Assessing drought tolerance in *Brassica* species by root characteristics and plant water relations

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Abstract

Thirty four accessions of *Brassica juncea* and twenty seven of *B. napus* were planted in drought micro plots (size 6 × 1 × 1.5 m) under un-irrigated conditions (only pre-sowing irrigation) for root characteristics, plant water relations, yield attributes and seed yield. All traits differed significantly within each species. Association among different traits showed that the two species adopted different mechanisms in response to water stress. In *B. juncea*, leaf relative water content (RWC) decreased with decreasing leaf water potential (WP) while in *B. napus* RWC followed osmotic potential, which indicate that the former species had greater osmotic adjustment than the latter. The argument is further supported by the facts that decrease in WP RWC and osmotic potential (OP) promoted root growth in *B. juncea* but not in *B. napus*. Higher root weight resulted into deeper root zone depth in both the species. On an average root zone depth was greater in *B. juncea* (118.2 cm) than in *B. napus* (111 cm). In *B. juncea*, increased root zone depth led to higher number of primary and secondary branches, pods per plant while in *B. napus* root zone depth was associated only with the number of pods per plant. Consequently, increased biomass and seed yield were recorded in *B. juncea* as biomass and seed yield were positively correlated with decreasing OP. No such association was found in *B. napus*. Accessions EC 552573, 552579, 552580, 552581, 552582, 552583 and Rohini of *B. juncea* showed OP lower than -1.5 MPa whereas in *B. napus*, accessions EC 552585, 552588, 552597, 552599, 552601, 552602, 552603, 552607, 552609 and Neelam showed OP lower than -1.5 MPa. But the accessions in *B. juncea* maintained higher RWC than in *B. napus*. It is interesting to note that seed size was reduced due to higher osmotic adjustment in both the species. Reduction in RWC due to water stress decreased primary branches but not the secondary branches in the two species. In conclusion, water deficit decreased WP and RWC in *B juncea* resulting into greater osmotic adjustment and higher root growth which helped the plants to explore greater soil volume for water resulting in better yield attributes and ultimately seed yield.

Introduction

Brassica species are mostly grown on conserved soil moisture with one supplemental irrigation in the Indian subcontinent. The soils of these areas are light textured with low water holding capacity. Therefore, occurrence of drought is a common feature during the crop growth period especially at reproductive phases of growth in *Brassica* species, when the seed yield is reduced drastically. During the last decade, there has been regular exchange of *Brassica* germplasm among Australia, China and India. New germplasm lines have been evolved from the exotic material, which require detailed study of physiology characters to understand their adaptability to local environments. Moisture stress has been shown to induce osmotic adjustment in *Brassica* species (Kumar *et al*., 1984, 1987), which help the plants to maintain growth and photosynthetic activity (Turner, 1982) over a wide range of soil water potentials could be advantageous in such situations. Very little information is available on the genetic variability in exotic material of *Brassica* species with regard to moisture stress in Indian conditions. The results reported in this paper have evaluated the nature and extent of variability in the two species, *Brassica juncea* and *B. napus* for root characteristics, plant water status and seed yield with regard to water deficit.

Materials and Methods

The study was conducted at Field Crop Physiology Laboratory, CCS Haryana Agricultural University, Hisar (29°10′N latitude, 75°46′E longitude and 215 M altitude). Thirty four accessions of *Brassica juncea* and 27 of *B. napus* were planted in drought micro plots of size 6x1x1.5m filled with dunal sand of 28% water holding capacity. The soil retained 11.3 and 4.3 cm water per meter soil depth at - 0.1 and - 15 bars of soil water potential, respectively. A pre-sowing irrigation was applied to the plots. At seeding, the soil contained 140 mm of available water in the top 120 cm layer. During the crop growing season cm rainfall was received. Plants of both the species were spaced 15cm plant to plant and 30cm between rows. The experiment was designed as randomized blocks with three replications.

Measurements of leaf water potential (by pressure chamber apparatus), osmotic potential (by 5100-B vapour pressure osmometer) and leaf relative water content (RWC) were made concurrently at six leaves within a plot at siliqua formation stage between 1200-1400 h. RWC of the same leaf was estimated by sampling 8-10 leaf disks of 15 mm diameter by using the equation (described by Kumar and Elston, 1992):

$$RWC = FW – DW / MW - DW,$$

where FW, DW and MW are the fresh, oven-dry and fully hydrated (maximum) fresh weights.

For root zone depth study, roots were separated from sand with a gentle water sprinkler and maximum root lengths were measured. At maturity, primary and secondary branches per plant, number of pods per plant, 1000-seed weight, total plant biomass and seed yield were recorded. Harvest index was calculated as the ratio of seed yield and total biomass.

Results

The accessions of two *Brassica* species displayed significant genetic variation in root zone depth, RWC, LWP and seed yield (Table 1). However, in general, *B. juncea* accessions showed higher seed yield per plant than the accessions of *B. napus*. Accessions EC 552573, 552583, 552584 in *B. juncea* and accessions EC 552586, 552588, 552604 and 552607 in *B. napus* were better performer than their respective checks. These accessions also displayed better plant water status.

Table 1. Variations in root depth. lea1 relative water content(RWC) and seed yield in *Brassica juncea* and *B. napus*

Brassica juncea					*Brassica napus*				
Accession	Root depth (cm)	Seed yield (g/plant)	RWC (%)	LWP (bar)	Accession	Root depth (cm)	Seed yield (g/plant)	RWC (%)	LWP (bar)
EC 552573	128.3	9.1	86.0	-11.3	EC 552585	104.7	7.3	84.7	-11.5
EC 552574	114.0	5.6	88.8	-10.0	EC 552586	142.7	9.2	87.8	-12.0
EC 552575	135.0	4.6	87.6	-10.8	EC 552587	89.0	2.6	86.2	-13.0
EC 552576	153.0	5.5	88.0	-10.8	EC 552588	50.7	9.5	79.7	-10.5
EC 552577	119.0	7.4	88.9	-10.3	EC 552589	117.7	4.4	85.2	-10.0
EC 552579	114.0	7.2	88.0	-10.0	EC 552590	108.3	2.8	88.7	-11.0
EC 552580	115.3	2.6	89.3	-10.0	EC 552591	116.7	3.5	86.3	-10.0
EC 552581	131.0	3.6	89.5	-9.8	EC 552592	61.3	4.9	90.3	-10.0
EC 552582	134.0	2.7	89.8	-9.8	EC 552593	86.0	1.7	88.5	-10.0
EC 552583	112.0	9.7	88.5	-10.0	EC 552594	103.0	2.8	87.7	-10.5
EC 552584	95.3	9.4	90.4	-10.8	EC 552595	98.0	5.8	87.0	-9.5
Varuna	121.3	5.0	90.5	-9.3	EC 552596	97.3	2.4	85.3	-10.0
Seetha	135.7	7.6	87.3	-11.3	EC 552597	125.3	3.8	85.8	-9.5
Sanjucta-Aseh	75.0	4.4	90.6	-10.8	EC 552598	128.7	3.2	86.8	-10.5
RH 30	139.0	4.5	89.8	-10.0	EC 552599	130.3	6.9	90.3	-9.5
RL 1359	94.7	5.0	90.8	-11.3	EC 552600	140.0	6.7	90.3	-10.0
Prakash	100.0	5.2	90.1	-11.5	EC 552601	146.0	7.1	86.5	-9.5
RH 781	121.7	5.5	92.6	-11.0	EC 552602	125.0	6.2	86.4	-10.0
PBR 97	109.0	5.0	91.4	-10.8	EC 552603	129.0	3.6	85.7	-10.0
RH 819	103.3	2.9	89.3	-11.8	EC 552604	64.3	9.2	88.5	-10.5
Durgamani	91.3	2.1	90.5	-11.0	EC 552605	153.0	7.2	88.7	-10.0
Sej 2	117.3	5.3	92.7	-11.0	EC 552606	81.0	2.6	89.5	-10.5
RH 8113	115.0	3.2	90.2	-10.8	EC 552607	146.0	11.6	87.5	-10.0
Kranti	113.3	5.7	86.7	-9.8	EC 552608	106.0	5.8	90.4	-11.0
PCR 7	120.7	3.9	89.2	-9.5	EC 552609	117.3	3.6	87.0	-11.0
Vardan	127.0	6.3	73.0	-11.0	Neelam	104.3	13.9	85.7	-11.0
RH 8812	125.0	4.3	84.5	-10.0	GSL 2	124.0	12.1	84.9	-11.0
GM 1	124.0	5.8	83.1	-11.8	CD (5%)	14.9	2.4	3.4	0.4
Vaibav	134.3	5.2	78.4	-13.0					
PBR 91	117.0	5.2	83.9	-11.8					
Rohini	131.7	4.5	87.6	-12.8					
RLM 619	113.7	7.7	83.7	-13.0					
RH 0270	96.7	4.2	80.6	-13.0					
RH 9304	127.0	4.4	81.3	-12.5					
CD (5%)	16.7	2.3	5.9	0.4					

As shown in Table 2 and 3, the correlation between the plant water status components, root zone depth, yield-attributes and seed yield differed between the two species. The major difference was that LWP and OP were related to most of the yield-attributes and seed yield in *B. juncea* and only to number of branches per plant in *B. napus*. RWC was related to root zone depth in *B. juncea* but not in *B. napus*. Similarly seed yield was negatively correlated with OP in *B. juncea* and showed no significant association in *B. napus*. RWC in *B. napus* decreased with decreasing OP but not in *B. juncea*, in which RWC followed LWP.

Table 2. Coefficient of correlation between water relations traits, yield attributes and yield in *Brassica juncea*

	Root depth	Primary branches	Secondary branches	Pods/ plant	Test weight	Biological yield	Seed yield	Harvest index	Leaf water potential	Osmotic potential
Primary branches	0.387									
Secondary branches	0.262	0.776								
Pods/plant	0.319	0.759	0.863							
Test weight	-0.114	-0.690	-0.675	-0.737						
Biological yield	0.402	0.457	0.344	0.434	-0.484					
Seed yield	0.377	-0.044	0.052	0.138	-0.188	0.684				
Harvest index	0.032	-0.529	-0.276	-0.254	0.271	-0.347	0.399			
Leaf water potential	0.199	0.345	0.127	0.182	0.391	0.261	0.125	-0.113		
Osmotic potential	-0.370	-0.446	-0.409	-0.482	0.496	-0.568	-0.314	0.309	0.023	
Relative water content	-0.303	0.135	-0.009	0.102	-0.228	0.034	-0.041	-0.103	0.459	-0.014

Table 3. Coefficient of of correlation between water relations traits, yield attributes and yield in *Brassica nupus*

	Root depth	Primary branches	Secondary branches	Pods/ plant	Test weight	Biological yield	Seed yield	Harvest index	Leaf water potential	Osmotic potential
Primary branches	0.2355									
Secondary branches	0.1005	0.605471								
Pods/plant	0.3746	0.777561	0.789495							
Test weight	-0.286	0.073881	0.173682	0.1074						
Biological yield	-0.167	0.036599	-0.160244	0.0294	0.231					
Seed yield	-0.185	0.212094	-0.113162	0.1723	0.344	0.905915				
Harvest index	-0.014	0.228078	0.112449	0.251	0.274	-0.39548	-0.012			
Leaf water potential	0.263	0.202	-0.032	0.052	0.09	-0.315	-0.134	0.419		
Osmotic potential	-0.147	-0.432	-0.334	-0.41	0.23	0.07	-0.01	-0.03	0.009	
Relative water content	0.1839	-0.23776	-0.476278	-0.2706	0.135	-0.08137	-0.094	0.1014	0.123	0.331

Discussion

Water deficits may induce osmotic adjustment in leaves, roots and reproductive parts of the plants (Kumar *et al*. 1984), resulting into near normal functioning of the metabolic activities of the plants. In *B. juncea*, RWC showed positive association with LWP indicating that RWC decreased with the decrease in LWP as a result of decreasing soil water potential or increasing water deficit. This shows that *B. juncea* plants were able to sense the degree of water deficit and made adjustment in their tissue water content. While in *B. napus,* RWC was positively correlated with OP, which means that decrease in OP also decreased RWC. This simply showed the effect of dehydration when decreasing water concentration in the tissues increased the solutes thereby reducing OP. This fact in *B. napus* is further supported by the lack of association between root zone depth and OP, whereas, both parameters were negatively associated in *B. juncea* indicating a greater degree of osmotic adjustment. Osmotic adjustment is reported to promot root growth in *B. juncea* (Kumar and Singh, 1998). On an average, root zone depth was 118.2 cm in *B. juncea* and 109 cm in *B. napus*. Higher root depth in *B. juncea* might have led to higher soil moisture extraction from deeper layers than that in *B. napus*. Increased water use in *B. juncea* improved plant water status (LWP and RWC) and photosynthetic activity. Root zone depth was positively correlated with the number of primary and secondary branches and number of pods per plant in *B. juncea* while no such association was found in *B. napus*. This indicates that maintenance of better plant water status improved yield-attributes and consequently higher biomass and seed yield were recorded in *B. juncea* than *B. napus*.

Conclusions

In conclusion, it may be stated that the accessions of *B. juncea* showed higher osmotic adjustment (as indicated by lower OP), exploited greater soil volume for soil moisture and therefore, able to maintain better plant water status resulting into improved yield-attributes and seed yield than that in *B. napus*. Thus, the measurements of plant water status at midday hours and root zone depth at siliqua formation stage could be exploited in *Brassica* species improvement programmes for the screening of relatively large number of germplasm lines for drought tolerance. However, identification and manipulation of genes controlling these beneficial traits in plant breeding programme is required.

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