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Short communication

Selection indices for enhanced selection efficiency in Indian mustard under terminal heat stress conditions

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Abstract

With global increase in temperature, terminal heat stress (THS) has emerged as a major challenge in food crops. Indian mustard *(Brassica juncea* L. Czern & Coss), C_3 plant, grows well at 15-20°C. Heat stress at seedling as well as at flowering stage leads to enhanced vegetative growth and flower abortion leading to loss in seed yield. Late sowing after cotton and rice harvest expose the crop to high temperature stress during reproductive stage of development. A fixed diversity stock of 486 Indian mustard lines were evaluated under delayed planting conditions to expose the crop to THS for two consecutive years. Selection indices were computed using four different combinations of traits via Kang_SAS Path computer program along with expected genetic advance (GA) at 5% selection intensity. Set1, comprised of five traits *viz*., plant height (PH), number of secondary branches (NSB), number of siliquae on main shoot (NSMS), seed yield (SY) and 1000-seed weight (TSW) were recorded the highest GA (8.612) in comparison to other trait combinations tested in present study. Other important finding was slight difference in GA of set I (8.612; SY included) and set II (8.599; SY excluded) with efficiency of selection index 131% and 130%, respectively. This recommended that in initial breeding generations (F_2/F_3), a breeder may base his selection on four yield related traits (PH, NSB, NSMS and TSW) only without significant loss in genetic gains. This will save resources and time of breeders to compute seed yield. This is the first report on computation of selection index for efficient simultaneous selection under THS in Indian mustard.

Key words: *Brassica juncea,* terminal heat stress, direct effects, indirect effects, yield traits

Indian mustard (*Brassica juncea* AABB; 2n = 36), can be grown as normal sown irrigated as well as rain-fed crop. Late harvesting of previous crops generally results in late sowing of Indian mustard and exposes the crop to terminal heat stress (THS), the stress during reproductive phase of the crop. Heat stress in plant is often defined as the rise in temperature beyond the threshold level for a period of time sufficient to cause irreversible damage to plant growth and development. THS is a major problem leading to reduced yield in many food crops such as wheat (Suryavanshi and Buttar 2016), corn (Hao et al. 2011) and rice (Shah et al. 2011) etc. In Indian mustard, stress during reproductive phase has been reported to cause problems in bud formation, pollen development, seed filling, seed development and maturity, and hence, resulted in 89% mean seed yield reduction (Angadi et al. 2000). Many researchers documented unfavourable effects of high temperature on crop growth leading to reduction of plant height, siliquae on main shoot, 1000 seed weight, seed per siliquae and seed yield (Ram et al. 2016 and Singh et al. 2014). Development of THS tolerant varieties in Indian mustard has emerged as an important objective for sustained productivity under contemporary climatic changes. Seed yield is complex trait and more prone to environmental fluctuations. Low heritability of seed yield and complexity of genotype-environment (G x E) interaction limit the effective selection based on seed yield only. Kang (1998) and Khayatnejab et al (2010) endorsed that owing to G x E interactions, selection based on seed yield only would not be effective for commercial breeding. Development of selection criteria will be important step towards the rapid development of THS tolerant varieties. But, selections are effective only when selected in target environment as traits as well as genotypes perform differently under different

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environments. Our group has developed selection indices in Indian mustard based on diversity stock of 486 genotypes under normal sown conditions (Sandhu et al. 2018). It is well established that primary target traits should be selected in target environments because responses are different under different environments (Wang et al. 2013; Rahimi et al. 2017). The present study reports the evaluation of germplasm stock of Indian mustard subjected to THS under natural field conditions through delayed sowing; computation of traits having high direct effects on seed yield based on path coefficient analysis and hence, the selection of optimal trait combinations to device effective selection index for higher genetic advance to accelerate breeding programme for THS in Indian mustard. The fixed diversity set of 486 Indian mustard germplasm lines, comprised of Indian and European collection; developed introgression lines; land races; cultivars/varieties developed by different research centers/SAUs and advanced PAU breeding lines, were used in this study. All of these lines are being maintained through continuous selfing at Punjab Agricultural University (PAU), Ludhiana. This set was evaluated using an alpha lattice design with two replications for two years (2015-2016 and 2016-2017) at the Regional Research Station, Abohar (30.14 N, 74.19 E), District Fazilka, which is situated in the south-western region of Punjab. Fazilka District represents the arid zone of Punjab state and ranks first in district-wise area under mustard cultivation. To expose the crop to THS, germplasm stock was sown late by 20 days (optimum sowing time for Indian mustard is from October 15 to November 15). Planting was done on December 2 in both the years (2015 and 2016) in plots, each of which consisted of two 5 meter long rows, with a row-to-row spacing of 30 cm and plant-to-plant spacing of 15 cm. At physiological crop maturity, five plants of each genotype from each replication were randomly selected and data on various agronomic traits were recorded. Plant height (PH, in cm) was determined in standing crop by measuring the height of plants from the base to the end of the main shoot. Main shoot length (MSL, in cm) was recorded by measuring the length of main raceme/shoot. Number of primary branches (NPB) were recorded by counting the siliquae-bearing branches emerging from the main shoot of the plant. Number of secondary branches (NSB) were recorded by counting siliquae-bearing branches emerging from primary branches. Number of siliquae on the main shoot (NSMS) were recorded by counting total siliquae on the main shoot of the plant. Five siliquae were taken from five plants of each genotype and siliqua length (SL_2 in cm) was measured and averaged. To determine number of seeds per siliqua, five siliquae were taken from the main raceme of five randomly selected plants and after thrashing, seeds were counted in each siliqua and averaged. The crop was manually harvested and thrashed plot-wise. After proper drying (moisture content ≈10-12%) of seeds, seed yield (SY, in grams) of each genotype was recorded on a plot basis in each replication using an electronic balance (A&D Company Pvt Ltd, Gurugram, Haryana, India). Seed weight/ plant crosses calculated by dividing seed yield of plot by number of plants harvested plot. Three samples of 1000 seeds per genotype were taken to determine 1000-seed weight (TSW, in grams). Seeds were counted manually, weighed and averaged across samples. Oil content (OC) of each genotype was determined using Near-Infrared Reflectance Spectroscopy (NIRS).

Using genetic correlation coefficients, path coefficient analyses was conducted to compute direct path coefficients using *Kang_SASPath* (Kang 2015). These were used to compute index weights (b values). Index weights were calculated using four different trait combinations. In Set 1, five traits (PH, NSB, NSMS, SY and TSW) were included. In Set II, four traits were used *viz*., PH, NSB, NSMS and TSW. SY, taken as one of the traits in Set 1, was excluded in set II. In Set III, again a combination of four traits (NSB, NSMS, SY and TSW) were used as in Set II, replacing PH with SY. In Set IV, three traits (NSB, NSMS and TSW) were used to compute index weights. The simultaneous equations were solved for index weights (b values) having higher direct effects on seed yield via Kang_SAS Path computer program (Kang 2015) using economic weights of four traits *viz*., PH, NSB, NSMS and TSW. The expected genetic advance was computed at 5% selection intensity (k=2.06) for each set of traits to determine the best combination of traits using a formula given in Kang 1994, p. 107.

SY exhibited positive and significant correlation with PH, MSL, NSB, NSMS and TSW (at 1% level of significance) and with NPB at 5 % level of significance. The genetic correlation coefficients of these SY related traits were subjected to path coefficient analysis to identify the traits having large direct effect on SY using *Kang_SASPath* (Kang 2015). Opting different trait combinations, three path coefficient analyses were conducted to identify the traits that consistently had large positive direct effects on SY under THS conditions. In the first path analysis (Path-1), seven variables, *viz*., PH, MSL, NPB, NSB, NSMS, SL and

TSW, were used. MSL and SL showed negative direct effects on SY (Table 1). In the second path analysis (Path-II), four variables *viz*., PH, NSB, NSMS and TSW were used; traits MSL, NPB and SL were dropped due to lesser direct-effect (Fig. 1). To determine traits having consistent high direct effect on SY, the third path analysis (Path-III) was conducted with three

Table 1. Direct genotypic path coefficients determined for Path-I (eight traits), Path-II (five traits) and Path-III (four traits). In all cases, seed yield was the dependent variable

Traits†	Path-I	Path-II	Path-III
PH	0.1087	0.0721	Dropped
MSL	-0.1328	Dropped	Dropped
NPB	0.0132	Dropped	Dropped
NSB	0.1273	0.1250	0.1416
NSMS	0.4045	0.3632	0.3907
SL	-0.0063	Dropped	Dropped
TSW	0.195	0.1807	0.1761

†PH: Plant height (cm), MSL: Main shoot length (cm), NPB: No. of primary branches, NSB: No. of secondary branches,
NSMS: No. of siliquae on main shoot, SL: Siliqua length (cm) and TSW: 1000-seed weight (g)

variables *viz*., NSB, NSMS and TSW; dropping PH having comparatively lesser but positive direct effect (Fig. 2). In all these cases, SY was the dependent variable.

The relative economic weight was assigned to four traits according to their value of direct path coefficients. The direct path coefficient value of NSMS, TSW, NSB and PH were 0.3632, 0.1807, 0.1250 and 0.0721, respectively and accordingly, economic weight assigned to these traits, after slight adjustments, were : NSMS=0.40; TSW=0.30; NSB=0.20 and PH=0.10.. The index weights for four sets and for SY alone are presented in Table 2. In set I, a combination of five traits *viz*., PH, NSB, NSMS, SY and TSW were taken and GA computed for this set was the highest (8.612) among all the set. In sets II, SY was excluded and rest of four traits *viz*., PH, NSB, NSMS and TSW were taken and GA obtained was 8.599. Exclusion of SY did not affect GA and hence, demonstrated the importance of selection based on multiple traits. If, somehow, breeder cannot record seed yield, he can base his selection on other related traits without, much loss in GA. But for

Table 2. Selection indices based on different trait† combinations with expected genetic advance

Trait combinations for selection Index		Index weight (b value)	Expected genetic advance at 5% selection intensity	Efficiency of selection index compared with selection for SY alone
Set I Five traits used			8.612	131%
	PH	0.098		
	NSB	0.195		
	NSMS	0.314		
	SY	0.068		
	TSW	0.295		
Set II Four traits used			8.599	130%
	PH	0.103		
	NSB	0.203		
	NSMS	0.322		
	TSW	0.345		
Set III Four traits used			6.661	101%
	NSB	0.196		
	NSMS	0.315		
	SY	0.07		
	TSW	0.337		
Set IV Three traits used			6.644	101%
	NSB	0.206		
	NSMS	0.325		
	TSW	0.337		
One trait	SY		6.593	100%

†PH: Plant height (cm), NSB: No. of secondary branches, NSMS: No. of siliquae on main shoot,
SY: Seed yield per plant (g) and TSW: 1000-seed weight (g)

enhanced selection efficiency, seed yield must be included as one of the traits. Breeder should base their selection on combination of five traits viz., PH, NSB, NSMS, SY and TSW for higher selection efficiency. The efficiency of this selection index (set1) was higher (131%) than other selection indices computed in comparison to selection to SY alone but there was not high difference in efficiency between set I and set II (130%). During early generations of selections (F_2/F_3), number of genotypes used to be very large in population. Recording yield data of large number of genotypes is a difficult task as well as less reliable (because of smaller plot size). Breeder may choose to base his selection on traits of set II *viz*., PH, NSB, NSMS and TSW with almost no compromise with genetic gain. The GA values 6.661 and 6.644, respectively for set III and set IV with same efficiency (101%) of selection indices over SY alone further emphasized that breeder may chose to not record data for seed yield only should prefer to base their selection on combination of yield contributing traits during initial stages of breeding program.

Breeders need to device specific SI for selection under THS conditions as SI computed based on data recorded under NS conditions may not be effective for high genetic gains. Under THS, NPB did not exhibit high direct effect on SY whereas this trait has emerged as one of the four main traits having high direct effect on seed yield under NS conditions (Sandhu et al. 2018). NSMS, with the highest index weight (0.314) amongst combination of traits, recommended as an important yield contributing trait. This trait was recorded with high direct effect under both NS and THS conditions. This is the first report on devising efficient SI for higher genetic gains in Indian mustard under terminal hear stress conditions.

Authors' contribution

Conceptualization of research (SKS, PS, JK, MS, KK); Designing of the experiments (SKS, PS, JK, MS, KK); Contribution of experimental materials (SKS, PS, JK, MS, KK); Execution of field/lab experiments and data collection (SKS, PS, JK, MS, KK); Analysis of data and interpretation (SKS, PS, JK, MS, KK); Preparation of manuscript (SKS, PS, JK, MS, KK).

Declaration

The authors declare no conflict of interest.

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