Indian J. Genet., 73(1): 101-104 (2013)
DOI : 10.5958/j.0019-5200.73.1.015

Short Communication

Genetic variation and correlations among physiological characters in Indian mustard (*Brassica juncea* L.) under high temperature stress

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(Received: December 2011; Revised: November 2012; Accepted: December 2012)

Abstract

Effects of high temperature stress during terminal stage on crop growth and genetic parameters were investigated in 18 advanced breeding lines and 4 varieties of Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson] under normal (E_1) and late sown (E_2) conditions. Genotypes BPR 538-10 showed terminal heat tolerance for biological yield/plant, seed yield/plant, total dry matter (60 days after sowing (DAS), crop growth rate (CGR) and relative growth rate (40-60 DAS) and heat use efficiency while RH 0216 possessed terminal heat stress tolerance only for biological yield/plant. Terminal heat stress decreased heat use efficiency by 16.1% in BPR-538-10 to 66.3% in BPR-327-1-B. Heat use efficiency had high PCV and moderate GCV under E_1. The seed yield/plant exhibited significant and positive association with leaf area index (LAI) at 40 days after sowing (r= 0.434*), CGR during 40-60 DAS (r = 0.592), total dry matter at 60 DAS (r = 0.590**), and heat use efficiency (0.795**) under high temperature stress. The study suggested that rapid leaf area development resulting in to high total dry matter production is vital for developing suitable varieties against terminal heat stress.**

Key words: Heat use efficiency, heliothermal units, grain growth duration, genetic parameters, heat stress, Indian mustard

Heat stress is often defined as the rise in temperature beyond a threshold level for a period of time sufficient to cause irreversible damage to plant growth and developments. In India, prevalence of heat stress at terminal stage of mustard is inevitable in substantial acreage under rapeseed-mustard, especially in eastern and northeastern parts, as well as central and western Uttar Pradesh due to delayed sowing after rice and mixed/intercropping mustard with wheat. Therefore, improving seed yield of Indian mustard under late sown conditions by genetic upscaling of thermotolerance at terminal stage would be vital for the sustainability in rapeseed-mustard production. Since, genetic variability is a prerequisite for the meaningful selection the heritability in conjunction with expected genetic advance determines its success. Further, correlated response to selection depends primarily on the nature and strength of relationship between characters. Keeping in view the above points, the present investigation was aimed to asses, genetic variability, genetic parameters and pattern of correlations of seed yield with other physiological characters.

The experimental materials, design and growing conditions were same as described elsewhere [1]. Leaf area index (LAI), specific leaf weight (SLW; mg/cm^2), crop growth rate (CGR; plant dry matter/unit time), relative growth rate (RGR, increase in dry matter/unit of dry matter/unit time), net assimilation rate (NAR, plant dry matter/unit of assimilatory surface/unit time) were computed following the formulae suggested by Radford [2]. Grain growth duration (GGD) was computed from the date of first anthesis to physiological maturity and expressed in days, heat degree days (HDDs) was computed as Σ (Mean daily temperature-base temperature) and b: Base

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Published by Indian Society of Genetics & Plant Breeding, F2, First Floor, NASC Complex, PB#11312, IARI, New Delhi 110 012
Online management by indianjournals.com

temperature was taken as 5^oC as given by Nanda *et al.* [3], heat use efficiency (HUE, g/plant/^{o} day) was calculated for seed yield per plant as per formula given by Rao *et al.* [4] and heliothermal units (HU) were calculated following the formula suggested by Singh *et al.* [5]. Heat stress effect (HSE) on different characters was as the change in the mean of a character under E_2 (Late sown facing high temperature) over that of E_1 (Timely sown facing normal temperature) and expressed in per cent. Yield and associated characters were estimated on 10 randomly taken competitive plants in each replication.

The character means for each replication were subjected to analysis of variance (ANOVA) for the factorial randomized complete block design. Heritability in broad sense ($h^2{}_b$) was calculated according to the formula suggested by Hanson [6]. Expected genetic advance at 5% selection intensity was estimated by using formula given by Johnson *et al.* [7]. The correlation coefficients at phenotypic (r_{pxy}) and genotypic level (r_{gxy}) among different characters were computed following standard methods.

Genetic variability

Highly significant genotypic effects indicated that the present set of genotypes differed appreciably for leaf area index (60 and 80 DAS), total dry matter (40, 60 and 80 DAS), crop growth rate (40-60 and 61-80 DAS), relative growth rate (40-60 and 61-80 DAS), net assimilation rate (40-60 and 61-80 DAS), heliothermal units, heat degree-days, heat use efficiency and grain growth duration. Further, environment also influenced the expression of all the characters to a large extent, as the environment effects were also highly significant. The genotypes had differential response under E_1 and E_2 for biological yield/plant, leaf area index (60 and 80 DAS), total dry matter (40, 60 and 80 DAS), crop growth rate, net assimilation rate (40-60 and 61-80 DAS), relative growth rate (40-60 DAS), heliothermal units and grain growth duration as evidenced by significant genotype x environment interactions.

Under E_1, the range for phenotypic and genotypic coefficients were 3.4-45.1% and 2.4-38.8% for heat degree-days and crop growth rate (61-80 DAS), respectively (Table 1). Phenotypic and genotypic coefficients of variability under E_2 varied from 5.1 (heat degree- days) to 75.6.1% (crop growth rate during 61-80 DAS) and 2.8 (for grain growth duration) –69.1% for crop growth rate during 61-80 DAS. The PCV > 30, 21-30, 10-20% and < 10% were classified as very

Table 1. Range, mean phenotypic (PCV) and genotypic coefficient of variability (GCV) for physiological characters under two contrasting environments

Characters	Environment E_1				Environment E_2			
	Range	Mean± S.Em	PCV	GCV (%)	Range (%)	Mean± S.Em	PCV	GCV (%)
LAI at 60 DAS	1.9-5.4	3.2±0.5	31.2	20.2	1.6-4.1	2.7±0.4	28.5	16.5
LAI at 80 DAS	3.9-9.4	6.6±0.7	26.8	21.7	1.3-4.9	3.0±0.5	33.5	25.1
RGR(40-60DAS)	22.5-47.5	38.1±2.9	17.9	14.2	20.7-44.8	32.8±3.9	20.6	12.0
RGR(61-80 DAS)	8.8-37.3	24.0±3.4	29.8	22.2	8.1-41.4	21.2±3.4	40.5	33.6
CGR(40-60 DAS)	4.1-16.4	10.5±1.5	33.3	25.9	2.4-8.1	4.5±0.8	40.0	30.1
CGR(61-80 DAS)	8.3-56.6	24.8±16.2	45.1	38.8	2.2-37.9	10.0±2.2	75.6	69.1
TDM at 40 DAS	29.8-55.2	41.1±3.5	18.3	13.7	15.5-37.6	24.5±2.6	22.8	17.1
TDM at 60DAS	126.8-282.0	243.6±30.6	28.5	22.2	74.1-184.7	114.3±16.1	33.3	26.7
TDM at 80 DAS	372.1-1420.8	739.9±77.1	32.6	29.0	139.7-892.0	314±41.9	50.2	46.5
NAR(40-60)	0.8-3.2	1.8±0.3	33.8	26.1	0.7-1.5	1.1±0.2	27.6	4.6
NAR(61-80)	0.4-2.8	1.5±0.3	44.2	32.8	0.4-2.9	1.0±0.2	56.0	47.7
HDD	1535.1-1644.2	1578±22.1	3.4	2.4	1427.2-1631.4	1505.6±25.2	5.1	4.2
HTU	7812.1-9220.5	8719.3±137.8	4.2	3.3	8736.5-10475.2	9499.8±661.3	16.5	11.2
HUE	0.4-0.7	0.5±0.7	25.4	14.5	0.2-0.4	0.3-0.03	33.3	13.4
GDD	67.3-78.0	72.0±1.7	5.1	3.1	60.7-68.7	64.2±1.8	5.6	2.8

SEm=Standard Error of mean; PCV=Phenotypic Coefficient of Variance; GCV=Genotypic Coefficient of Variance high, high, moderate and low, respectively and GCV > 20%, 10-20% and < 10% were classified as high, moderate and low.

The LAI, TDM, CGR, RGR and NAR determined the growth and development of the crop, had high to very high genetic variability except RGR (40-60 DAS) and TDM at 40 DAS (Table 1). The PCV invariably increased for all the characters except LAI at 40 DAS and genetic variability did not show any consistent pattern of change under E_2 suggesting that non-heritable factors contributed to the increased phenotypic variability and large genotypes x environment interactions play an important role in the expression of these characters.

Heliothermal units, heat degree-days and grain growth duration had low phenotypic and genotypic variation. Heat use efficiency had high PCV and moderate GCV under E_1. The estimates of PCV and GCV for heliothermal units and heat use efficiency increased to varying level under E_2. High to very high variability available for physiological characters, heat use efficiency, seed yield/ plant and 1000-seed weight in the present materials could be quite useful for selection.

Heritability and genetic advance

The estimates of heritability under E_1 varied substantially from 6.2 % for CGR during 40-60 DAS to 79.5 % for TDM at 80 DAS. The genetic advance (GA) was the highest (68.8%) for CGR during 61-80 DAS and the lowest (3.9%) for grain growth duration (Table 2). Under E_2 the heritability values ranged from 16.3% for heat use efficiency to 85.8% for TDM at 80 DAS. The genetic advance was the highest (130.0%) for CGR (61-80 DAS) and the lowest (11.2%) for heat use efficiency. The heritability estimates >70, 50-70 and < 50% were classified as high, moderate and low, respectively. The genetic advance was categorized as high (>50%), moderate (25-50%) and low (< 25%). High differences in the estimates of PCV and GCV indicated the large environmental influence and consequently the lower estimates of heritability. The heritability was for total dry matter at 80 DAS and crop growth rate (61-80 DAS) under both E_1 and E_2 and NAR (61-80 DAS) only under E_2. Under E_2 most of the physiological characters had moderate heritability. Under E_1 and E_2, except heliothermal units, heat degree-days, heat use efficiency and grain growth duration had low heritability and low to moderate

Table 2. Estimates of heritability (in broad-sense), actual genetic advance (GA) and as % of mean (GS) for morpho-physiological characters in Indian mustard in two contrasting environments

Characters	E_1			E_2		
	Heritability (%)	GA	GS	Heritability (%)	GA	GS
LAI at 60 DAS	42.0	0.90	27.0	33.6	0.50	19.7
LAI at 80 DAS	65.6	2.4	36.2	55.8	1.2	38.6
RGR(40-60DAS)	62.9	8.8	23.2	34.0	4.7	14.4
RGR(61-80 DAS)	55.5	8.2	34.1	68.6	12.1	57.2
CGR(40-60 DAS)	6.2	4.2	41.3	56.6	2.1	46.6
CGR(61-80 DAS)	74.1	17.1	68.8	83.4	13.0	130.0
TDM at 40 DAS	56.0	8.7	21.1	56.3	6.5	26.4
TDM at 60DAS	61.0	87.2	35.8	64.4	50.5	44.2
TDM at 80 DAS	79.5	394.7	53.3	85.8	278.5	88.7
NAR(40-60)	59.4	0.80	41.4	-	-	-
NAR(61-80)	55.0	0.80	50.1	72.4	0.80	83.6
HDD	48.6	53.4	3.4	67.7	107.1	7.1
HTU	58.2	442.8	5.1	64.3	6135.3	6.3
HUE	32.8	0.10	17.1	16.3	0.03	11.2
GDD	36.9	2.8	3.9	25.7		

*DAS: Days after sowing; GA: Genetic Advance; GS: Stomatal Conducfance genetic advance. Except TDM at 80 DAS, CGR during 61-80 DAS (E_1 and E_2) and NAR during 61-80 DAS (E_2) where additive effects were apparently had predominant role in the genetic control owing to high heritability and genetic advance, the expression of other characters were under the control of non-additive gene action. Moderate heritabilty with moderate/high genetic advance for LAI, TDM, CGR, RGR and NAR indicated the involvement of both additive and non-additive effects in the genetic control of these characters. Although, heritability estimates of physiological characters did not follow a consistent pattern of change under E_1 and E_2.

Correlations

Under E_1 seed yield/plant had positive and significant correlations with LAI at 60 DAS (r = 0.455*) and heat use efficiency (r = 0.990**). Biological yield/plant showed positive and significant association with heat use efficiency (r = 0.866**), LAI at 40 (r = 0.425*) and 60 DAS (r = 0.510*). However, seed yield/plant exhibited significant and positive association with LAI at 40 days after sowing (r = 0.434*), CGR during 40-60DAS (r = 0.592**), total dry matter at 60 DAS (r = 0.590**), and heat use efficiency (0.795**) under high temperature stress. Biological yield showed positive and significant relationship with heat degree days (r = 0.994**) and grain growth duration (r = 0.569**). Heat degree days and 1000-seed weight were also positively correlated (r = 0.475*). Positive and significant correlation of seed yield with dry matter at harvest [8, 9] has also been reported earlier. Reddy [10] also reported positive and significant association of seed yield and LAI. The study suggested that rapid leaf area development resulting in to high total dry matter production is vital for developing suitable varieties for terminal heat stress. Further, rapid leaf area development resulting in to high total dry matter production is vital for developing suitable varieties for terminal heat stress.

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