Biological Forum – An International Journal 15(11): 230-236(2023)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Evaluation of Heat Tolerance Genotypes in Indian Mustard [*Brassica juncea* (L.) Czern & Coss] based on Heat Susceptibility Index

Anita[1], Deepak Gupta[1], S.S. Punia[2], D.K. Gothwal[1], Manohar Ram[1], G.K. Mittal[3] and Anil Kumar[4]*
[1]*Department of Genetics and Plant Breeding,*
Sri Karan Narendra Agriculture University Jobner, Jaipur (Rajasthan), India.
[2]*Department of Genetics and Plant Breeding,*
Rajasthan Agricultural Research Institute, Durgapura, Jaipur (Rajasthan), India.
[3]*Department of Biochemistry, Sri Karan Narendra Agriculture University Jobner, Jaipur (Rajasthan), India.*
[4]*Department of Genetics and Plant Breeding,*
Swami Keshwanand Rajasthan Agriculture University Bikaner (Rajasthan), India.

(Corresponding author: Anita)*
(Received: 10 September 2023; Revised: 09 October 2023; Accepted: 19 October 2023; Published: 15 November 2023)
(Published by Research Trend)

ABSTRACT: In the area of global warming, heat stress, particularly at the seedling stage, is a major problem that affects the production and productivity of mustard that are grown in cooler climates. Fifty five (ten parents and forty five F_1's) mustard genotypes were evaluated under three environments created by different dates of sowing *i.e*. timely sown, late sown and very late sown during *Rabi* 2022-23.The experimental materials were evaluated in Randomized block design with three replications under three date of sowing *i.e*. timely sown, late sown and very late sowing. In the present study, the heat susceptibility index value of parents and crosses for yield and its contributing characters were calculated and genotypes were classified into four different categories *i.e*. highly heat tolerant, heat tolerant, moderately heat tolerant and heat susceptible. From the result of heat susceptibility index (HSI), parent LAXMI was found most desirable parents in both late and very late date of sowing. Among the cross BPR 543-2 x PM 25, showed the superiority under heat stress environment for seed yield and more than two characters. These parents and crosses could be utilized as a promising breeding material for the development of heat stress tolerant mustard varieties.

Keywords: Mustard, heat susceptibility index (HSI) and heat stress.

INTRODUCTION

Indian mustard [*Brassica juncea* (L.) Czern & Coss] is the major oil seeds crops of India. The Indian mustard is commonly known as brown mustard, leaf mustard, chinese mustard. The genus Brassica belongs to *Cruciferae* or *Brassicaceae* family. Indian mustard is a natural amphidiploid (2n=36) of *Brassica campestris* (2n=20) and *Brassica nigra* (2n=16) (Nagaheru, 1935). It is a predominantly naturally autogamous species 85-90 per cent with 5-15 per cent cross-fertilization owing to insects, especially the honeybees (Vaghela *et al*., 2011).

In India, rapeseed-mustard has grown in 8.06 million hectares with production of 11.75 mt with average productivity of 1458 kg per ha (Anonymous, 2022-2023). In Rajasthan mustard is cultivated on about 3.37 million hectares with 5.48 mt production and 1627 kg per ha productivity (Anonymous, 2022-23). In Rajasthan, district Alwar ranks first in area and production followed by Bharatpur, Sri Ganganagar, Tonk, Jodhpur, Hanumangarh and Sawai Madhopur.

Mustard plays a major role in catering to edible oil demand of the country. The oil is utilized for human consumption throughout Northern India in cooking and frying purposes. Its seed contains about 38 to 43 per cent oil and is considered to be the healthiest and nutritious cooking medium. The seed and oil of mustard have a peculiar pungency due to presence of glucosinolate and its hydrolysis products such as allyl-isothio-cynate making it suitable to be used as condiment in the preparation of pickles and for flavoring curries and vegetables. The oil of mustard possesses a sizeable amount of erucic acid (38-57%), together with linolenic acid (4.7 to 13.0%). The protein content in rapeseed and mustard normally ranges between 24-30 per cent on the whole seed basis and between 35-40 per cent on the meal basis. It is also used in the preparation of soaps, hair oil, lubricants, paints, plasticizers (Prakash and Hinata 1980). The oil cakes are used as a cattle feed and manures. Green stems and leaves are a good source of green fodder for cattle (Reed, 1976). The leaves of young plants are used as green vegetables as they supply enough sulphur and minerals in diet.

Flowering is the most sensitive stage for high temperature damage probably due to vulnerability during pollen development, anthesis and fertilization leading to reduced crop yield (Hall and Rao 1992). High temperature in brassica inhibits plant development and causes flower abortion with appreciable loss in seed yield. Flowering stage have a strong influence with rise of >30 ^{0}C day temperature, leading to drastic decline in seed yield (Nuttal *et al*., 1992).

Harmful effects of heat stress are always observed in mustard, being a *Rabi* season crop of arid and semi-arid regions. Delay in sowing shortens vegetative phase, reduces dry matter accumulation and also reduction in its full genetic yield potential. High temperature at pod formation also causes heat blast and more gap between pods and grains. Thus, sustainable seed yield of Indian mustard under late sown condition is only possible through minimizing effect of high temperature during reproductive stage with the use of heat tolerant genotypes of mustard. Keeping the above facts in view, the current study was conducted to magnify the yield level of mustard in high temperature areas by selecting stress tolerant parents and cross combinations for future breeding programme.

MATERIALS AND METHODS

The experimental material consisted of 55 diverse genotypes of mustard including ten parents and forty five F_1's. The experimental materials were evaluated in Randomized block design with three replications under three environments grown under three different dates of sowing *i.e*. timely sown (15th October), late sown (30th October) and very late sown (15th November) at Instructional Farm, Sri Karan Narendra College of Agriculture, Jobner (Rajasthan) during *Rabi* 2022-23. Each entry was grown in two rows with 2 m row length and spacing row to row 45 cm with 20 cm inters plant distance. All the recommended cultural practices were adopted to raise the crop. Observations were recorded on 16 characters *viz*., days to 50% flowering, days to maturity, plant height (cm), primary branches per plant, siliqua per plant, siliqua length (cm), seeds per siliqua, 1000-seeds weight (g), biological yield per plant (g), seed yield per plant (g), harvest index (%), chlorophyll content at siliqua stage (SPAD value), relative water content at siliqua stage (%), membrane stability index at siliqua stage (%), prolin content (mg/g) and oil content (%). Five randomly selected competitive plants in each replication were recorded for all the traits under study except days to 50% flowering, days to maturity and 1000-seed weight which were recorded on plot basis. Heat susceptibility index (HSI) was calculated for seed yield and other attributes by using the formula as suggested by Fischer and Maurer (1978).

HSI = [1- YD/YP]/ D

Where,

YD = mean of the genotype in stress environment

YP = mean of the genotype in non- stress environment

D = 1- [mean YD of all genotype/ mean YP of all genotypes].

RESULTS AND DISCUSSION

In the present scenario of changing agro climatic conditions where there is depleting underground water and increased terminal temperature, the plant breeders have two challenges in the oilseed production, first the yield potential should further be increased in traditional area of mustard cultivation and second, short duration and heat tolerant oilseed varieties should be developed to maintain the production in the state and serve as an alternative to wheat in non- traditional areas. The results obtained from the present investigation revealed that mean performance of parents, F_1's declined under late sown (E_2) and very late sown (E_3) condition in comparison to normal sown (E_1) condition. Similar finding also obtained by Chauhan (2009); Chauhan *et al*. (2014); Sharma and Sardana (2014); Ram *et al.* (2014); Tripathi *et al.* (2020); Ram *et al*. (2021), Sharma *et al*. (2021). Yield is complex traits and is final product of action and interaction of number of component characters. Thus, selection based on yield per se will not be much effective. Therefore, in order to determine the tolerance of different parents and crosses for heat stress, the heat susceptibility index was estimated based upon the values and direction of desirability of different characters used in the study. Based upon the value and direction ofdesirability, ranking was done for different genotypes as highly heat tolerant (HSI < 0.50), heat tolerant (HSI: 0.51-0.75), moderately heat tolerant (HSI: 0.76-1.00) and heat susceptible (HSI >1.00).

On the basis of heat susceptible index of seed yield (Table 1), the parent DRMR 2017-15 (0.10), PM 25 (-1.03), EC 766136 (0.42) and LAXMI (-1.04) were least affected under heat stress (E_2). These parents were also least affected under heat stress (E_2) for others traits. Parent DRMR 2017-15 also exhibited low HSI value for seeds per siliqua, 1000- seed weight, biological yield, harvest index and oil content. Similarly, PM 25 showed heat tolerant genotype for seed yield per plant, primary branches, seeds per siliqua, 1000- seed weight, biological yield and harvest index while, genotype EC 766136 heat tolerant genotype for days to maturity, seeds per siliqua, 1000- seed weight, harvest index and oil content. LAXMI was least affected for primary branches, siliqua length, 1000- seed weight and biological yield under late sown condition (E_2). Crosses BPR 543-2 x DRMR 2017-15 (0.02),BPR 543-2 x PM 25 (0.07), BPR 543-2 x PM 28 (-0.43), BPR 543-2 x EC 766136 (-1.46), BPR 543-2 x LAXMI (-1.25), BPR 349-9 x PM 25 (-0.80), BPR 349-9 x RAJAT (-0.11), DRMR 2017-15 x PM 25 (-0.90), DRMR 2017-15 x PM 28 (-6.55), DRMR 2017-15 x LAXMI (-1.68), PM 25 x PM 28 (-2.34), PM 25 x IC 122449 (0.27) and EC 766136 x LAXMI (0.41) showed HSI values less than 0.50 and were least affected under heat stress environment (E_2) for seed yield per plant.

In addition to seed yield per plant, crosses BPR 543-2 x PM 25 was least affected under heat stress environment (E_2) for seeds per siliqua, 1000 seed weight and biological yield per plant; BPR 543-2 x EC 766136 for siliqua length, seeds per siliqua and 1000 seed weight; BPR 543-2 x LAXMI for days to maturity, chlorophyll content at siliqua stage and oil content; BPR 349-9 x PM 25 for primary branches per plant, siliqua length, seeds per siliqua, 1000 seed weight, biological yield per plant and oil content; BPR 349-9 x RAJAT for days to maturity, plant height, siliqua per plant and oil content; DRMR 2017-15 x PM 25 for 1000 seed weight, biological yield per plant, seeds per siliqua, harvest index and oil content; DRMR 2017-15 x PM 28 for days to maturity, primary branches per plant, seeds per siliqua and chlorophyll content at siliqua stage; DRMR 2017-15 x LAXMI for siliqua length, 1000 seed weight and seeds per siliqua; PM 25 x IC 122449 for primary branches per plant, siliqua per plant, 1000 seed weight and seeds per siliqua and EC 766136 x LAXMI for primary branches per plant, siliqua length, biological yield per plant and oil content.

On the basis of heat susceptible index of seed yield (Table 2), the parent NRCHB 101 (0.40), PM 28 (0.45) and LAXMI (0.25) were least affected under heat stress (E_3). These parents were also least affected under heat stress (E_3) for other characters. In addition to seed yield per plant, parent NRCHB 101 also exhibited least heat susceptibility index (value less than 0.50) for primary branches per plant, siliqua length, harvest index and oil content, whereas LAXMI exhibited heat tolerant genotype for primary branches per plant, 1000- seed weight and biological yield per plant under very late sown condition (E_3).

The data present in Table 2 revealed that in the crosses BPR 543-2 x PM 25 (0.29), NRCHB 101 x RAJAT (0.43) and NRCHB 101 x LAXMI (0.03) had HSI values less than 0.50 and were least affected under heat stress environment (E_3) for seed yield per plant. Crosses BPR 543-2 x PM 25 was least affected under heat stress environment (E_3) for seed yield per plant as well as siliqua length, biological yield per plant and harvest index. Similarly, NRCHB 101 x RAJAT showed heat tolerant genotypes for seed yield as well as siliqua length, 1000 seed weight and harvest index and NRCHB 101 x LAXMI for seed yield per plant, biological yield per plant, harvest index and oil content under very late sown condition (E_3).

Perusal of Table 1 to 2 revealed that parent LAXMI and BPR 543-2 x PM 25 showed superiority under both heat stress environment for seed yield and more than two characters.

Table 1: Heat susceptibility index (HSI) behavior of mustard genotypes for seed yield along with contributing attributes in E_2 (Late sown) in comparison to E_1 (Normal) environment.

Sr. No.	Parents/ Crosses	Seed Yield (HSI Value)	Other characters
Parents			
Highly heat tolerant			
1	DRMR 2017-15	0.10	Seeds per siliqua, 1000- seed weight, biological yield per plant, harvest index and oil content
2	PM 25	-1.03	Primary branches per plant, seeds per siliqua, 1000- seed weight, biological yield per plant and harvest index
3	EC 766136	0.42	Days to maturity, seeds per siliqua, 1000- seed weight, harvest index and oil content
4	LAXMI	-1.04	Primary branches per plant, siliqua length, 1000 seed weight, biological yield per plant and harvest index
Moderate heat tolerant			
5	BPR 543-2	0.87	Plant height and siliqua per plant
Susceptible			
6	BPR 349-9	2.08	Days to maturity, primary branches per plant, siliqua length, relative water content at siliqua stage, membrane stability index and oil content
7	NRCHB 101	2.06	Days to 50% flowering, siliqua per plant, seeds per siliqua, 1000- seed weight, relative water content at siliqua stage and membrane stability index at siliqua stage
8	PM 28	1.38	Days to 50% flowering, seeds per siliqua, 1000- seed weight, biological yield per plant, chlorophyll content at siliqua stage, relative water content at siliqua stage, prolin content and oil content
9	IC 122449	2.59	Days to 50% flowering, days to maturity, siliqua per plant, seeds per siliqua, 1000 seed weight, biological yield per plant, chlorophyll content at siliqua stage, relative water content at siliqua stage and membrane stability index
10	RAJAT	3.05	Days to 50% flowering, days to maturity, siliqua length, seeds per siliqua, 1000 seed weight, biological yield per plant, chlorophyll content at siliqua stage, relative water content at siliqua stage, membrane stability index, prolin content and oil content
Crosses			
Highly heat tolerant			
1	BPR 543-2 x PM 25	0.07	Seeds per siliqua, 1000- seed weight and biological yield per plant
2	BPR 543-2 x DRMR 2017-15	0.20	Siliqua length, seeds per siliqua, 1000 seed weight and biological yield per plant
3	BPR 543-2 x PM 28	-0.43	Siliqua length, membrane stability index and oil content
4	BPR 543-2 x LAXMI	-1.25	Days to 50% flowering, chlorophyll content and oil content
5	BPR 543-2 x EC 766136	-1.46	Siliqua length, seeds per siliqua and 1000- seed weight
6	BPR 349-9 x PM 25	-0.80	Primary branches per plant, siliqua length, seeds per siliqua, 1000- seed weight, biological yield per plant and oil content
7	BPR 349-9 x RAJAT	-0.11	Days to maturity, plant height, siliqua per plant and oil content

8	DRMR 2017-15 x PM 25	-0.90	1000- seed weight, biological yield per plant, seeds per siliqua and chlorophyll content at siliqua stage
9	DRMR 2017-15 x PM 28	-6.55	Days to maturity, primary branches per plant, seeds per siliqua and chlorophyll content at siliqua stage
10	PM 25 x PM 28	-2.34	Biological yield per plant
11	DRMR 2017-15 x LAXMI	-1.68	Siliqua length, seeds per siliqua, chlorophyll content at siliqua stage and oil content
12	PM 25 x IC 122449	0.27	Primary branches per plant, siliqua per plant, 1000- seed weight and harvest index
13	EC 766136 x LAXMI	0.41	Primary branches per plant, siliqua length, biological yield per plant and oil content
Moderate heat tolerant			
14	BPR 349-9 x EC 766136	0.93	Chlorophyll content at siliqua stage, relative water content at siliqua stage and oil content
15	PM 25 x RAJAT	0.86	Days to 50% flowering, siliqua length and chlorophyll content at siliqua stage
Susceptible			
16	BPR 543-2 x BPR 349-9	1.07	Days to maturity, plant height, primary branches per plant, siliqua per plant, seeds per siliqua, biological yield per plant, harvest index, chlorophyll content at siliqua stage and membrane stability index at siliqua stage
17	BPR 543-2 x NRCHB 101	2.93	Siliqua per plant, biological yield per plant and prolin content
18	BPR 543-2 x IC 122449	1.43	Days to 50% flowering, siliqua length, 1000- seed weight, biological yield per plant, harvest index, relative water content at siliqua stage, membrane stability index at siliqua stage and oil content
19	BPR 349-9 x NRCHB 101	1.69	Days to 50% flowering, siliqua per plant, seeds per siliqua, relative water content at siliqua stage and oil content
20	BPR 349-9 x PM 28	1.98	Days to 50% flowering, primary branches per plant, biological yield per plant, seeds per siliqua, chlorophyll content at siliqua stage, relative water content at siliqua stage, prolin content and oil content
21	BPR 349-9 x IC 122449	2.02	days to maturity, plant height, siliqua length, seeds per siliqua chlorophyll content at siliqua stage and membrane stability index at siliqua stage
22	BPR 349-9 x LAXMI	1.48	Siliqua per plant, seeds per siliqua, chlorophyll content at siliqua stage and membrane stability index at siliqua stage
23	DRMR 2017-15 x NRCHB 101	3.08	Days to maturity, primary branches per plant, 1000- seed weight, biological yield per plant, seeds per siliqua and membrane stability index at siliqua stage
24	DRMR 2017-15 x IC 122449	2.09	Plant height, primary branches per plant, siliqua per plant, siliqua length, 1000- seed weight, seeds per siliqua, chlorophyll content at siliqua stage, membrane stability index at siliqua stage and prolin content
25	DRMR 2017-15 x EC 766136	3.10	Days to 50% flowering, days to maturity, Plant height, biological yield per plant, seeds per siliqua and chlorophyll content at siliqua stage
26	PM 25 x NRCHB 101	1.36	Days to 50% flowering, days to maturity, 1000- seed weight, seeds per siliqua, harvest index, chlorophyll content at siliqua stage and membrane stability index at siliqua stage
27	PM 25 x EC 766136	2.39	Days to 50% flowering, days to maturity, Plant height, primary branches per plant, siliqua per plant, siliqua length, 1000- seed weight, biological yield per plant, harvest index, chlorophyll content at siliqua stage and membrane stability index at siliqua stage
28	PM 25 x LAXMI	1.78	Days to 50% flowering, days to maturity, Plant height, siliqua per plant, siliqua length, 1000- seed weight, biological yield per plant, chlorophyll content at siliqua stage and relative water content at siliqua stage
29	NRCHB 101 x PM 28	2.09	1000- seed weight, membrane stability index at siliqua stage, prolin content and oil content
30	NRCHB 101 x RAJAT	2.78	1000- seed weight, membrane stability index at siliqua stage, prolin content and oil content
31	PM 28 x IC 122449	1.53	Days to 50% flowering, plant height, primary branches per plant, siliqua per plant, 1000- seed weight, biological yield per plant, chlorophyll content at siliqua stage, prolin content and oil content
32	PM 28 x RAJAT	2.16	Days to 50% flowering, plant height, primary branches per plant, siliqua per plant, siliqua length, 1000- seed weight, biological yield per plant, harvest index, chlorophyll content at siliqua stage, membrane stability index at siliqua stage, prolin content and oil content
33	PM 28 x LAXMI	1.40	Days to 50% flowering, plant height, primary branches per plant, siliqua per plant, 1000- seed weight, biological yield per plant, chlorophyll content at siliqua stage, prolin content and oil content
34	IC 122449 x EC 766136	1.38	Days to maturity, plant height, primary branches per plant, siliqua length, chlorophyll content at siliqua stage, membrane stability index at siliqua stage and prolin content
35	EC 766136 x RAJAT	3.30	Days to 50% flowering, plant height, primary branches per plant, siliqua per plant, biological yield per plant, seeds per siliqua, prolin content and oil content
36	RAJAT x LAXMI	3.56	Days to maturity, 1000- seed weight, biological yield per plant, seeds per siliqua and prolin content

Table 2: Heat susceptibility index (HSI) behavior of mustard genotypes for seed yield along with contributing attributes in E_3 (Very late sown) in comparison to E_1 (Normal) environment.

Sr. No.	Parents/ Crosses	Seed Yield (HSI Value)	Other characters
Parents			
Highly heat tolerant			
1	NRCHB 101	0.40	Primary branches per plant, siliqua length, harvest index and oil content
2	LAXMI	0.25	Primary branches per plant, 1000- seed weight and biological yield per plant
3	PM 28	0.45	Harvest index
Moderate heat tolerant			
4	BPR 543-2	0.77	Days to 50% flowering, siliqua length, seeds per siliqua, biological yield per plant, chlorophyll content at siliqua stage and prolin content
5	BPR 349-9	0.98	Days to 50% flowering, plant height, primary branches per plant, siliqua per plant and relative water content at siliqua stage
Susceptible			
6	DRMR 2017-15	1.42	Days to 50% flowering, days to maturity, primary branches per plant, siliqua per plant, seeds per siliqua, biological yield per plant, harvest index, chlorophyll content at siliqua stage and membrane stability index
7	PM 25	1.51	Days to maturity, primary branches per plant, siliqua per plant, seeds per siliqua, biological yield per plant chlorophyll content at siliqua stage, membrane stability index at siliqua stage and prolin content
8	IC 122449	1.08	Seeds per siliqua, 1000- seed weight, harvest index, prolin content and oil content
9	EC 766136	1.35	Days to 50% flowering, days to maturity, primary branches per plant, biological yield per plant, chlorophyll content at siliqua stage, relative water content at siliqua stage and prolin content
10	RAJAT	1.34	Days to 50% flowering, plant height, siliqua length, chlorophyll content at siliqua stage, relative water content at siliqua stage, membrane stability index, prolin content and oil content
Crosses			
Highly heat tolerant			
1	BPR 543-2 X PM 25	0.29	Days to maturity, primary branches per plant, siliqua length, biological yield per plant and harvest index
2	NRCHB 101 x RAJAT	0.43	Siliqua length, 1000- seed weight and harvest index
3	NRCHB 101 x LAXMI	0.03	Biological yield per plant, harvest index and oil content
4	DRMR 2017-15 x NRCHB 101	0.33	Seeds per siliqua, 1000 seed weight and harvest index
Heat tolerant			
5	BPR 543-2 X RAJAT	0.66	Days to 50% flowering, days to maturity and siliqua length
6	BPR 349-9 x NRCHB 101	0.67	Days to maturity, primary branches per plant and siliqua length
7	EC 766136 x RAJAT	0.59	Primary branches per plant, siliqua length, biological yield per plant and harvest index
Moderate heat tolerant			
8	BPR 543-2 x BPR 349-9	0.80	Days to 50% flowering, primary branches per plant, seeds per siliqua, chlorophyll content at siliqua stage, relative water content at siliqua stage and prolin content
9	BPR 543-2 x DRMR 2017-15	0.96	Siliqua length, biological yield per plant, relative water content at siliqua stage and prolin content
10	BPR 349-9 x PM 25	0.83	Days to 50% flowering, primary branches per plant, siliqua per plant, biological yield per plant, relative water content at siliqua stage, membrane stability index and prolin content
11	BPR 349-9 x IC 122449	0.89	Primary branches per plant, siliqua per plant, 1000 seed weight, biological yield per plant, harvest index, chlorophyll content at siliqua stage and prolin content
12	PM 25 x IC 122449	0.96	Days to 50% flowering, siliqua per plant, siliqua length, 1000 seed weight and prolin content
13	NRCHB 101 x EC 766136	0.80	Days to 50% flowering, days to maturity, primary branches per plant, siliqua per plant and prolin content
14	EC 766136 x LAXMI	0.97	Primary branches per plant, seeds per siliqua, 1000 seed weight, chlorophyll content at siliqua stage, membrane stability index and oil content
Susceptible			
15	BPR 543-2 x NRCHB 101	1.11	Days to maturity, plant height, primary branches per plant, seeds per siliqua, 1000 seed weight, biological yield per plant, membrane stability index at siliqua stage, prolin content and oil content
16	BPR 543-2 x PM 28	1.08	Plant height, siliqua length, seeds per siliqua, harvest index, relative water content at siliqua stage, membrane stability index and oil content
17	BPR 543-2 x EC	1.15	Days to maturity, plant height, primary branches per plant, siliqua per plant, 1000

	766136		seed weight, chlorophyll content at siliqua stage and oil content
18	BPR 543-2 x LAXMI	1.12	Days to maturity, primary branches per plant, siliqua per plant, siliqua length, seeds per siliqua, 1000 seed weight, biological yield per plant, harvest index, chlorophyll content at siliqua stage, membrane stability index and oil content
19	BPR 349-9 x DRMR 2017-15	1.11	Days to maturity, plant height, primary branches per plant, primary branches per plant, siliqua per plant, seeds per siliqua, biological yield per plant, harvest index, chlorophyll content at siliqua stage and membrane stability index
20	BPR 349-9 x PM 25	1.10	Primary branches per plant, siliqua per plant, siliqua length, seeds per siliqua, harvest index and chlorophyll content at siliqua stage
21	DRMR 2017-15 x PM 25	1.86	Primary branches per plant, siliqua per plant, siliqua length, seeds per siliqua, 1000 seed weight, biological yield per plant, harvest index, chlorophyll content at siliqua stage, prolin content and oil content
22	DRMR 2017-15 x PM 28	1.86	Primary branches per plant, siliqua per plant, siliqua length, seeds per siliqua, 1000 seed weight, biological yield per plant, harvest index, chlorophyll content at siliqua stage, prolin content and oil content
23	DRMR 2017-15 x IC 122449	1.93	Primary branches per plant, siliqua per plant, siliqua length, seeds per siliqua, 1000 seed weight, biological yield per plant, chlorophyll content at siliqua stage and relative water content at siliqua stage
24	DRMR 2017-15 x RAJAT	1.02	Days to maturity, plant height, primary branches per plant, siliqua per plant, 1000 seed weight, biological yield per plant, relative water content at siliqua stage, chlorophyll content at siliqua stage, membrane stability index and prolin content
25	PM 25 x NRCHB 101	1.46	Days to maturity, plant height, primary branches per plant, siliqua per plant, seeds per siliqua, 1000 seed weight, biological yield per plant, relative water content at siliqua stage, chlorophyll content at siliqua stage, membrane stability index, prolin content and oil content
26	PM 25 x PM 28	1.31	Plant height, siliqua length, seeds per siliqua, 1000 seed weight, biological yield per plant, harvest index, chlorophyll content at siliqua stage, membrane stability index and prolin content
27	PM 25 x EC 766136	1.32	Days to 50% flowering, 1000 seed weight, biological yield per plant, harvest index, relative water content at siliqua stage, membrane stability index, prolin content and oil content
28	PM 25 x RAJAT	1.03	Days to maturity, plant height, primary branches per plant, siliqua per plant, biological yield per plant relative water content at siliqua stage and prolin content
29	NRCHB 101 x PM 28	1.48	Siliqua per plant, seeds per siliqua, biological yield per plant, relative water content at siliqua stage, membrane stability index and prolin content
30	NRCHB 101 x IC 122449	1.18	Days to maturity, primary branches per plant, siliqua per plant, harvest index, chlorophyll content at siliqua stage, membrane stability index and oil content
31	PM 28 x LAXMI	1.08	Days to maturity, plant height, siliqua length, harvest index, relative water content at siliqua stage, prolin content and oil content
32	IC 122449 x EC 766136	1.83	Biological yield per plant, harvest index, relative water content at siliqua stage, prolin content and oil content
33	IC 122449 x RAJAT	1.24	Days to maturity, plant height, primary branches per plant, siliqua length, harvest index, relative water content at siliqua stage, membrane stability index and prolin content

CONCLUSIONS

The heat susceptibility index (HSI) values of all genotypes have been ranked for each character as per the criterion mentioned above. The overall ranking that the LAXMI was found most desirable parents in both late and very late dates of sowing. Among the cross, BPR 543-2 x PM 25 showed superiority under a heat stress environment for seed yield and more than two characters.

Acknowledgement. The authors are thankful to the Incharge Directorate of Rapeseed Mustard Research (DRMR) at Bharatpur for providing the parents and the Department of Plant Breeding and Genetics, S.K.N College of Agriculture, Jobner (Rajasthan) for providing the facilities to carry out this research work.

REFERENCES

Anonymous (2022-23). Agricultural Statistics at a Glance, Ministry of Agriculture, Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmer Welfare, Govt. of India. www.agricoop.nic.in.

Chauhan, J. S., Meena, M. L., Saini, M., Meena, D. R., Singh, M., Meena, S. S. and Singh, K. H. (2014). Heat stress effects on morpho-physiological characters of Indian mustard (*Brassica juncea* L.).

Chauhan, Y. S. (2009). Inheritance of seed weight in Indian mustard (*Brasica juncea* L.). *Indian Journal of Genetics and Plant Breeding*, *40*, 597-599.

Fisher, R. A. and Maurer, R. (1978). Drought resistance in spring wheat cultivars I. Grain yield responses. *Australian Journal of Research*, *29*, 897-912.

Hall and Rao (1992). Effect of high temperature on flowering and photosynthesis in soybean. *Indian Journal of Agronomy*, *42*(1), 143-138.

Nagaharu, U. (1935). Genome analysis in Brassica with special reference to the experimental formation of *Brassica napus* and peculiar mode of fertilization. *Japanese Journal of Botany*, *7*, 389−452.

Nuttal, G. S. (1992). Effect of salicylic acid alleviates decreases in photosynthesis under heat stress and accelerates recovery in sunflower. *International Journal of Agriculture Science*, *57*(3), 407-310.

Prakash, S. and Hinata, K. (1980). Taxonomy, cytogenetics and origin of crop Brassicas. *Opera Botanica*, *55,* 1-5.

Ram, B., Meena, H. S., Singh, V. V., Singh, B. K., Nanjundan, J., Kumar, A., Singh, S. P., Bhogal, N. S. and Singh, D. (2014). High temperature stress tolerance in Indian mustard (*Brassica juncea*) germplasm as evaluated by membrane stability index and excised-leaf water loss techniques. *Journal of Oilseed Brassica*, *5*(2), 149-157.

Ram, B., Priyamedha, Kumar, M. S. S., Sharma, H. K., Rani, R., Singh, K. H., Singh, V. V., Kumar, V. and Rai P. K. (2021). Development and evaluation of early maturing thermo-tolerant Indian mustard (*Brassica juncea* L.) genotypes for cultivation in semi-arid region of India. *Electronic Journal of Plant Breeding*, *12*(1), 200-206.

Reed, C. F. (1976). Information summaries on 1000 economic plants. Typescripts submitted to the USDA.

Sharma, P. and Sardana, V. (2014). Screening of Indian mustard (*Brassica juncea*) for thermo tolerance at seedling and terminal stages. *Journal of Oilseed Brassica*, *4*(2), 61-67.

Sharma, H. K., Singh, V. V., Kumar, A., Meena, H. S., Meena, B. L., Sharma P. and Rai, P. K. (2021). Genetic study of terminal heat stress in indigenous collections of Indian mustard (*Brassica juncea* L.) germplasm. *Journal of Environmental Biology*, ttp://doi.org/10.22438/eb/43/1/MRN-1887.

Tripathi, S. K., Lallu, Srivastava, S.K., Yadav, V. and Singh, M. (2020). Effect of Terminal Heat Stress on Variability in Physiological Traits of Indian Mustard [*Brassica juncea* (L.)] due to late sown situation. *International Journal of Current Microbiology and Applied Science*, *9*(1), 1620-1628.

Vaghela, P. O., Thakkar, D. A., Bhadauria, H. S., Sutariya, D. A., Parmar, S. K. and Prajapati, D. V. (2011). Heterosis and combining ability for yield and its component traits in Indian mustard (*Brassica juncea* L.). *Journals of Oilseed Brassica*, *2*(1), 39-43.

How to cite this article: Anita, Deepak Gupta, S.S. Punia, D.K. Gothwal, Manohar Ram, G.K. Mittal and Anil Kumar (2023). Evaluation of Heat Tolerance Genotypes in Indian Mustard [*Brassica juncea* (L.) Czern & Coss] based on Heat Susceptibility Index. *Biological Forum – An International Journal, 15*(11): 230-236.