <sub>3</sub> , X <sub>22</sub>	X <sub>18</sub> , X <sub>19</sub> , X <sub>21</sub>
X <sub>11</sub>	X <sub>6</sub> , X <sub>11</sub> , X <sub>19</sub>	X <sub>9</sub> , X <sub>17</sub> , X <sub>18</sub> , X <sub>22</sub>
X <sub>12</sub>	X <sub>2</sub> , X <sub>6</sub> , X <sub>12</sub> , X <sub>17</sub>	X <sub>13</sub>
X <sub>13</sub>	X <sub>3</sub> , X <sub>13</sub> , X <sub>22</sub>	X <sub>2</sub> , X <sub>6</sub> , X <sub>9</sub> , X <sub>17</sub> , X <sub>18</sub> , X <sub>19</sub>
X <sub>14</sub>	X <sub>1</sub> , X <sub>18</sub> , X <sub>19</sub>	X <sub>3</sub> , X <sub>13</sub> , X <sub>22</sub>
X <sub>15</sub>	X <sub>2</sub> , X <sub>13</sub>	X <sub>17</sub> , X <sub>19</sub>
X <sub>16</sub>	X <sub>1</sub> , X <sub>2</sub> , X <sub>11</sub> , X <sub>18</sub> , X <sub>19</sub>	X <sub>3</sub> , X <sub>4</sub> , X <sub>9</sub> , X <sub>17</sub> , X <sub>22</sub>
X <sub>17</sub>	X <sub>2</sub> , X <sub>9</sub> , X <sub>18</sub>	X <sub>11</sub> , X <sub>13</sub> , X <sub>20</sub>
X <sub>18</sub>	X <sub>3</sub> , X <sub>13</sub> , X <sub>20</sub> , X <sub>22</sub>	X <sub>3</sub> , X <sub>13</sub>
X <sub>19</sub>	X <sub>6</sub> , X <sub>11</sub> , X <sub>18</sub> , X <sub>19</sub>	X <sub>3</sub> , X <sub>13</sub>
X <sub>20</sub>	X <sub>11</sub> , X <sub>13</sub> , X <sub>20</sub>	X <sub>9</sub> , X <sub>17</sub> , X <sub>18</sub>
X <sub>21</sub>	X <sub>4</sub>	X <sub>22</sub> , X <sub>23</sub>
X <sub>22</sub>	X <sub>3</sub> , X <sub>13</sub> , X <sub>22</sub>	X <sub>2</sub> , X <sub>18</sub> , X <sub>19</sub> , X <sub>21</sub>
X <sub>23</sub>	X <sub>3</sub> , X <sub>6</sub> , X <sub>11</sub> , X <sub>22</sub> , X <sub>23</sub>	X <sub>2</sub> , X <sub>4</sub> , X <sub>13</sub> , X <sub>21</sub>
X <sub>24</sub>	X <sub>3</sub> , X <sub>13</sub> , X <sub>22</sub> , X <sub>23</sub>	X <sub>2</sub> , X <sub>4</sub> , X <sub>17</sub> , X <sub>18</sub> , X <sub>21</sub>
X <sub>25</sub>	X <sub>3</sub> , X <sub>9</sub> , X <sub>23</sub> , X <sub>5</sub>	X <sub>2</sub> , X <sub>4</sub> , S <sub>21</sub>

potential efficiency of photosystem II and reliable indicator of adaptation to stress conditions (Belkodja *et al.*, 1994). The other variables which are of importance are SOD and fresh pod weight.

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#### Half sib analysis in cocoa

The F1 hybrid seedlings were planted in 1991 for field evaluation. The four hybrid combinations were subjected to half-sib analysis.

Field measurements on photosynthesis and related parameters were measured using L1-6200 portable photosynthetic system (Balasimha et al. 1991). Leaf water potential was measured using pressure chamber (Soil Moisture Equipment Co.). Chlorophyll fluorescence parameters were measured with Plant Efficiency Analyser (Hansatech). Specific leaf weight was measured in known leaf area after oven drying and expressed as mg/sq.cm. Biochemical parameters were determined by standard procedures spectrophotometrically.

The characters studied are listed below:

Lipid Peroxidation (Absorbance units) Nitrate reductase activity ( $\mu\text{mol/g/h}$ ) Superoxide dismutase (units/mg protein) Peroxidase (units/mg protein) Polyphenol oxidase (units/mg protein) Acid phosphatase (units/mg protein) Specific Leaf Weight (mg/sq.cm) Starch (mg/g) Sugars (mg/g) Potassium (%) Proline ( $\mu\text{g/g}$ ) Total Chlorophyll (mg/g) Epicuticular Wax ( $\mu\text{g/sq.cm}$ ) Leaf Temperature ( $^{\circ}\text{C}$ ) Photosynthesis ( $\mu\text{mol/sq.m/s}$ ) Transpiration ( $\mu\text{mol/s}$ ) Stomatal Resistance (s/cm) Internal  $\text{CO}_2$  (ppm) Water Potential (bars) Stomatal Conductance ( $\text{mol/sq.m/s}$ ) Fo Fv/Fm Fresh Pod Weight (g) Bean Number/Pod Single Dry Bean Weight (g) Dry Bean Yield/Tree (g).

The genotypic and phenotypic variances, genotypic and phenotypic coefficients of variation, heritability, expected genetic gain were calculated as per Singh and Choudhary (1977). Coefficients of correlation (Robinson et al., 1951), path coefficients (Dewey & Lu, 1959) and correlated response (Janssens, 1979) were also worked out. Frequency of statistically significant correlation for each trait was estimated (Harding et al., 1990) using genotypic correlation and for positive and negative correlation.

## RESULTS AND DISCUSSION

**Heritability estimates:** Genotypic variance was lesser than phenotypic variance under both non-stress and stress conditions. Coefficient of variation also followed a similar trend, indicating

the influence of the environment on the expression of these traits (Table 1). Therefore, the apparent variation observed for the different characters is not only due to the genotypic differences but also due to the environmental effect.

Heritability estimates on the other hand, indicate the heritable portion of the variation and is based on the total genetic variance. However, since only broad sense heritability has been estimated, it includes both the fixable (additive) and non-fixable (dominance, epistatic) variances. Peroxidase activity, PPO activity, total chlorophyll content showed high heritability under non-stress while lipid peroxidation, SOD activity, acid phosphatase activity, potassium and proline content in leaves, leaf temperature and leaf water potential showed high heritability under stress conditions. The characters - PPO activity, Internal  $\text{CO}_2$  content and Fv/Fm ratio showed moderate heritability under stress while acid phosphatase activity under non-stress showed moderate heritability. The other characters showed low heritability indicating the greater influence of the environment (Table 1). Hybrid combination I-21 x NC42/94 had higher water potential under field conditions (Balasimha et al., 1999) similar to drought tolerant parent. Stomatal resistance also showed significant variations with reference to drought tolerance and positively correlated with water potential. However the heritability of this character has not been found to be significant.

**Correlations:** Frequency of statistically significant genotypic correlation coefficients, both negative and positive, was greater than phenotypic correlation coefficients, both under stress and non-stress conditions (Table 2). The frequency of significant positive phenotypic correlation varied from 0.14-0.05 under non-stress and from 0.24 to 0.05 under stress condition. The frequency of significant negative correlations varied from 0.00-0.14 and 0.00-0.19, under non-stress and stress, respectively. In the case of genotypic correlation, significant positive frequency ranged from 0.67-0.24 under both non-stress and stress, while significant negative frequency ranged from 0.00-0.62 under non-

**Table 1. Genetic parameters.**

Trait	Mean		SD		Var (Geno)			Var (Pheno)			C.V (Geno)		C.V (Pheno)		Heritability		Genetic Advance	
	Non Stress	Stress	Non Stress	Stress	Non Stress	Stress	Non Stress	Stress	Non Stress	Stress	Non Stress	Stress	Non Stress	Stress	Non Stress	Stress	Non Stress	Stress
1.	0.22	0.47	0.04	0.37	0.00	0.30	0.00	0.03	0.03	7.23	12.92	0.312	0.668	0.02	0.12	0.00	0.00	
2.	402.26	611.28	108.16	197.67	3638.00	0.00	14037.29	30516.77	15.09	0.01	29.40	32.52	0.283	0.000	84.29	0.00		
3.	14.08	30.40	3.34	7.14	1.70	20.48	7.60	42.52	9.20	18.06	19.80	21.45	0.610	0.523	1.25	8.37		
4.	24.29	41.81	8.38	9.98	19.86	1.41	31.48	8.63	18.34	2.85	23.08	7.18	0.654	0.157	7.29	0.97		
5.	188.74	328.50	54.89	98.96	1597.89	4783.70	4492.48	11148.84	20.88	20.37	27.68	81.37	0.244	0.420	14.27	83.46		
6.	36.24	100.43	5.02	18.40	12.86	317.08	29.40	327.62	8.14	17.73	13.84	18.02	0.436	0.969	4.88	35.11		
7.	7.58	9.07	0.83	0.88	0.00	0.30	0.45	0.67	0.42	8.30	8.87	10.29	0.002	0.340	0.00	0.65		
8.	153.91	203.78	30.30	13.36	0.00	27.84	282.70	126.53	0.02	2.58	23.27	5.52	0.003	0.279	0.00	5.08		
9.	34.24	45.98	8.54	8.58	0.00	11.30	85.08	110.75	0.04	3.37	26.86	23.19	0.053	0.030	0.00	0.10		
10.	1.75	2.00	0.28	0.28	0.00	0.06	0.07	0.09	1.80	12.70	15.47	14.83	0.014	0.733	0.01	0.43		
11.	42.99	111.49	8.30	13.20	0.00	93.80	103.72	130.62	0.07	8.88	23.89	10.23	0.000	0.777	0.00	18.87		
12.	2.26	1.05	0.32	0.30	0.09	0.30	0.11	0.05	13.30	1.70	14.91	13.30	0.770	0.076	0.53	0.01		
13.	19.98	28.83	2.17	2.37	1.72	0.07	5.34	6.64	6.67	1.32	11.86	9.82	0.322	0.071	1.24	0.08		
14.	32.14	38.14	2.54	1.38	0.00	0.71	0.99	1.21	0.13	2.21	3.10	2.88	0.007	0.580	0.00	1.33		
15.	4.98	3.70	1.11	3.93	0.00	0.30	1.63	1.18	0.83	3.85	27.19	29.04	0.007	0.001	0.00	0.00		
16.	4.98	4.58	1.18	3.82	0.00	0.28	0.97	1.03	0.63	12.17	19.81	22.80	0.007	0.288	0.00	0.00		
17.	2.04	3.49	0.53	0.75	0.00	0.30	0.53	0.64	1.55	3.91	35.71	22.82	0.002	0.002	0.00	0.00		
18.	201.48	278.21	10.77	14.08	0.00	83.78	117.39	204.49	0.01	3.20	3.83	5.14	0.000	0.470	0.00	12.07		
19.	7.80	13.91	1.70	3.99	0.00	0.80	2.68	0.93	0.41	5.71	21.70	6.85	0.000	0.676	0.00	1.35		
20.	0.38	0.14	0.12	0.36	0.00	0.31	0.02	0.03	0.08	16.99	17.66	17.02	0.008	0.231	0.02	0.02		
21.	693.68	722.48	75.28	112.79	0.00	0.00	7582.05	11320.03	0.00	3.30	13.75	14.63	0.000	0.000	0.00	0.00		
22.	0.73	0.69	0.05	0.34	0.00	0.00	0.00	0.00	4.33	3.18	8.37	4.80	0.287	0.423	0.03	0.03		

**Table 2. Frequency of statistically significant positive and negative phenotypic and genotypic correlations.**

Trait	Non Stress				Stress			
	Phenotypic		Genotypic		Phenotypic		Genotypic	
	+	-	+	-	+	-	+	-
1.	0.05	0.00	0.48	0.29	0.19	0.19	0.33	0.24
2.	0.10	0.00	0.33	0.38	0.05	0.00	0.29	0.00
3.	0.10	0.00	0.48	0.29	0.19	0.19	0.38	0.38
4.	0.14	0.00	0.52	0.19	0.10	0.00	0.52	0.10
5.	0.14	0.05	0.57	0.24	0.05	0.05	0.24	0.43
6.	0.05	0.05	0.29	0.62	0.24	0.05	0.57	0.29
7.	0.05	0.00	0.29	0.43	0.05	0.05	0.52	0.10
8.	0.05	0.00	0.24	0.10	0.24	0.05	0.67	0.19
9.	0.14	0.10	0.38	0.19	0.05	0.00	0.52	0.19
10.	0.05	0.05	0.43	0.29	0.10	0.14	0.33	0.29
11.	0.05	0.00	0.38	0.52	0.19	0.10	0.52	0.38
12.	0.14	0.05	0.52	0.29	0.14	0.05	0.48	0.38
13.	0.14	0.10	0.33	0.33	0.05	0.10	0.29	0.57
14.	0.05	0.00	0.43	0.29	0.14	0.05	0.29	0.24
15.	0.05	0.00	0.33	0.33	0.19	0.05	0.52	0.33
16.	0.05	0.05	0.38	0.29	0.24	0.05	0.33	0.29
17.	0.10	0.14	0.57	0.29	0.05	0.05	0.29	0.33
18.	0.14	0.10	0.33	0.14	0.10	0.00	0.33	0.24
19.	0.05	0.00	0.67	0.19	0.19	0.05	0.38	0.24
20.	0.14	0.10	0.29	0.33	0.24	0.10	0.67	0.10
21.	0.05	0.00	0.24	0.00	0.05	0.10	0.48	0.05
22.	0.05	0.00	0.48	0.19	0.10	0.00	0.52	0.24
Mean	0.09	0.04	0.41	0.28	0.13	0.06	0.43	0.25



**Table 5. Path Analysis - Matrix of Direct and Indirect Effects.**

**DIRECT EFFECTS ON MAIN DIAGON**

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.
1	0.3251	1.1834	0.8437	0.3852	0.2238	0.4692	0.0381	0.2225	-0.1237	-0.1918	0.3258	0.3318	0.8997	0.1482	-0.0177	0.0828	0.3471	-1.5195	0.3773	0.1283	0.2314	0.2972	-0.1543	0.0038	-0.0044
2	-0.2832	0.0028	-0.4885	0.5183	0.0126	0.2480	0.3618	-0.0711	-0.1879	-0.0881	0.0584	0.5872	-0.8288	0.0024	-0.1136	0.0182	0.3856	-0.0444	-0.1513	-0.0181	-0.0783	0.8877	-0.9704	-0.1082	-0.0283
3	-0.5878	1.4051	1.9513	-0.6658	0.0185	-0.8728	0.0299	0.4496	-0.2804	-0.1179	-0.148	0.0171	0.9191	0.1387	0.0164	0.0687	0.5787	-1.6878	-1.0963	0.1080	-0.1440	1.9238	0.6175	-1.1738	0.0490
4	0.2218	1.1810	0.3463	-1.6510	0.0083	0.7189	0.0528	0.0256	-0.5957	0.0442	0.0407	0.0184	0.0935	-0.0407	0.0385	-0.0288	-0.1871	0.0600	0.0181	0.0821	-0.0585	0.4027	0.6079	-1.1251	0.0252
5	-0.984	0.4127	0.2167	-1.0183	0.1108	0.6260	0.5705	0.0037	-0.3888	0.0107	0.4404	0.4983	2.0878	-0.0508	-0.0581	-0.0384	0.3766	0.2519	0.6877	-0.0270	-0.4188	0.0774	-0.7926	0.9877	0.0212
6	0.1118	0.7530	0.2354	0.8888	-0.0843	1.2482	0.1679	0.0499	0.3887	-0.0827	-0.6454	-0.4483	2.4239	0.0425	-0.0144	0.0278	0.7027	-0.997	0.8490	-0.0298	0.5160	-0.0725	-0.2907	-0.0852	0.0002
7	-0.5841	2.1887	0.1978	0.1414	0.0127	-0.1920	0.0182	-0.3281	-0.1987	-0.1728	0.4315	0.2417	0.7030	-0.0212	-0.1808	0.0137	-0.1884	-0.2888	1.0148	0.0584	-0.3736	0.1016	-0.0383	0.0038	0.0073
8	-0.8943	0.2077	0.7081	-0.6884	0.0008	-0.0840	0.0183	0.0015	-0.4038	-0.1078	0.0341	0.1189	1.7858	0.0874	-0.0322	0.0341	-0.3016	-1.0828	-0.9028	0.0806	-0.4875	0.8888	0.0248	-0.0818	0.0071
9	0.0789	0.4124	-0.1007	0.5811	0.0084	0.3950	0.0701	-0.2089	1.6477	0.0638	0.6549	0.1786	0.5095	0.0280	0.0520	0.0439	-0.1000	1.7384	0.9890	0.0015	-0.0840	0.9005	-0.0110	-0.0610	0.0226
10	-0.5186	0.7895	0.4627	0.2228	-0.0058	-0.3332	0.3261	0.0236	0.9314	-0.3836	0.6613	-0.1262	1.0736	0.0824	-0.1288	0.0537	0.7808	-0.8383	0.6838	-0.0385	-0.1728	0.9012	0.0038	0.0286	0.0229
11	-0.7886	0.2338	-0.0788	-0.0528	0.0318	0.9858	0.1413	0.0178	-0.8811	0.0108	1.5381	-0.0427	0.3777	-0.0328	0.0149	-0.0487	-0.3884	-0.4882	1.0080	0.2582	-0.1572	-0.8388	0.3875	0.0031	-0.0074
12	-0.3082	2.2428	0.0217	-0.0383	0.0554	0.6888	0.1439	-0.0884	-0.3855	0.0843	0.6858	0.9380	0.8145	0.0320	-0.0178	0.0178	-0.0038	-0.3518	0.8888	0.0874	0.0080	0.0040	0.0858	-0.0112	0.0158
13	0.1848	-1.8108	0.4184	-0.2483	0.0387	0.4858	0.0852	0.2147	-0.0307	0.0245	-0.0488	-0.5388	0.8781	0.0285	-0.0438	-0.0085	-1.8321	-1.5818	1.0188	0.5280	0.0574	0.4789	-0.1881	0.0280	0.0017
14	0.8284	0.0138	0.7440	0.3882	0.0248	0.2428	0.0023	0.3886	0.1788	1.1288	0.2283	0.1251	1.8474	0.2320	0.0801	0.1518	0.1688	0.6780	1.2877	0.2314	0.8777	1.2887	0.1044	0.0078	0.0018
15	-0.3888	0.9388	-0.0788	0.3888	0.0098	0.0088	0.3888	0.0815	-0.9745	-0.1927	-0.0408	0.0611	1.8848	0.0478	-0.0500	-0.0480	-0.8487	0.9040	-0.9618	0.0181	-0.4845	0.1417	0.0156	-0.0970	-0.0078
16	0.4788	0.8740	-0.7217	-0.4087	0.2881	0.5108	0.0703	-0.2281	-0.8427	0.0311	0.9885	0.1884	0.9888	0.1882	-0.1001	-0.1288	0.3882	1.4878	1.1082	0.1618	0.0067	1.3881	-0.0278	-0.0383	-0.0148
17	-0.2888	0.8588	0.0273	0.1270	0.0171	-0.0888	0.0803	-0.3882	0.9885	-0.0883	-0.8212	0.4518	0.8845	0.0148	0.0749	0.0448	2.4343	0.8814	0.3738	-0.5478	0.0378	0.1123	-0.2887	-0.0834	0.0118
18	-0.5888	0.1178	0.8723	0.3374	0.0082	-0.0882	0.0882	0.0882	0.0882	0.0882	0.2385	0.1149	0.4851	0.1889	0.0285	0.0386	-0.7872	0.0485	0.6878	0.5388	0.0824	0.8858	-0.0887	0.0088	0.0018
19	0.1888	0.2829	0.8888	0.3771	0.0041	0.9887	0.2784	0.8183	0.8877	0.0884	0.7388	0.1178	2.9889	0.1247	0.1185	0.0888	0.4843	1.2888	2.2888	0.1418	0.2150	1.2874	-0.1880	0.0274	0.0018
20	-0.1838	0.0784	0.1853	-0.2147	0.0043	0.1843	0.1858	-0.2140	0.0180	0.9820	0.0943	0.0788	0.0784	-0.0278	0.0178	1.8813	0.3888	0.4488	0.7888	0.1718	0.0888	0.1880	0.0427	-0.0285	
21	-0.7807	0.9038	-0.1884	0.5881	0.0527	0.4818	0.4874	-0.8888	0.1777	0.1488	0.0068	0.9808	0.0907	0.0827	-0.0007	0.0849	-0.7888	0.3833	0.0888	1.4878	-1.4813	-0.4889	-0.1889	-0.0910	
22	-0.7887	-1.1281	0.7114	-0.3888	0.0088	0.0450	0.2289	0.3874	1.1889	0.1482	-0.4482	-0.0284	1.4833	0.1923	-0.0184	0.0778	0.1280	0.5478	1.5488	0.0888	0.0842	2.1889	0.3884	0.1288	0.0088
23	-0.2891	-1.2715	0.7058	-0.9089	0.0789	0.5883	0.0202	0.1823	-0.0133	-0.0820	0.4843	0.0882	1.0016	0.0212	-0.0340	0.0030	0.7883	0.2443	0.3833	0.1184	-0.8182	0.7454	-1.0733	0.0181	0.0332
24	-0.5133	-1.4543	0.8363	-0.7884	0.0413	0.5204	0.2788	0.2501	-0.3838	-0.0820	0.5217	-0.0425	1.3844	0.0321	0.0290	0.0172	-0.8881	-0.8843	0.2371	0.1154	-0.7443	1.5713	0.5138	0.2818	0.0428
25	0.0818	2.0788	0.7781	0.7830	0.0384	-0.2042	0.6878	0.6882	0.6383	0.1128	0.1703	0.2328	1.1788	0.0588	0.0321	0.0288	0.4887	-0.4820	1.7890	0.2184	0.4823	0.9843	0.8882	0.8884	0.0088

Residual = 0.0000

Value of determinant of corr. mat. of ind. var. = -0.37842117-110

stress and 0.00-0.57 under stress. Very high frequency of positive genotypic correlation was observed for many traits.

**Correlated response:** Under non-stress, correlated response was high between lipid peroxidation and NR activity (Table 3). High negative correlated response was observed between leaf proline content and epicuticular wax content. Polyphenol oxidase activity had better correlated response with lipid peroxidation, SOD and peroxidase activity. Total chlorophyll content in the leaf showed better correlation with proline content, while epicuticular wax showed better correlation with leaf sugar content.

Under stress condition (Table 4), higher correlated response was observed between lipid peroxidation and PPO activity. High but negative correlated response was observed between peroxidase and PPO activity. SOD activity showed better correlated response with PPO and acid phosphatase activity. The better correlated responses of lipid peroxidation and

SOD are indications that these characters are important in imparting drought tolerance. Proline content showed better positive correlated response with lipid peroxidation and acid phosphatase activity, and better negative correlated response with SOD activity.

**Path analysis:** The path analysis indicating direct and indirect effects are presented in Table 5. The Table 6 indicates the influence of each character directly and indirectly on yield. From the Table it is evident that NR shows very high positive effect via 9 variables and negative via 5 variables followed by Fv/Fm which showed positive effects via 8 variables and negative variables via 5 variables. Nitrate reductase activity is also important in terms of its relation to yield as well as stability during drought. The Fv/Fm showed significant difference and the tolerant lines maintained higher values during stress as compared to susceptible ones (Balasimha and Anil Kumar, 2000). This parameter is a quantitative measure of the