Drought induced changes in water use efficiency and other morpho-physiological characters in Indian mustard (*Brassica juncea* L.)

Maharaj Singh, J.S. Chauhan and S. S. Meena
Directorate of Rapeseed-Mustard Research, Sewar, Bharatpur-321 303, Rajasthan, India
E.mail : ms_nrcrm@yahoo.com

ABSTRACT

Drought induced changes in water use efficiency and other morpho-physiological characters were investigated during *rabi* (Oct. to April) season of 2008-09 utilizing 22 advance breeding lines/ varieties of Indian mustard (*Brassica juncea* L.). Photosynthesis (Pn), transpiration (Tr), water use efficiency WUE), stomatal conductance (Gs), leaf area index (LAI), specific leaf area (SLA), total dry matter (TDM) and seed yield were significantly affected by genotypes, environment and genotypes x environment interactions except genotypes x environment interaction effects for transpiration and LAI. Drought reduced Pn, Tr, WUE, LAI, SLA, TDM and seed yield by 0-63.0%, 6.2-34.5%, -5.0-67.0%, 2.0-36.0%, 14.0-79.0% and 18.8-77.1%, respectively. Specific leaf area showed significant and negative association with seed yield under both irrigated (r = -0.863**) and rainfed (r = -0.788) conditions. Photosynthesis, water use efficiency and TDM had positive and significant association with seed yield under irrigated as well as rainfed conditions. The contribution of Pn, WUE, SLA and TDM to seed yield/plant was 63.0%, 59.2%, 61.9% and 87.0%, respectively under rainfed conditions. The results of the present study revealed that Pn, WUE, and SLA had direct influence over seed yield through increased dry matter production.

Key words: Water use efficiency- stomatal conductance- SLA- LAI-*Brassica juncea*

INTRODUCTION

India contributes 21.7 % and 14.3 % to the total world acreage and production of rapeseed-mustard (FAO, 2009). Of the 5.82 m ha under rapeseed-mustard during 2007-08 in India, nearly one third was rainfed, where crop suffers from high temperature during crop establishment stage as well as drought through out the cropping season, adversely affecting the crop productivity. High water use efficiency (WUE), ability of the plant to produce dry matter / unit of water is a genetic character, dependent on photosynthetic rate (Pn) and transpiration rate (T), is very crucial for productivity of the crop under drought stress. Since low photosynthetic efficiency is believed to be one of the major constraints in achieving high yield (Thurling 1992), enhancing photosynthetic efficiency would be a possible approach in improving yield. Genotypic variation in WUE has been reported in peanut (Wright et al. 1988) and mustard (Singh et al. 2007) using carbon isotope discrimination technique. However, this technique being expensive is not suitable for mass screening (Hall et al. 1997). Recently, Anyia and Herzog (2003) in cowpea and Singh et al. (2008) in mustard used gas exchange parameters to evaluate WUE. Seed yield is also limited by the relatively short duration of the growing season and the severity of soil moisture deficits experienced during the later phases of reproductive development (Gunasekera et al. 2003). The contribution of photosynthesis of pods to the seed yield in Brassicas is about 70% (Singal et al. 1992), therefore, genotypes with high WUE during this phase would be highly desirable. The objective of the present study was to investigate drought induced changes in WUE during pod formation stage and other related characters and their interrelationships in Indian mustard.

MATERIAL AND METHODS

Experimental materials for the present study consisted of 22 advanced breeding lines/ varieties evaluated in factorial randomized complete block design with three replications during *rabi* season (October to April) 2008-09 under irrigation and rainfed conditions. Each genotype was sown in 5.0 x 1.5 m plots of 5 rows spaced 30 cm apart. Plant-to-plant distance was maintained about 10 cm within a row by thinning. A fertilizer dose of 40 N: 40: P_2O_5: 20 K_2O kg / ha was applied at the time of sowing. Two irrigations at 35 and 65 days after sowing were given to irrigated treatment plots only. Plant protection measures were adopted as and when required. Photosynthesis, transpiration, internal CO_2 concentration and stomatal conductance were recorded on 3rd and 4th fully expanded leaf from the top of three randomly taken plants in each replication with the help of portable photosynthesis system (CIRAS-2) during 80-85 day after sowing coinciding with pod formation stage. Water use efficiency (WUE) was computed as the ratio of photosynthesis to transpiration and expressed in µmoles/mmole. Leaf area was determined for the plants from 50 cm row length taken at 80-85 DAS. Leaf area was measured using LICOR 3100 leaf area meter. The leaves were dried at 80°Cfor at least 48 hours and dry weight was recorded. Specific leaf area was computed as the ratio of leaf area to dry weight and expressed in cm^2/g. Five plants/genotype/replications were taken at harvest to record total dry matter and seed yield / plant. The change (%) in mean of a character under rainfed conditions over that of irrigated conditions was computed for each character separately.

Analysis of variance to separate genotypic, environment and genotypes x environment interaction effects was conducted using multiple randomized complete block design by Indostat-version 2003. Simple correlations and regression for different characters was conducted following standard statistical methods (Gomez and Gomez 1984).

RESULTS

Variation in soil moisture content

The soil moisture content at the time of sowing was 12.4 -14.4%(0-15 cm); 12.8- 15.8% (15-30 cm) and 13.5 -16.8 % (30-.60 cm). Under rainfed condition, the soil moisture content declined with the advancement of the crop and reached up to 3.0% (0-15), 5.0%(30-60cm) and 6.0%(30-60 cm) at the time of maturity. Under irrigated condition, the soil moisture content decreased from sowing to 35 DAS. The increase in soil moisture content under irrigated condition was noted at 45 and 75 DAS immediately after 2nd irrigation (Fig.1). The soil moisture content during 65–75 DAS varied from 13.6-16.4%(15-30 cm) and 14.2–16.8% (30-60 cm) under irrigated condition while from 5.6 -5.3% (15 - 30cm) and 7.4- 6.8% (30-60 cm) under rainfed condition.

Drought induced changes

Analysis of variance indicated significant genotypic, environment and genotypes x environment interactions effects for all the characters except genotypes x environment interaction effects for transpiration and LAI suggesting presence of substantial variability in the experimental materials. However, the environment significantly influenced all the characters and genotypes had differential response to both the environments.

Leaf area index varied from 0.62 (RLM-619)-1.23 (BPR-549-9) and from 0.38 (RLM-619) to 0.92 (BPR-549-9) under irrigated and rainfed conditions, respectively. The decrease in LAI varied from 2.0% (BPR 543-2)– 42% (RH-819) under rainfed condition. The specific leaf area varied from 155.6 (BPR-537) to 381.0 cm^2/g (RH-819) under irrigated condition while under rainfed condition it varied from 123.5 (BPR-537) to 245 cm^2/g (RH-819) and the percent decrease under rainfed conditions ranged from - 0.61-22.5%.

Photosynthesis rate was 13.97 – 22.3 µ moles / m^2 / s under irrigated condition with the mean value of 17.9 ± 0.53.The genotype BPR-349-9 and BPR-172-7 showed maximum photosynthesis under irrigated and rainfed condition, respectively. Photosynthesis was reduced under rainfed conditions by up to 63.0% (BPR-542-14) while the genotype BPR-541-3, BPR-541-2, BPR-139-8, RH-819, Urvashi, RCC-4 and Varuna showed low decrease (< 20%) under rainfed condition.

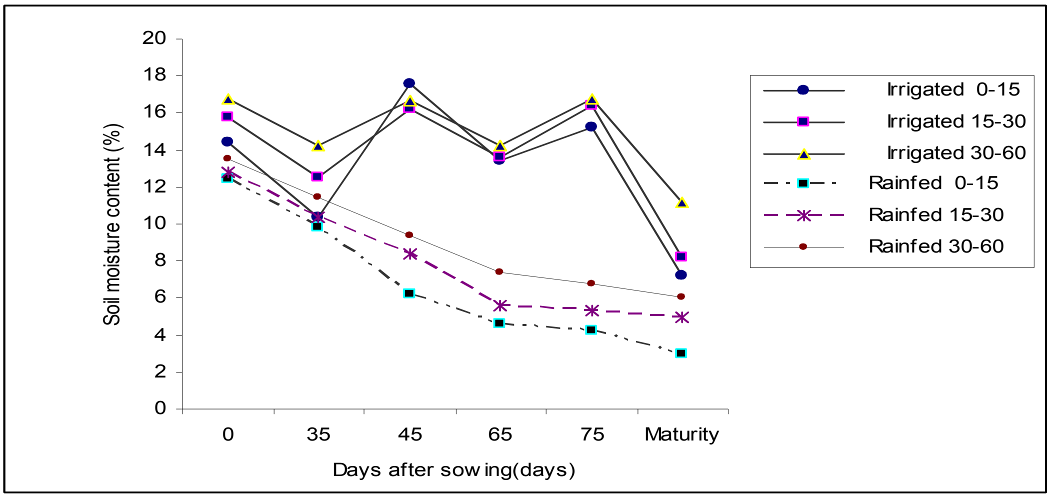

Fig. 1. Pattern of soil moisture content during cropping season

Transpiration rate was considerably reduced by up to 34.5% under rainfed conditions. Genotypes BPR-541-3, BPR-541-4, BPR-542-14, BPR-549-2 and BPR-349-9 showed minimum transpiration under rainfed condition (2.77 to 2.87). Stomatal conductance increased significantly under rainfed condition. It ranged from 142 (RLM-619) - 290 m moles / m^2 / s (BPR-139-8) and224 (BPR-541-2)-352 m moles / m^2 / s (BPR-549-9), respectively, under irrigated and rainfed condition (Table 1).

Table 1. Range and mean of different morpho-physiological characters of Indian mustard under irrigated and rainfed conditions

Character	Irrigated		Rainfed	
	Range	Mean ± SEM	Range	Mean ± SEM
Specific leaf area (cm^2/g)	155.6 – 381.0	259 ± 15.9	123.5 – 245.5	178.9 ± 5.79
Leaf area index	0.62 – 1.23	0.85 ± 0.029	0.38 – 0.92	0.65 ± 0.027
Photosynthesis (μ moles/ m^2/s)	13.97 – 22.3	17.9 ± 0.53	6.77 – 17.5	13.1 ± 0.56
Transpiration (m moles/ m^2 / s)	3.46 – 5.43	4.31 ± 0.13	2.77 – 5.08	3.41 ± 0.12
Stomatal Conductance (m moles / m^2 / s)	142 – 290.0	187.6 ± 7.96	224.3 – 351.7	285.8 ± 8.82
Water use efficiency (μ moles/ m mole)	2.62 – 8.06	5.00 ± 0.31	2.07 – 5.48	3.98 ± 0.19
Total dry matter (g/plant)	39.1 – 54.8	48.8 ± 0.84	11.3 – 38.0	21.0 ± 1.69
Yield (g/plant)	11.4 – 17.2	14.5 ± 0.33	3.69 – 11.2	6.31 ± 0.44

Water use efficiency showed a range of 2.62 (RH -819) to 8.06 µ moles/ m mole (BPR-349-9) and 2.07(BPR-541-5) to 5.48 µ moles/ m mole (BPR-541-3), respectively, under irrigated and rainfed condition. The genotypes, BPR-349-9, BPR-549-2, BPR-542-14 and RLM-619 showed higher WUE under irrigated condition (> 6 µ moles/ m mole) while the genotypes, BPR-349-9, BPR-541-3, BPR-541-4 and Urvashi under rainfed condition.

Total dry weight / plant varied from 39.1(Varuna) to 54.8 g (BPR-349-9) with the mean value of 48.8 ± 0.84 under irrigated condition and 11.3 (BPR-125-5) to 38.0 g (RCC-4) with mean value of 21.0 ± 1.69 under rainfed condition. The genotypes RH-819, Urvashi, BPR-538-12, RCC-4 and BPR-541-5 showed high dry matter accumulation under rainfed condition (28.3-38.5 g). The minimum (14%) reduction was observed in RH 819 closely followed by RCC (19%). Seed yield under rainfed condition was declined by 18.8-77.7% with genotypes RH 819, RCC 4 and Urvashi having the reduction of < 32 %.

Correlation and Regression

Leaf area index showed significant and negative relationship with total dry matter/plant under irrigated condition(r = -0.794**) only. Specific leaf area had significant and negative association with WUE, total dry matter, as well as seed yield under both irrigated and rainfed conditions. The correlation coefficient were 0.621**, 0.674** and 0.786**, respectively, under irrigated and 0.822**, 0.672** and 0.789**, respectively, under rainfed condition. Photosynthesis, however, showed positive and significant association with WUE (r= 0.621**), total dry matter (r= 0.674**) and seed yield (r=0.786**) under irrigated condition. The corresponding correlation coefficients were 0.822**, 0.672** and 0.789** under rainfed conditions. Water use efficiency under irrigated condition was positively and significantly correlated with total dry matter (r=0.826**) and seed yield (r=0.904**). The association of WUE under rainfed condition with total dry matter (r=0.632**) and seed yield (r=0.712**) was also positive and significant. Total dry matter and seed yield were also positively interrelated under irrigated(r= 0.850**) and rainfed condition (r=0.952**). Transpiration showed positive and significant relationship with stomatal conductance (r=0.516*) and LAI (r=0.446*) under irrigated condition only.

Regression analysis revealed that SLA, photosynthesis and water use efficiency contributed 74.5%, 61.5 % and 81.8%, respectively to the variation in variability under irrigated conditions. The corresponding contribution of these characters under rainfed conditions was 61.9%, 63.0% and 59.2% respectively (Fig 2). Further, SLA, photosynthesis and water use efficiency also contributed 52.0%, 70.0 % and 68.3%, respectively to the total dry matter. The corresponding contributions of these characters under rainfed conditions were 72.0%, 62.0% and 52.9% respectively to the total dry matter.

DISCUSSION

The decrease in leaf area index in the present investigation could be due to reduced leaf growth rate and/ or abscission under drought as also has been observed earlier in cowpea (Aniya and Herzog 2003) consequently leading to reduced SLA. The decrease in SLA in the present study corroborated the previous findings of Bala Subramanian and Maheswari (1992) in cowpea. Significant negative relationship of SLA with seed yield as observed in the present study under both irrigated and rainfed conditions indicated that increased specific leaf weight (inverse of SLA) could be due to more assimilatory capacity of the leaves. The SLW has also been reported with stress tolerance and water use efficiency in groundnut (Wright et al. 1988, Nautiyal et al. 2008).

Photosynthesis is closely related with dry matter production in most crops and plant responses and adaptation to abiotic stresses is reflected in changes in photosynthetic rates. Gimeenez and Fereres (1986) also reported drought induced genotypic changes in photosynthetic efficiency due to change in leaf area and leaf area duration in sunflower. Differences between genotypes in transpiration on the other hand might have resulted mainly from differences in leaf area development and stomata regulation. Under well-watered condition, genotypes transpired more water, maintained more opened stomata and high water use before flowering (Aniya and Herzog 2003). The observed reductions in photosynthesis in the present study under rainfed condition could be due to reduced leaf area.

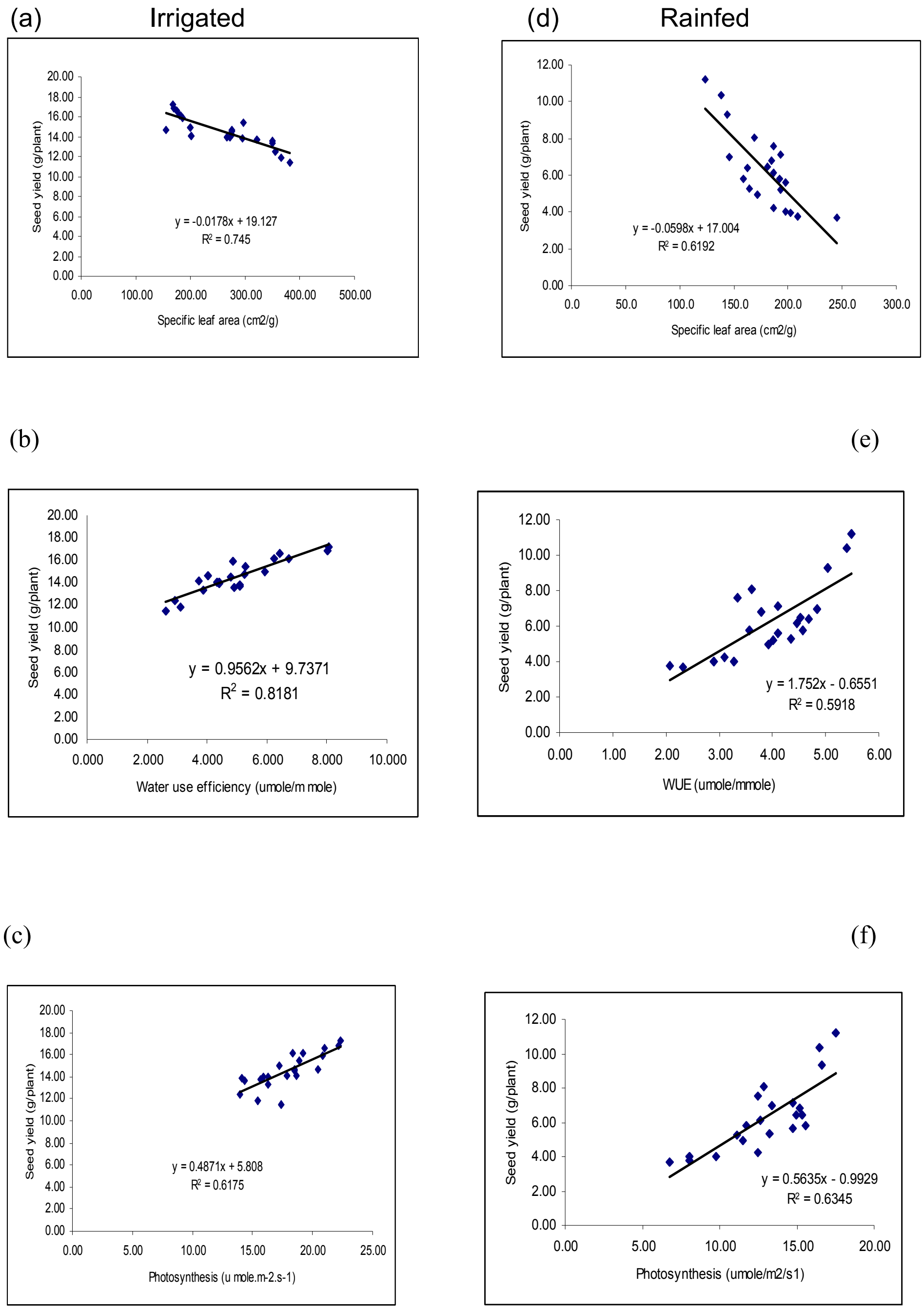

Fig. 2. Relationship between seed yield with specific leaf area, water use efficiency and photosynthesis in Indian mustard under irrigated (a-c) and rainfed (d-f) condition

Transpiration efficiency, the amount of dry matter produced per unit of water transpired is very crucial for the success of the crop under water stressed conditions. It also influenced WUE. The positive association of WUE with total dry matter and seed yield supports this contention Udayakumar et al. (1998) also reported positive and significant association of WUE with total dry matter in groundnut while in Indian mustard it had positive association with seed yield/plant and dry matter/plant (Singh et al. 2008). The results of the present study revealed that Pn, WUE, and SLA had direct influence over seed yield through increased dry matter production.

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