Evaluation of Castor (*Ricinus communis* L.) Germplasm for Water Use Efficiency (WUE) and Root Characters

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Sixty-four germplasm lines were sown in two root structures (30 m length, 1.5 m height and 2.4 m width on either side of central 30 cm permanent wall), thirty-two genotypes per structure replicated twice during 2006-07 at Narkhoda research farm of Directorate of Oilseeds Research, Hyderabad. Plants were grown for 100 days and observations on water use efficiency (WUE) traits, root characters and total dry matter (TDM) were recorded. Root length, root volume, root dry weight and leaf area index (LAI) showed strong positive correlation with TDM, hence lines with better root characters and TDM are considered as best lines for WUE and root characters. Fifteen lines showed root length of >195 cm, root volume of >200 cm^3, root dry weight of >35 g, LAI >2.0 and TDM >250 g/plant. These lines include RG 82, RG 89, RG 122, RG 152, RG 211, RG 240, RG 272, RG 282, RG 298, RG 539, RG 627, RG 786, RG 941, RG 1667 and RG 2048.

Key Words: Castor, Root characters, TDM, Water use efficiency

Introduction

With the prediction of extreme events due to climate change, world over now there is more emphasis on breeding varieties and hybrids that can tolerate drought. As it is realized that breeding for yield *per se* is increasingly becoming difficult because of high Genotype×Environment interaction, trait based breeding is suggested. The prerequisite for such breeding programmes is identification of genotypes with one or more of such traits that impart tolerance. Among the many traits associated with drought tolerance, root characters and water use efficiency (WUE) are considered to be most relevant as the former is related to acquisition of water from soil and latter referring to efficient use of absorbed water. Improvement of these traits has been shown to increase the productivity in several species (Sheshshayee *et al.*, 2003). Therefore, an experiment was conducted to identify genotypes with better root growth and WUE traits.

Materials and Methods

Sixty-four germplasm lines with pest (Spodoptera, Semilooper, Jassids) and disease (wilt) tolerance were sown during 2006-07 in two specially constructed root structures of 30 m length, 1.5 m height and 2.4 m width on either side of central 30 cm permanent wall. Thirty-two lines were sown per structure and were replicated twice. There were four plants per replication. The spacing adopted was 90×60 cm. Recommended dose of fertilizers were applied. Plants were grown for 100 days and then root structures were dismantled and plants along with roots were separated by using water. Observations on growth parameters *viz*., plant height, branches, leaf number, stem girth, WUE traits like SPAD chlorophyll meter reading (SCMR), specific leaf area (SLA) and root characters *i.e*., root length, fresh weight, dry weight, root volume and total dry matter (TDM) were recorded. SCMR was measured using SPAD chlorophyll meter, SLA was computed by measuring leaf area and dry weight (SLA = leaf area (dm^2) / leaf dry weight (g)). Root volume was measured by quantifying the amount of water displaced by roots. Dried leaves which were used for measuring SCMR, SLA were powdered and these samples were sent to National facility of Isotope Ratio Mass Spectrometer (IRMS) at UAS, Bangalore for measuring ^{13}C and ^{18}O. Principal component analysis was done (Dunteman, 1994) for selecting the efficient castor genotypes with high performance in terms of shoot and root characters. In the first stage indices were developed separately for shoot and root characters using principal component analysis based on the correlation matrices. Thus, developed indices were utilized as variables for second stage principal component analysis to develop a composite index for selecting the castor genotypes. The genotypes were ranked based on the index in ascending order to select the efficient genotypes with high ranks.

Results and Discussion

The mean, range and standard deviation for different

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Table 1. Mean, range and standard deviation for different root and shoot characters in castor genotypes

Character	Plant height (cm)	Leaf number	Secondary branch number	Tertiary branch number	Stem girth (cm)	SCMR	SLA (dm^2/g)
Mean	72	23	2	2	8.5	37.0	1.76
Range	27-177	12-36	1-3	0-5	6.2-11.4	24.8-53.8	1.15-2.7
Standard deviation	37.1	5.7	0.5	1.2	1.2	5.0	0.3
Character	Root length (cm)	Root volume (cm^3)	Root dry weight (g)	LAI	TDM (g)	Root density (W/V)	Root /shoot ratio
Mean	185	169	26.7	1.8	226	0.80	13.6
Range	117-223	65-355	9.8-57.7	0.3-5.3	90-412	0.54-0.95	8.8-19.6
Standard deviation	17.6	64.1	11.1	0.84	71.2	0.09	2.5

shoot and root characters is presented in Table 1. Large genotypic variation is seen for these characters. Plant height ranged from 27 to 177 cm with an average of 72 cm. Secondary and tertiary branch number ranged from 1 to 5 with an average leaf number of 23/plant. Variation for SCMR is from 24.8 to 53.8 and for SLA it ranged from 1.15 to 2.7 dm^2/g. Among different characters recorded, root length, root volume, root dry weight and leaf area index (LAI) showed strong positive correlation of >0.70 with TDM (Table 2). Different germplasm lines recorded root length ranging from 117-223 cm with an average of 185 cm; root volume differed from 65 to 355 cm^3 average being 169 cm^3. 10-58 g root dry weight was recorded with an average of 27 g/plant. LAI ranged from 0.3–5.3 and TDM from 90-412 g/plant. On an average, LAI of 1.8 and TDM of 226 g were recorded. The lines with better root characters and TDM are considered as best lines for WUE and root characters as these characters showed strong positive correlation with TDM.

Among the 64 lines screened, germplasm lines with >195cm root length, root volume of >200 cm^3, root dry weight of >35 g, LAI >2.0 and TDM >250 g/plant and with high SCMR (>40), and low SLA (1.5) were selected and presented in Table 3. Fifteen lines which showed better growth for at least 2 to 3 shoot and root characters were selected. These lines include RG 82, RG 89, RG 122, RG 152, RG 211, RG 240, RG 272, RG 282, RG 298, RG 539, RG 627, RG 786, RG 941, RG 1667 and RG 2048. Different shoot characters of these lines were presented in Table 4, and root characters, composite index and isotopic composition in Table 4b. Only four of these 15 lines (RG 211, RG 627, RG 941and RG 2048) showed high SCMR (>40) and six lines showed low SLA (d" 1.6) which include RG 82, RG 89, RG 152, RG 282, RG 941 and RG 2048. These 15 lines also showed low ^{13}C and high ^{18}O values which shows their better WUE. Based on the composite index values, the top 5 genotypes include RG 152, RG 240, RG 539, RG 786 and RG 2048. These genotypes which are ranked as top ones showed efficient performance for both shoot and root growth thus confirming the composite index performed well for selecting the efficient genotypes.

Plant root system plays an important role in regulation of water uptake and extraction from deep soil layers.

Table 2. Correlation coefficients among different growth characters in castor

Characters	Mean
Root length *vs* TDM	0.78
Root Volume *vs* TDM	0.86
Root dry weight *vs* TDM	0.92
LAI *vs* TDM	0.71
SCMR *vs* TDM	0.04
SLA *vs* TDM	-0.01
SCMR *vs* SLA	0.011

Table 3. Castor lines with better root and shoot characters

Lines with		Genotypes
High Root length	>195 cm	RG 34, 82, 89, 122, 152, 211,240, 272, 282, 661, 539, 564, 627, 786, 941, 1667, 2048, 2710
High Root Volume	>200 cm^3	RG 82, 89, 122, 152, 211, 240, 272, 282, 298, 539, 627, 694,786, 941,1667, 2048
High Root dry weight	>35 g	RG45, 82, 122, 152, 211,240,272, 298, 539, 627,786, 941, 2048
High leaf area index	>2.0	RG 81, 82, 117, 122, 152, 211,240, 272, 289, 298, 539, 627, 786, 941, 2048
High total dry matter	>250 g	RG 34, 45, 66, 82, 89, 90, 117,122, 152, 211, 240, 272,282,297,298, 539, 564, 627, 630, 694,7 86,941, 1667, 2048
High SPAD chlorophyll meter reading	>40	RG 45, 211, 214, 226, 297,313, 541, 627, 941,1 057, 1202,1771, 2046, 2048
Low specific leaf area	£1.5 (dm^2/g)	RG 52, 66, 78, 82, 89, 152, 282, 313, 661, 1427, 348, 357, 398, 541, 1096,1608, 1771, 2048, 2710

Table 4. Plant growth characters of castor genotypes (per plant)

Germplasm lines	Plant height (cm)	Leaf number	Node number	Stem Girth (cm)	SPAD chlorophyll reading (SCMR)	Specific leaf area (SLA)	Leaf area index (LAI)	Total dry matter (TDM) (g)
RG 82	95.8	29	14	8.8	26	1.4	2.5	371
RG 89	94.8	30	15	8.9	31.2	1.5	2.4	286
RG 122	120.1	28	17	10.1	36.4	1.8	3.3	341
RG 152	145.7	21	18	10.1	36.4	1.5	2.7	389
RG 211	70.4	34	13	9.8	47.1	2.0	3.3	362
RG 240	143.1	25	17	10.7	38.8	2.7	5.3	351
RG 272	96.8	14	16	11.0	32.8	1.7	3.1	384
RG 282	84.8	29	14	9.4	38.1	1.5	2.0	315
RG 298	61.5	28	11	9.7	34.5	2.1	2.8	281
RG 539	177.3	26	21	11.4	34.9	1.93	3.5	412
RG 627	110.0	28	16	11.1	45.2	1.89	3.2	354
RG 786	120.3	27	18	10.7	34.4	1.75	2.8	333
RG 941	57.1	25	12	8.6	41.9	1.65	2.2	281
RG 1667	33.8	21	9	9.1	36.2	1.74	1.7	258
RG 2048	59.3	28	11	9.7	42.0	1.64	2.2	313
SEm ±	6.23	2.41	1.21	0.69	2.2	0.02	0.37	21.3
CD (0.05)	18.0	6.9	3.3	2.0	6.4	0.06	1.1	61.2
CV(%)	13.2	15.7	13.9	11.6	8.5	1.7	29.7	13.2

Table 5. Root characters and mass isotopes per plant in castor genotypes

Germplasm	Root characters			Isotopic composition		Composite index
	Length (cm)	Volume (cm^3)	Dry weight (g)	^{13}C	^{18}O	
RG 82	223	279	41.1	-26.762	28.529	
RG 89	209	203	33.9	-27.547	29.398	
RG 122	198	233	39.7	-27.018	29.326	
RG 152	218	265	59.1	-27.143	29.716	0.848
RG 211	204	206	35.7	-26.990	29.810	
RG 240	198	355	57.7	-26.306	29.419	1.037
RG 272	198	273	48	-27.541	28.287	
RG 282	198	211	33.8	-26.431	30.702	
RG 298	190	255	38.1	-26.826	29.948	
RG 539	213	317	49.4	-26.836	30.511	0.648
RG 627	203	279	47.4	-26.077	29.750	
RG 786	200	334	46.5	-25.914	30.811	0.606
RG 941	199	209	41.3	-27.137	30.068	
RG 1667	206	202	28.2	-26.098	29.652	
RG 2048	221	307	45.6	-26.701	31.021	0.730
SEm ±	11.2	19.8	4.34			
CD (0.05)	32.0	56.9	12.5			
CV(%)	8.6	16.6	23.2			

A well endowed root system is a vital mechanism of crop plants to grow under moisture deficit conditions. This in turn influences the performance of the shoot growth and has a bearing on yield potential of that genotype. Root length is an indicator of the plant's ability to absorb water from the deeper layers of soil and is influenced by better root penetrability. Among the different characters studied, root length, root volume, root dry weight and LAI showed strong positive correlation with TDM. The lines that showed better root length (>195 cm) also showed more root dry weight, LAI and TDM (Table 5). A deep rooted plant maintains leaf temperature by way of maintaining higher transpiration even under moisture stress thus reiterates the importance of root characters. Li *et al*. (2005) have demonstrated that deep rooted rice variety exhibits significantly higher drought tolerance than shallow rooted one. Deep rooting, root length density and root distribution have been identified as drought adaptation traits. Root length and dry weight showed significant positive correlation with grain yield in stress in rice (Hanamaratti *et al*., 2008).

Alternate approaches for measuring WUE include measuring specific leaf area (SLA), SPAD chlorophyll meter reading (SCMR). SLA is used as alternate method for estimation of genetic variability for transpiration efficiency (TE) or water use efficiency (Wright *et al*.,

1988). Similarly, SPAD reading can also provide a good estimate of leaf chlorophyll content and, hence, specific leaf nitrogen (SLN). The relation between SCMR and TE was established by Sheshshayee *et al*. (2001) in groundnut. In castor, SCMR and SLA did not show strong correlation with TDM. Only four among the 15 lines showed high SCMR (>40) and six lines showed low SLA (d" 1.6). ^{18}O can be used as a surrogate for transpiration and stomatal conductance (gs) and high ^{18}O shows high amount of water transpired which is directly related to yield (Bindu Madhava *et al*., 1999). Relationship between carbon isotope discrimination (CID) and WUE is studied by Farquhar and Richards (1984). Higher ^{13}C shows less WUE. The best lines identified also showed low ^{13}C and high ^{18}O values which shows their WUE. The selected fifteen lines will again be sown in field during late *rabi* along with poor root growth and WUE lines as checks by imposing stress to study their performance under field conditions.

Thus, the lines with better root length, root volume, root dry weight, LAI, TDM, high SCMR, low SLA, low ^{13}C and high^{18}O were selected as best lines for WUE and root characters in castor.

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