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Growth and Yield of Different Castor Genotypes Varying in Drought Tolerance

P. Lakshmamma, Lakshmi Prayaga, C. Lavanya and K. Anjani
Directorate of Oilseeds Research, Rajendranagar, Hyderabad, 500 030, India

Abstract: An experiment was conducted to evaluate twelve castor germplasm lines (tolerant to fusarium wilt and differing in bloom/epicuticular wax load) under drought during *rabi* 2005-06 in split plot design with three replications. Stress was imposed by withholding irrigation from 45-120 DAS (stress-1) or 65-120 DAS (stress-2). Total dry matter (TDM) and seed yield significantly reduced with stress. Control plants recorded 62.2 g seed plant^{-1}, whereas stressed plants recorded 42.2, 42.4 g plant^{-1} in stress-1 and stress-2, respectively. Lines RG 2317, RG 923 recorded <30% yield reduction and <0.5 drought susceptibility index (DSI) in both stress treatments. There was significant increase in epicuticular wax load/bloom due to stress i.e. 18.6% in S1 and 17.1% in S2 compared to control. Genotypes also showed similar response except DPC-9, DPC-10, which are of zero bloom type pistillate lines and DCS-86, a breeding line. RG 2317, which is a mild triple bloom type, recorded higher bloom content both in control and under stress compared to other genotypes.

Key words: Castor, EWL/bloom, stress, drought susceptibility index (DSI).

Evaluation of genotypes under stress is useful in breeding programs because it allows a direct estimate of drought tolerance or susceptibility of individual genotypes. Castor, a crop more tolerant to water deficits, is frequently grown in marginal and sub-marginal shallow soils with low inputs under rainfed conditions, which may experience water stress resulting in reduced yields. As it is considered a drought tolerant crop, no attempt was made to improve it further.

Yield under stress is often used as a preliminary screening criterion, with more discriminating tests being applied subsequently to identify accessions with different mechanisms of tolerance. Several efforts were made to identify traits for selection for drought resistance including epicuticular wax load (EWL) in crops like sorghum (Premchandra *et al.*, 1992), groundnut (Samdur *et al.*, 2003), etc. When water deficit becomes severe enough to induce stomatal closure, the rate of water loss is determined directly by the conductance of the cuticle to water vapor. Genotypes with low cuticular transpiration rates usually have a functional advantage during water deficits (Paje *et al.*, 1988). An important acclimation to water stress is the increased wax deposited on the cuticle often giving rise to enhanced glaucousness (Jordan *et al.*, 1983). The epicuticular wax (bloom) on leaves reduces surface transpiration (Premchandra *et al.*, 1992), minimizes leaching losses and protects from injury due to various environmental factors and thus improves water use efficiency.

Hence experiment was conducted to evaluate 12 castor germplasm lines for drought tolerance and influence of water deficit on bloom content.

Materials and Methods

Twelve germplasm lines, mostly tolerant to wilt and differing in bloom content/epicuticular wax load, viz. RG 2317, 362-1 (with mild triple bloom i.e. low bloom content on stem and both sides of leaf), RG 1057, TMV-5 (with dense triple bloom i.e. high bloom content on stem and both sides of leaf), pistillate lines DPC-9, DPC-10 (with zero bloom i.e. without bloom on stem or leaf), DCS-86, 362-1 (breeding lines), RG 122, RG 18, RG 332, RG 923 and RG 1427 were sown during *rabi* 2005-06 in split plot design with three replications. Crop was sown during December 2005 and harvested in May 2006. Stress was imposed from 45-120 days after sowing (DAS) (stress-1) i.e., from primary spike initiation stage to secondary spike maturity stage and 65-120 DAS (stress-2) i.e. from secondary spike initiation stage to secondary spike maturity stage. During stress treatments, there was 40.4 mm rainfall in few spells. Control plants received 9 irrigations, while stress-1 received 3 and stress-2 received 4 irrigations during the crop growth period. Observations on growth, bloom content were recorded before relieving stress (BRS). Bloom content was estimated by taking ten leaf discs of known leaf area (Ebercon *et al.*, 1977) and immersing in 15 ml redistilled chloroform for 15 seconds and the extract was filtered and evaporated on a boiling water bath till entire chloroform evaporated. To this 5 ml potassium dichromate reagent (40 ml deionized water and 20 g potassium dichromate powder mixed vigorously with 1.0 L concentrated sulfuric acid and heated below boiling point until a clear solution is obtained) was added and kept in boiling water bath for 30 min. and cooled. 12 ml deionized water was added and color was developed for several minutes. Optical density was measured at 590 nm. Standard graph was prepared using poly ethylene glycol (PEG). Bloom content was measured form the standard graph and expressed as µg cm^{-2}.

Total dry matter (TDM) and seed yield was recorded at harvest (180 DAS). Drought susceptibility index (DSI) values were calculated following Fischer and Maurer (1978). DSI = (1-(mean yield of genotype under stress/mean yield of genotype under non stress))/Drought intensity index (DII) where, DII = 1-(mean yield averaged across genotypes in stress/mean yield averaged across genotypes in non stress).

Results and Discussion

Growth and TDM

Stress reduced plant height (23%), leaf number (22%), secondary (40%), tertiary (33%) branch production and TDM (Table 1). RG 1427 recorded significantly higher TDM followed by DCS-86 in control. In stress-1, RG 1427 recorded significantly higher TDM, which was at par with RG 923 followed by DCS-86. Whereas in stress-2, RG 18-1 recorded significantly higher TDM, which was at par with DPC-9.

Yield and yield components

Stress did not significantly reduce the primary capsule number, but there was significant reduction in capsule and seed weight and the reduction was more in stress-1 (Table 2). Secondary capsule number, weight and seed yield also significantly reduced with stress treatments and the reduction was comparable in both stress treatments. Even tertiary seed yield was significantly reduced with stress. Hence, there was significant reduction in total seed yield with stress. Control plants recorded 62.2 g $plant^{-1}$, whereas stressed plants recorded 42.2, 42.4 g $plant^{-1}$ in stress-1 and stress-2, respectively. Differences in harvest index were not significant between control and stress treatments.

DCS-86 recorded significantly higher seed yield in control and stress-1 followed by RG1427. RG 1427 and RG 332 showed higher seed yield and were on par followed by DCS-86 in stress-2 (Table 3).

Among different genotypes studied, RG 332, RG 1057, RG 2317,RG 923, RG 1427 and TMV-5 recorded <30% yield reduction in stress-1, RG 332, RG 2317, DPC-10, RG 923 and DPC-10 recorded <30% yield reduction in stress-2 (Table 3). Lines RG 1057, RG 2317, RG 923 and TMV-5 in stress-1,

Table 1. Growth and genotypic differences in TDM at harvest

Treatment	Plant ht. (cm)	Leaf no. $plant^{-1}$	Sec. br. $plant^{-1}$	Tert br. $plant^{-1}$	TDM (g $plant^{-1}$)
Control	51.3	32.0	5	3	217.0
Stress-1 (45-120 DAS)	40.1	22.0	3	2	163.2
Stress-2 (65-120 DAS)	39.1	28.0	3	2	161.9
Mean	43.5	28.0	4	2	180.7
CD (0.05)					
Main plots	1.9	5.1	1	0	16.9
Sub-plots	3.4	2.7	1	0	16.9
Interaction 1	5.9	4.7	1	1	29.3
Interaction 2	5.8	5.8	1	1	30.6
CV (%) 1	6.6	28.3	19	21	14.3
CV (%) 2	8.4	10.5	18	19	10.0

Genotypes	TDM at harvest (g $plant^{-1}$)		
	Control	Stress-1	Stress-2
RG 122	230.6	146.6	162.1
RG 332	213.0	173.6	187.5
RG 1057	179.7	134.5	108.5
RG 2317	175.8	111.2	118.3
DPC-10	167.5	97.2	108.8
RG 923	203.1	209.0	123.5
362-1	188.3	130.8	175.1
RG 1427	323.4	226.8	195.1
DCS-86	289.7	206.1	180.6
RG 18-1	252.3	168.6	240.4
DPC-9	190.3	181.7	232.4
TMV-5	189.8	172.2	111.0
Mean	217.0	163.2	161.9
CD (0.05)		16.9	

Table 2. Yield and yield components

Treatment	Primary spike characters			Secondary spike characters			Tertiary seed wt. (g $plant^{-1}$)	Total seed yield (g $plant^{-1}$)	HI
	Capsule no. $plant^{-1}$	Capsule wt. (g $plant^{-1}$)	Seed wt. (g $plant^{-1}$)	Capsule no. $plant^{-1}$	Capsule wt. plant-1	Seed wt. (g $plant^{-1}$)			
Control	42	37.0	22.1	19	54.6	31.7	8.4	62.2	0.28
Stress-1 (45-120 DAS)	33	29.6	16.9	16	33.5	19.1	6.1	42.2	0.26
Stress-2 (65-120 DAS)	36	33.7	19.1	16	33.1	19.2	4.1	42.4	0.26
Mean	37	33.4	19.4	17	40.4	23.4	6.2	48.9	0.27
CD (0.05)									
Main plots	NS	1.5	1.4	1.8	6.2	7.5	1.8	9.3	NS
Sub-plots	7.7	6.0	2.3	2.3	8.6	6.3	1.6	7.3	0.03
Interaction 1	NS	8.7	4.0	4.1	14.9	10.9	2.7	12.7	0.06
Interaction 2		8.4	3.9	4.1	14.9	11.7	2.9	13.8	0.06
CV (%) 1	30.1	6.7	10.9	16.1	23.4	49.3	44.5	29.0	20.9
CV (%) 2	22.1	15.9	12.6	14.6	22.6	28.6	27.1	15.9	13.4

RG 2317, RG 923 and DPC-10 in stress-2 recorded low DSI (<0.5) values. The genotypes with low/moderate DSI (<0.7) were considered least drought susceptible in wheat also (Chowdhury *et al.*, 1988). Lines RG 2317, RG 923 recorded <30% yield reduction and <0.5 DSI values in both stress treatments. Very low yields were recorded in TMV-5 in stress-2, which might be due to more wilt incidence in this line compared to other genotypes.

Bloom content

Bloom content (μg cm^{-2}) increased significantly with stress treatments (Table 4). The range in bloom content in 12 genotypes ranged from 269.7 to 588.0 in control, 239.3 to 650.0 in stress-1 and 259.4 to 702.0 μg cm^{-2} in stress-2 treatments. On average there was significant and substantial increase because of stress in bloom content (18.6% in S1 and 17.1% in S2 compared to control). Similar accumulation was reported in groundnut by

Table 3. Genotypic differences in seed yield and DSI

Genotypes	Total seed yield (g $plant^{-1}$)			% redution in seed yield		DSI	
	Control	Stress-1 (45-120 DAS)	Stress-2 (65-120 DAS)	Stress-1 (45-120 DAS)	Stress-2 (65-120 DAS)	Stress-1 (45-120 DAS)	Stress-2 (65-120 DAS)
RG 122	72.4	32.8	48.5	54.7	33.0	1.70	1.04
RG 332	81.8	61.5	63.6	24.8	22.2	0.77	0.70
RG 1057	38.2	40.8	25.1	-6.8	34.3	-0.21	1.08
RG 2317	31.4	36.1	28.5	-15.0	9.2	-0.46	0.29
DPC-10	35.9	24.6	33.5	31.5	6.7	0.98	0.21
RG 923	22.4	19.7	22.3	12.1	0.4	0.37	0.01
362-1	61.1	27.5	45.8	55.0	25.0	1.71	0.79
RG 1427	88.8	65.9	65.5	25.8	26.2	0.80	0.82
DCS-86	100.3	90.6	56.3	39.6	43.9	1.23	1.38
RG 18-1	85.5	42.5	52.1	50.3	39.1	1.56	1.23
DPC-9	73.9	42.1	43.3	43.0	41.4	1.34	1.30
TMV-5	54.7	52.0	24.1	4.9	55.9	0.15	1.76
Mean	62.2	42.2	42.4				
CD (0.05)		7.3					

Table 4. Genotypic differences in Bloom content before relieving stress

Treatment	Bloom content ($\mu g\ cm^{-2}$)	Genotypes	Bloom content ($\mu g\ cm^{-2}$)		
			Control	Stress-1 (45-120 DAS)	Stress-2 (65-120 DAS)
Control	393.9	RG 122	269.7	445.1	460.9
Stress-1 (45-120 DAS)	467.2	RG 332	400.9	517.3	468.7
Stress-2 (65-120 DAS)	460.9	RG 1057	388.9	490.9	480.1
Mean	440.7	RG 2317	588.0	650.0	702.0
CD (0.05)		DPC-10	282.4	278.5	285.2
Main plots	7.5	RG 923	357.7	455.0	425.8
Sub-plots	15.6	362-1	337.3	421.0	452.0
Interaction 1	27.0	RG 1427	465.3	548.4	560.9
Interaction 2	26.4	DCS-86	490.3	481.7	495.5
CV (%) 1	12.6	RG 18-1	440.7	566.2	444.3
CV (%) 2	13.8	DPC-9	270.5	239.3	259.4
		TMV-5	335.1	513.5	496.4
		Mean	393.9	467.2	460.9
		CD (0.05)		15.6	

Samdur *et al.*, 2003. Higher levels of leaf epicuticular wax have been shown to be correlated with relative drought tolerance in oat cultivars (Bengston *et al.*, 1978) and with greater water use efficiency in wheat (Johnson *et al.*, 1983). Vakharia *et al.* (1997) also observed increase in epicuticular wax load after imposing drought while leaf moisture and relative water content declined in groundnut.

Genotypes also showed similar response except DPC-9, DPC-10, which are of zero bloom type and DCS-86, a breeding line. RG 2317, which is a mild triple bloom type, recorded higher bloom content both in control and stress compared to other genotypes. RG122, TMV-5 recorded significantly higher bloom content in both stresses compared to control. RG122 showed drought tolerance in previous experiments (Lakshmamma *et al.*, 2004). Though TMV-5 is a dense triple bloom type, it's bloom content is lower than that of RG 2317. Rain might have washed off some amount of bloom.

Thus, the plants subjected to water deficit showed reduced crop growth, accumulated greater bloom content than those grown under regularly irrigated conditions. There is significant increase in bloom content (18.6% in S1 and 17.1% in S2 compared to control) because of imposition of stress. The lines with high bloom content in both stresses compared to control include RG1427, RG2317.Lines RG332, RG 18-1, RG1427 and DCS-86 recorded high TDM (>160 g $plant^{-1}$) in stress. The seed yield was also significantly reduced with stress. Lines RG332, RG 923, RG1427 and RG 2317 recorded <30% yield reduction and RG 923, RG 2317 also showed <0.5 DSI values in both stress treatments. The differences are non significant between two stress treatments as the duration of stress was almost similar.

Results reveal that castor plants show an adaptive response to water deficit by increasing bloom content. Such adaptive responses and associated genotypic differences have been reported in sorghum also (Premchandra *et al.*, 1992; Jordan *et al.*, 1983).Though the role of bloom in drought tolerance in castor cannot be justified at present, it may contribute to drought tolerance as seen in the genotype RG2317, which with high initial levels of bloom content showed better drought tolerance compared to other genotypes and also it has accumulated more bloom during stress compared to control. Most of the genotypes showed increased bloom content in response to stress thus acquire tolerance by minimizing transpiration. Such reduction in transpiration because of EWL was also reported in brassica by Denna (1970). The bloom content showed negative correlation with DSI values (-0.45 in S1 and -0.06 in S2), which also shows its accumulation in drought.

Thorough studies are needed to quantify contribution of bloom in imparting drought tolerance and its influence on reducing the loss of seed yield in castor. Then suitable parents with high initial bloom content or the parents that can accumulate bloom in drought as an adaptive response can be identified for introducing this trait into breeding programmes.

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