



## Heterosis for drought tolerant traits in coconut

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### Abstract

Heterosis expressed by four tall (West Coast Tall-WCT; Laccadive Ordinary Tall-LCT; Philippines Ordinary Tall-PHOT; and Andaman Ordinary Tall-AOT) and one dwarf coconut cultivar (Chowghat Green Dwarf-CGD) and cross combinations of tall cultivars with CGD (total eight crosses) were examined. Observations on three drought traits viz., leaf water potential, lipid peroxidation and photochemical efficiency were made during non-stress, stress and recovery periods. As the observations made in the three conditions are from the same plant, analysis of repeated measures was employed for testing the effects. Results of the analysis indicate good degree of heterosis in some of the cross combinations for leaf water potential and lipid peroxidation. CGD x WCT recorded significant mid parent heterosis (39 %) for leaf water potential after recovery from stress. Significant heterosis for lipid peroxidation over better parent as well as mid-parent was observed for PHOT x CGD under non-stress (28.9 and 31.3%, respectively). Photochemical efficiency (Fv/Fm) values did not show significant heterosis (<6%) over their parents indicating the trait is likely to be governed by additive genes. To provide an estimate of heritability of the traits, data generated for two consecutive years in the same combinations were pooled and effect due to cultivars/crosses was taken as random. Heritability was also worked out for different conditions separately. Although the study uses an important dwarf cultivar, CGD known for drought and root (wilt) resistance, it needs to be confirmed by experimentation with other dwarf and tall cultivars.

**Keywords:** Drought tolerance, heterosis, leaf water potential, lipid peroxidation, water stress

### Introduction

Heterosis is broadly defined as the increased vigour of hybrids in comparison to their parents and is typically detected in adult hybrid plants as increased yield or vigour compared to their parental inbred lines. In coconut (*Cocos nucifera* L.) heterosis has been exploited as early as 1937 by Patel for collar girth, number of leaves and seedling vigour. Heterosis also has been exploited for yield characters (Ramanathan, 1989; Dhamodaran *et al.*, 1991) and along with other morphological traits (Louis and Chopra, 1991). Heterosis and heterobeltiosis to the tune of 12 to 13 % for oil content in coconut has been reported (Nallathambi *et al.*, 1986). In an earlier study Ramadasan *et al.* (1985) reported that dry matter production in coconut is a heritable factor. Their results indicated high heritability for total shoot dry weight, the NAR and total chlorophyll content. Later Shivashankar *et al.* (1985) observed that the F<sub>1</sub> progeny of Chowghat Dwarf Orange and West Coast Tall (D x T) cross tend to

be highly heterozygous with respect to total chlorophyll content, nitrate reductase activity, leaf area and shoot dry mass than its parents. Rajagopal *et al.* (2007) based on line x tester (2 x 4) mating design, studied the combining ability and gene action with respect to drought responsive physiological traits. Their results revealed significant differences among parents and hybrids for all characters and the possibility of exploiting the nature of gene action governing drought sensitive traits in breeding for drought tolerance in coconut.

In coconut some of the important stress sensitive traits like leaf water potential ( $\Psi_{leaf}$ ), lipid peroxidation (LP) and photochemical efficiency (Fv/ Fm) have been used extensively for screening for drought tolerance (Rajagopal *et al.*, 1988, 1991 and 2000; Chempakam *et al.*, 1993; Naresh Kumar *et al.*, 2007). In an earlier study Kasturi Bai *et al.*, 2001 and 2006) observed significant negative correlation between  $\Psi_{leaf}$  and peroxidation of cell wall lipids as well as positive correlation between of  $\Psi_{leaf}$  and Fv/Fm.

Information on heterosis of useful traits relevant to physiological parameters responsive to drought are least studied in plantation crops especially in coconut, except the studies by Rajagopal *et al.* (2007). More over choice of correct parents to cross in a breeding programme in order to maximize heterosis is essential. Therefore, the purpose of the present study is to determine the heritability and levels of heterosis expressed by a set of hybrid combinations derived by crossing four tall parents with one dwarf hybrid (i.e., a total of eight crosses) for three drought responsive physiological traits viz; leaf water potential, peroxidation of lipids in cell wall and photochemical efficiency.

### Materials and Methods

Six seedlings (18 months old) each of four tall cultivars viz; West Coast Tall (WCT), Laccadive Ordinary Tall (LCT), Philippines Ordinary Tall (PHOT) and Andaman Ordinary Tall (ADOT) and one dwarf cultivar Chowghat Green Dwarf (CGD) and cross combinations of tall cultivars with CGD (total eight crosses) were the experimental material for the study. Observations on three drought responsive traits viz., leaf water potential ( $\Psi_{leaf}$ ) (Milburn and Zimmermann, 1977 and Rajagopal *et al.*, 1987), lipid peroxidation (LP) (Heath and Packer, 1968) and photochemical efficiency (Fv/Fm) (Kasturi Bai *et al.*, 2006) were made during non-stress, stress and recovery periods. The seedlings were grown in red sandy loam soil in the Institute farm and all the observations were carried out during summer months of March- April. Irrigation was provided to the seedlings continuously till saturation of the soil (non stress) and the seedlings were subjected to stress condition by withholding irrigation for 20 days to induce stress and thereafter irrigated for seven days to make observations on recovery period.

### Statistical analysis

The statistical analysis was carried out with the following model:

$$Y_{ijk} = \mu + \gamma_i + \beta_j + \gamma_i \beta_j + \epsilon_{ij}$$

Where  $Y_{ijk}$  is the value of the trait for  $k^{\text{th}}$  plant ( $k=1$  to 6) of cultivars/crosses,  $j$  ( $j = 1$  to 13) in the condition  $i$  ( $i=1, 2, 3$ );  $\gamma_i$  is the effect due to the condition;  $\beta_j$  is the effect due to the cultivars/crosses;  $\gamma_i \beta_j$  is the interaction and  $\epsilon_{ij}$  is the error. As the observations made in the three conditions are from the same plant, analysis of repeated measures was employed for testing the effects. On testing it was found that the assumption of sphericity of error variance covariance matrix holds for all the traits and hence ANOVA (analysis of variance)

for split plot design (with condition as sub-plot) was employed. Data for the two consecutive years were analyzed separately. However, for estimating heterosis average values were used.

### Results and Discussion

Significant difference among the crosses/cultivars was noticed for all the characters except for  $\Psi_{leaf}$  in the first year (Table 1). The interaction between the factors was significant only with regard to  $\Psi_{leaf}$  in the second year. Since the error mean sum of squares is not significant between the years for all the characters, pooled analysis was performed for comparison between cultivars/crosses. The average values of the characters for different conditions are provided in Table 2.

Table 1. Mean sum of squares of the drought traits in coconut seedlings

Source	$\Psi_{leaf}$ (bars)		LP (ab. values)		Fv/Fm (units)	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Variety	12.73	13.82**	0.078**	0.139**	0.01**	0.005*
Non stress, Stress (NSS)	316.27**	175.22**	0.25**	0.288**	0.108**	0.049**
Variety X NSS	8.25	10.31*	0.01	0.01	0.004	0.002
Error	5.165	5.210	0.011	0.009	0.003	0.002

\* or \*\* indicates the level of significance at 5 % or 1 %

### Heterosis for traits

Heterosis for the traits has been worked out based on mid parent as well as better parent values. Since the trend remained more or less similar in the combinations only the data pertaining to mid parent alone was given in Table 3. The  $\Psi_{leaf}$  among the parents is the highest in ADOT (-4.93) which is significantly different from others during non-stress period. The rest of the parents are on par with regard to this character. There was no heterosis (in terms of better parent as well as mid parent values) observed in the crosses for  $\Psi_{leaf}$  during non-stress period (Table 3). However, the  $\Psi_{leaf}$  value of CGD x ADOT was significantly lower than CGD. During stress,  $\Psi_{leaf}$  of PHOT (-11.62) was significantly lower than the rest of the parents. Significant heterosis (over mid-parent value) was observed with CGD x LCT and CGD x PHOT which is worked out to be 30.53 % and 22.7 %, respectively. Higher revival capacity of this cross (CGD x PHOT) after stress relief has been reported by Rajagopal *et al.* (2007). The cross ADOT x CGD has value significantly lower than the mid-parent value. During recovery, significantly the highest  $\Psi_{leaf}$  was for LCT compared to other parents. Significant heterosis (over mid-parent value) was noticed for CGD x WCT (38.6 %). In sorghum, no significant heterosis was observed for  $\Psi_{leaf}$  (Blum *et al.*, 1990). During non-stress, there was no significant difference

**Table 2.** Average value of drought responsive traits under different conditions in coconut seedlings

Conditions/ Cultivars	$\Psi_{leaf}$ (bars)			LP (ab. values)			Fv/Fm (units)		
	Parent	CGD x Tall	Tall x CGD	Parent	CGD x Tall	Tall x CGD	Parent	CGD x Tall	Tall x CGD
<i>Non Stress</i>									
WCT	-6.43	-5.09	-6.16	0.601	0.668	0.631	0.836	0.824	0.807
LCT	-6.67	-5.54	-5.73	0.509	0.680	0.532	0.803	0.784	0.828
ADOT	-4.93	-4.57	-6.55	0.634	0.554	0.569	0.833	0.836	0.803
PHOT	-6.43	-5.47	-6.83	0.674	0.576	0.448	0.827	0.803	0.829
CGD	-6.48			0.630			0.819		
<i>Stress</i>									
WCT	-9.23	-8.91	-9.49	0.687	0.766	0.724	0.801	0.719	0.709
LCT	-8.80	-6.28	-9.32	0.521	0.693	0.545	0.750	0.722	0.743
ADOT	-9.65	-7.58	-11.42	0.693	0.645	0.623	0.805	0.776	0.759
PHOT	-11.62	-8.08	-11.02	0.717	0.589	0.569	0.768	0.744	0.768
CGD	-9.28			0.652			0.764		
<i>Recovery</i>									
WCT	-7.67	-4.25	-6.92	0.588	0.660	0.628	0.805	0.795	0.792
LCT	-5.33	-6.42	-6.50	0.390	0.607	0.497	0.801	0.803	0.818
ADOT	-6.58	-5.92	-7.00	0.722	0.608	0.486	0.831	0.804	0.833
PHOT	-6.17	-5.33	-5.58	0.648	0.514	0.453	0.823	0.814	0.825
CGD	-6.17			0.654			0.790		
CD (P = 0.05)	1.74				0.115			0.045	

**Table 3.** Heterosis (%) based on mid parent values and the reciprocal differences in coconut cultivars during NS (non stress), S (stress) and Rec. (recovery) periods

Cultivar	$\Psi_{leaf}$			LP			Fv/Fm		
	NS	S	Rec.	NS	S	Rec.	NS	S	Rec.
CGD x WCT	-21.15	-3.73	-38.58	8.53	14.41	6.28	-0.42	-8.12	-0.31
WCT x CGD	-4.57	2.54	0.00	2.52	8.14	1.13	-2.48	-9.39	-0.69
CGD x LCT	-15.74	-30.53	11.65	19.40	18.16	16.28	-3.33	-4.62	0.94
LCT x CGD	-12.85	9.87	13.04	-6.58	-7.08	-4.79	2.10	-1.85	2.83
CGD x ADOT	-19.89	-19.92	-7.14	-12.34	-4.09	-11.63	1.21	-1.08	-0.80
ADOT x CGD	14.81	20.66	9.80	-9.97	-7.36	-29.36	-2.78	-3.25	2.78
CGD x PHOT	-15.26	-22.68	-13.61	-11.66	-13.95	-21.04	-2.43	-2.87	0.93
PHOT x CGD	5.81	5.45	-9.56	-31.29	-16.87	-30.41	0.73	0.26	2.29
Sem	4.57	6.32	6.08	5.43	4.62	6.00	0.74	1.19	0.53
Reciprocal differences									
WCT CGD	-16.98	-6.27	-38.58	6.01	6.27	5.15	2.06	1.27	0.38
LCT CGD	-2.89	-40.4	-1.39	25.98	25.24	21.07	-5.43	-2.77	-1.89
ADOT CGD	-34.7	-40.58	-16.94	-2.37	3.29	17.73	3.99	2.17	-3.58
PHOT CGD	-21.07	-28.13	-4.05	19.63	2.91	9.37	-3.16	-3.13	-1.36

noticed between the cross and reciprocal cross with regard to  $\Psi_{leaf}$  except for ADOT. However, during stress, non significant difference was noticed only for the cross with WCT. But on recovery, the cross with WCT alone showed significant difference between the reciprocal cross.

The value of lipid peroxidation was more or less the same with all parents except of LCT during non-stress. Significant heterosis over better parent as well as mid-parent (Table 3) was observed for PHOT x CGD under non-stress (28.9 and 31.3 %, respectively). No

heterosis was observed for this character during stress. During recovery, CGD x ADOT, CGD x PHOT and CGD x PHOT showed significant heterosis over mid parent (29.4 %, 30.4 % and 21 %, respectively) as well as over better parent (25.7 %, 30.1 % and 21.7 %, respectively). Significant difference between the cross and reciprocal cross was noticed for lipid peroxidation during non-stress with respect to LCT and PHOT. The cross involving LCT had shown significant reciprocal effect during stress and recovery as well. During recovery, cross with ADOT has also shown significant difference between reciprocal

cross. The peroxidation of membranes lipids will be enhanced when plants are exposed to the diverse stresses or become senescence. Generally the enhanced peroxidation is evaluated by an increased malondialdehyde (MDA) content. Dong *et al.* (2006) demonstrated that MDA content of hybrid Cikangzal was significantly lower than that of commercial hybrid Xiangzhamian 2.

Photochemical efficiency (Fv/Fm) values which represent an index of photo inhibition (Genty *et al.*, 1989) did not show significant heterosis over their parents indicating that the trait is likely to be governed by additive genes. In CMS hybrid cotton, the extent of heterosis showed a distinct fluctuation over the growth stages and relatively smaller heterosis in fluorescence parameters compared with photosynthetic parameters (Chen *et al.*, 2005). There was no significant difference between cross and reciprocal cross with respect to this character in either of the situation. The reciprocal difference among the crosses differed during the stress conditions studied.

#### Coefficient of heritability

To provide an estimate of heritability of the traits, data generated in the two years were pooled and the effect due to cultivars/crosses was taken at random. Heritability was also worked out for different conditions separately and is provided in Table 4.

**Table 4. Estimates of heritability (broad based) of characters under different conditions**

Character	Condition	Genetic var.	Environmental var.	Heritability
$\Psi_{leaf}$	Non Stress	0.386	1.076	0.264
	Stress	1.024	11.88	0.079
	Recovery	0.370	3.945	0.086
LP	Non Stress	0.003	0.016	0.158
	Stress	0.0028	0.0279	0.092
	Recovery	0.0061	0.0311	0.163
Fv/Fm	Non Stress	0.00013	0.00128	0.090
	Stress	0.00008	0.00734	0.010
	Recovery	0.00007	0.00138	0.049

Heritability estimates are very low for Fv/Fm value and this trait also did not record any heterosis. Environmental component of the variation of leaf water potential and lipid peroxidation during non-stress were lower than that during stress. But during non-stress condition, the heritability values are high. Although the study uses an important dwarf variety CGD known for drought and root (wilt) tolerance, it needs to be confirmed by experimentation with other dwarf and tall varieties.

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