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Research Article

ASSESSING GENE ACTION AND COMBINING ABILITY IN Brassica napus L. UNDER DROUGHT STRESS CONDITIONS, AN EFFORT TOWARDS BREEDING RESILIENT VARIETIES

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Abstract

Drought stress is the limiting factor in productivity as well as quality of any crop. Drought stress effects are crucial in *Brassica napus* but severity depends on the duration, intensity and developmental stages. İn the present study, eight drought tolerant lines and three drought sensitive testers were crossed in the line × tester fashion. Developed germplasm accesions with their parents were evaluated under standard and drought stress conditions in RCBD having split plot arrangements. Various qualitative and quantitative parameters were recorded. Among the parents, ZMR-2, Dunkled, and Garchi exhibited potential based on their general combining ability (GCA) under both control and drought stress conditions.. The best cross combinations, identified through significant positive values for specific combining ability (SCA), included ZMR-2 × ZMR-18, Winner × ZMM-12 and Garchi × ZMR-18 under control and drought stress treatment T_1. Similarly, G-51 × ZMR-18, Dunkled × ZMR-18, and DGL × ZMR-18 performed well under drought stress treatment T2. GCA variance surpassed the SCA varinace, depicting the presence of additive gene action in studied material. So, these crosses could be selected readily without moving towards segregating generations in the future drought breeding programes.

Keywords: *Brassica napus*, Drought stress, Climate change, GCA, SCA
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1. INTRODUCTION

Climate change becomes a challenge for agriculture productivity which includes several inter-linked stresses (Clapco et al., 2018). Stress is always termed as the disturbed physiological condition of the crop plant due to any factor that leads the crop away from the equilibrium stage. Plants are subjected to various stresses while growing in natural environment. Common stresses include water shortage or scarcity, flooding, heavy metal stress, low and high temperature, salt and oxidative stress (Jamil et al., 2019). Water scarcity is considered as the major damaging issues in terms of severity as it damages the metabolic pathway and ultimately the productivity of crops (Zhang et al., 2015).
Water scarcity in field crops is defined in diverse ways; plants show different physiological changes under different water deficit conditions. Metrologically, drought stress is defined as period without appropriate amount of rainfall. Water scarcity occurs when the amount of water in the soil is less and the condition becomes more severe under drastic environmental conditions which promote more water loss (Farooq et al., 2009). Different oilseed crops are grown in the country, but among

them, Brassica napus has the greatest potential to enhance edible oil production in Pakistan. Yield has always been the targets of any breeder, but as the climate change become a global issue so we couldn't neglect its impacts. That's why, a breeder must be aware of the future scenario of water shortage around the world.

Drought stress effects are inevitable in Brassica napus, but severity depends on the duration, intensity and developmental stage of crop. Drought stress induces a cessation of the vegetative period, prompting the initiation of the reproductive phase. Consequently, leaves start falling and crop ultimately moves towards the lower rate of photosynthesis and reduced plant height (Marchin et al., 2020). Decreased plant height due to the competition between reproductive and vegetative phase results in reduced number of branches per plant. İn this way, biological yield reduces under drought stress in Brassica napus. Drought causes a significant decrease in the number of flowers in the crop which ultimately reduces number of siliques and consequently, yield (Chaghakaboodi et al., 2012). Physiological processes are also affected by drought stress. Availability of less water during stem elongation, development of silique and flowering causes reduction of silique per plant. Rapid falling of flowers during drought stress period reduces the seed yield.

In the current study, Brassica napus is evaluated using a line × tester mating design to assess combining ability, identify the type and extent of gene action, evaluate hybrid vigor for yield and related traits, and determine optimal crosses for future drought breeding programs.

2. MATERIALS AND METHODS

2.1. Germplasm Collection

This experiment was conducted to evaluate drought tolerance in different genotypes of *Brassica napus* L. The germplasm was collected from the Oilseed Research Field, Department of Plant Breeding and Genetics, UAF, Faisalabad. In the present study, eight drought tolerant lines and three drought sensitive testers of *B. napus* were hybridized in line x tester mating fashion during year 2023, which are listed in the Table 1. The F1 progeny, along with their parents, were subsequently evaluated under field conditions.

2.2. Location of the Experiment

Table 1. List of accessions used for Line × Tester mating scheme of drought tolerance in *Brassica napus* L.

Sr. No.	Lines	Sr. No.	Testers
1	ZMR-2	**1**	ZMR-18
2	Dunkled	**2**	Rainbow
3	G96	**3**	ZMM-12
4	Winner		
5	Garchi		
6	DGL		
7	G-51		
8	Hyola		

The research was carried out at the research field of UAF, Faisalabad in spring 2023. Faisalabad exists between latitude of 31.418° North and longitudes of 73.079° East and the altitude is 184.4 m. It is present in North-East Punjab and possesses an arid climate and loamy soil in the field. During 2023 crop season, average maximum and minimum temperature was recorded 41.1 and 14.2°C respectively, with average rainfall of 42.68 mm (https://www.weather-atlas.com/en/pakistan/faisalabadclimate#temperature).

2.3. Experimental layout and conditions

Current experiment was performed in triplicate Randomized complete block design having split-plot arrangement. Row x row distance was 75 cm while plant x plant distance was 25 cm. Necessary agronomic and cultural practices were performed from the time of sowing to till the harvesting of crop.

2.4. Treatments

Different irrigation levels were applied to induce drought stress and access the combining ability for drought tolerance among *B. napus* accessions. The experiment, under field condition, involved three levels of drought stress, as outlined in Table 2.

Table 2. Treatment details of Experiment at maturity stage

Sr. No.	Treatments	Application Strategy
1	Treatment No. 1 (T_1)	All normal irrigations
2	Treatment No. 2 (T_2)	Alternate irrigation was skipped
3	Treatment No. 3 (T_3)	Single irrigation except rauni

2.5. Recording of statistics

Five plants from each experimental unit/repeat were randomly selected. Data recording for each treatment was performed at maturity stage. Various quantitative characters including height of individual plant (cm), No. of branches/plant, Length of main inflorescence, No. of silique/plant, No. of seeds/silique, 1000-seed weight (g), and seed vintage/plant (g) were recorded.

2.6. Plant Height (cm)

Tallness of tagged entries was measured starting from the base to tip including inflorescence by using meter rod and then their average was computed.

2.7. No. of Branches/plant

Branches originating from the core stem were counted by observing each of the tagged plant. Then their mean was calculated for supplementary analysis.

2.8. Extent of main inflorescence

Main inflorescence length from each tagged plant was measured using meter rod from the base of main inflorescence to its tip.

2.9. Sum of silique/plant

Sum of seed-bearing silique/plant entry was reckoned by observing each marked entry and their mean value was computed for supplementary analysis.

2.10. Sum of seeds/silique

Five silique from each tagged plant were threshed separately. The total number of seeds were counted from each silique and their average value was determined.

2.11. 1000-seed weight (g)

One thousand seeds were counted and weighted by utilizing an electric weight balance (Setra- BL4105).

2.12. Seed yield (g)

Each marked plant was harvested and winnowed separately. The obtained seeds were weighed by using an electric weight balance (Setra- BL4105).

2.13. Statistical Analysis

Data were recorded for yield and related traits under all treatments. Analysis of Variance (Steel et al., 1997) was conducted on the recorded statistics to assess the presence of genomic variability among the studied *B. napus* accessions. The analysis was performed by using Statistics 8.1 Software. Tukey test, with a significance level of 5 percent, was utilized to compare the average values of the traits studied in each accession. To determine the statistics regarding General Combining Ability (GCA), Specific Combining Ability (SCA), and gene action, records of various traits were analyzed using Line × Tester analysis (Kempthorne, 1957).

3. RESULTS AND DISCUSSION

3.1. Genetic variability

The mean sum of square values of various traits of B. napus under control and water deficit conditions are accessible in Table 3. Under control conditions all traits disclose substantial variances for genotypes, lines, testers, their interactions, parents and parents Vs. crosses, apart from number of branches per plant for testers. Mall et al., (2010); Kang et al., (2013); Synrem et al., (2015) and Rameeh, (2017) investigated similar results for lines, testers, their interactions, parents and parents Vs. Crosses.

Under water deficit condition, T1 results revealed that significant differences were present for genotypes, crosses, lines, and parent Vs. crosses for all the parameters. Whereas parents, testers and interaction between line x tester were also showed significant differences for various traits as number of branches perplant, sum of seeds/silique, extent of main inflorescence and 1000-seeds weight. Farshadfar et al., (2013); Gami and Chauhan, (2013); Shehzad et al., (2015); Kumar et al., (2016); Rameeh, (2016) and Khalil and Raziuddin, (2017) also showed significant differences for various traits in Brassica napus under drought stress.

Table 3. Mean square records derived from variance analysis for quantitative traits of B. napus under standard and water deficit state.

S.O.V	DF	Treatments	PT	LMI	NB/P	SS/P	S. seed/S	TSW	SP
Replications	2	T_0	0.08	5.58	1.48*	15.45	0.35	0.02	0.02
		T_1	0.11	20.06**	33.32**	0.98*	18.86**	17.85**	0.18
		T_2	0.17**	0.03**	0.03**	15.20	3.46**	9.72	27.69**
Genotypes	34	T_0	668.51**	690.05**	2.27**	2788.45**	36.55**	1.72**	9.95**
		T_1	12.81**	751.03**	420.54**	1.00**	3317.89**	17.97**	1.34*
		T_2	1.06**	7.12**	610.99**	161.12**	0.36	994.85**	6.40**
Parents	10	T_0	589.55**	183.26**	0.73**	1795.83**	15.08**	0.84**	14.52**
		T_1	2.91	504.05**	310.09**	0.41	769.09**	10.63**	0.90
		T_2	0.55**	0.52	433.83	41.75	0.08	141.25	2.88 **
Parents vs Crosses	1	T_0	2833.79**	4138.49**	8.66**	19541.09*	188.35*	6.55**	20.51**
		T_1	2240.05**	2240.05**	607.01**	3.11**	19141.81**	8.52**	1.16
		T_2	1.62**	38.88**	2582.55*	56.01	0.03	1791.49**	12.38**
Crosses	23	T_0	608.70**	760.47**	2.66**	2491.65**	39.28**	1.89**	7.51**
		T_1	15.23**	793.67**	460.46**	1.16**	3738.07**	21.57**	1.54
		T_2	1.26*	8.68**	861.66	418.81**	0.43	3135.80**	10.27**
Lines (L)	7	T_0	446.13**	211.23**	0.83*	1483.80**	22.90**	0.83**	5.18**
		T_1	28.48**	921.39**	429.32**	0.59*	3293.69**	27.00**	2.68*
		T_2	1.22**	8.68**	861.66	418.81**	0.43	3135.80**	10.27**
Testers (T)	2	T_0	532.11**	133.00**	0.77	2397.79**	34.89**	1.26**	2.53*
		T_1	11.95	806.84**	419.34**	0.79*	3866.72**	20.04**	1.56
		T_2	1.57**	12.78**	555.93	192.26	0.54	861.29	3.72**
L × T	14	T_0	765.10**	945.36**	0.005**	3008.99**	48.11**	2.40**	9.38**
		T_1	9.08	727.92**	481.90**	1.50**	3941.88**	19.07**	0.96
		T_2	1.23*	7.98*	479.24	120.59	0.52	496.25	6.94**
Error	68	T_0	1.94	6.90	0.37	6.58	1.01	0.04	0.21
		T_1	6.08	0.55	4.90	0.26	0.57	0.48	0.03
		T_2	0.47	2.86	434.92	80.03	0.34	504.79	12.38

S.O.V= Source of variation, DF= Degree of freedom, PT= Plant tallness, LMI= Extent of main inflorescence, SB/P= Sum of branches/plant, SS/P= Sum of siliques/plant, S. seed/S= Sum of seeds/silique, TSW= 1000-seeds weight, SP= Seed produce

At drought stress level (T2), genotypes showed significant differences for traits like plant tallness, sum of siliques/plant, sum of branches/plant and extent of core inflorescence. While parents had significant differences for plant height whereas parents Vs. crosses depicted noteworthy differences regarding tallness of plant, sum of branches/plant, 1000-seeds weight, extent of main inflorescence. Lines and crosses showed significant differences for plant tallness, sum of siliques/plant, 1000-seeds weight and extent of core inflorescence. Whereas testers and interaction between line x tester disclosed substantial variances regarding extent of core inflorescence and plant tallness. Significant differences for yield and its associated parameters were found by Mahmud et al., (2009); Mall et al., (2010); Kang et al., (2013); Meena et al., (2015); Synrem et al., (2015) and Rameeh, (2017) in Brassica napus showing significant variability under normal and different levels of drought stress.

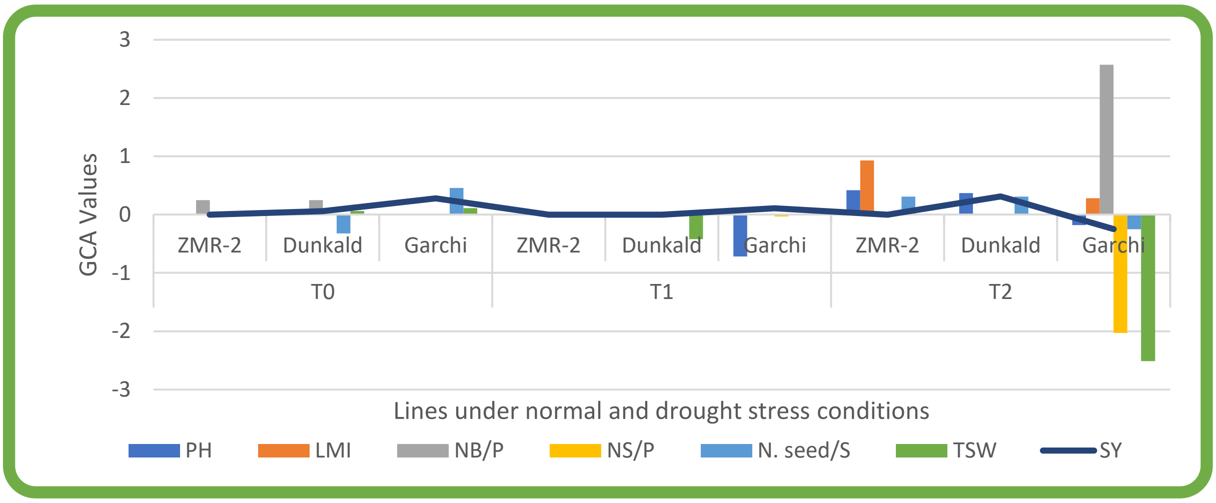

Figure 1. GCA effects of selected potential Lines of Brassica napus under normal and drought stress conditions.

SOV= Source of variation, DF= Degree of freedom, PH= Plant height, LMI= Length of main inflorescence, NB/P= No. of branches/plant, NS/P= No. of siliques/plant, N. seed/S= No. of seeds/silique, TSW= 1000-seeds weight, SY= Seed yield

3.2. Analysis for combining ability

3.2.1. GCA (General combi ning ability) effects

General combining ability (GCA) effects possessed by the lines for different quantitative parameters of Brassica napus under the control and water deficit conditions are accessible in Fig 1.

Noteworthy and positive GCA properties for maximum traits were observed in line ZMR-2 under the control and water deficit conditions. Line Garchi showed substantial and positive GCA effects for control and mild stress conditions (T1). While Dunkled behaved excellent under both drought stress treatments (T1 and T2).

Among testers, Rainbow disclosed positive and substantial GCA properties for maximum parameters under normal and drought stress treatments (T1 and T2). While tester ZMR-18 showed positive and substantial GCA properties for normal and moderate stress treatment (T1). Mahmud et al., (2009); Mall et al., (2010) and Meena et al., (2015) acquired positive and substantial GCA properties regarding various parameters in B. napus. GCA properties possessed by the testers regarding different quantitative parameters of B. napus under the control and water deficit conditions are given in Fig 2.

3.2.2. SCA (Specific combining ability) effects

Specific combining ability (SCA) properties for quantitative attributes

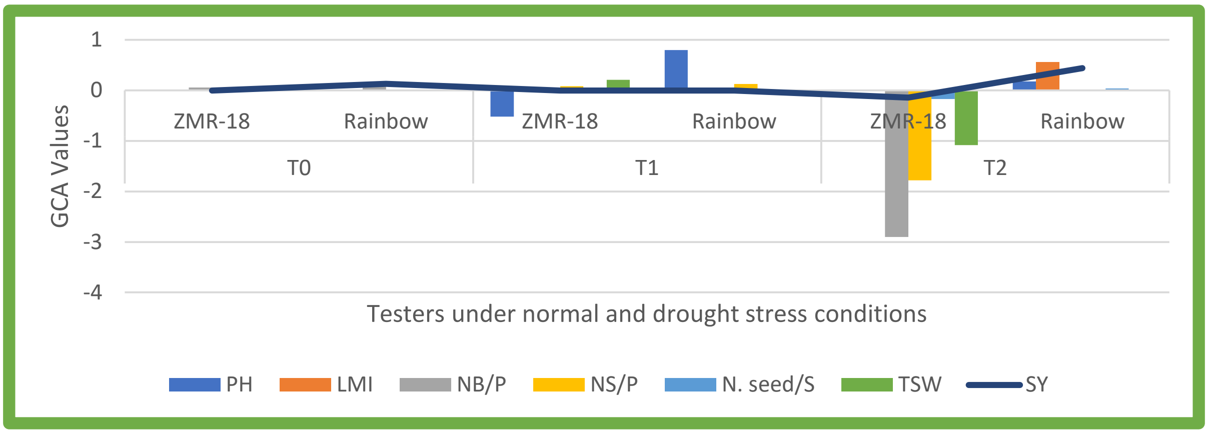

Figure 2. GCA effects of selected potential Testers in B. napus under standard and water deficit states

SOV= Source of variation, DF= Degree of freedom, PH= Plant height, LMI= Length of main inflorescence, NB/P= No. of branches/plant, NS/P= No. of siliques/plant, N. seed/S= No. of seeds/silique, TSW= 1000-seeds weight, SY= Seed yield

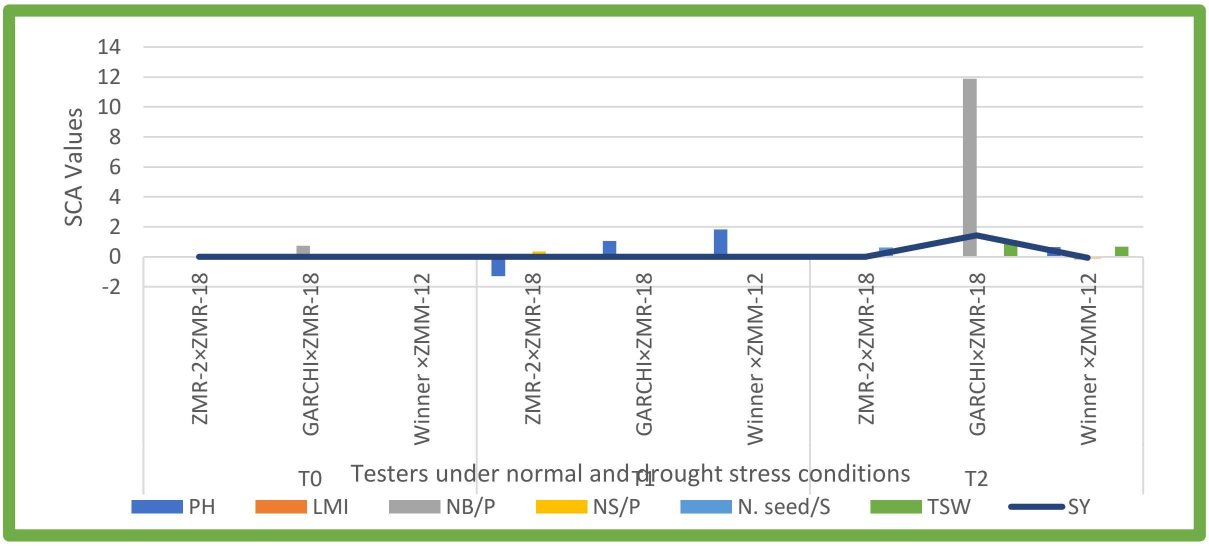

Figure3. SCA effects of selected potential Crosses in B. napus under standard and water deficit states

SOV= Source of variation, DF= Degree of freedom, PH= Plant height, LMI= Length of main inflorescence, NB/P= No. of branches/plant, NS/P= No. of siliques/plant, N. seed/S= No. of seeds/silique, TSW= 1000-seeds weight, SY= Seed yield

regarding various hybrids of *Brassica napus* under control and drought stress treatments are presented in Fig. 3. Crosses ZMR-2 × ZMR-18, Winner × Rainbow, Winner × ZMM-12 showed significant and positive SCA properties for maximum yield related parameters under normal as well as drought stress condition T_1. While G51× ZMR18, Dunkled × ZMR18 and DGL × ZMR18 behaved good under severe stress condition T_2. This unexpected result may be due to allelic, non-allelic attraction or due to different environmental conditions. Arifullah et al., (2012) and Kumar et al., (2016) studied substantial and positive SCA effects for 1000-seeds weight and sum of branches/plant. Mahmud et al., (2009) and

Farshadfar et al., (2013) studied substantial and positive SCA effects for seed yield.

4. CONCLUSION

Genetic variability in different accessions of *Brassica napus* under drought stress conditions is present. This exhibited that this genetic material can be used in further breeding programs conducted to create the drought stress tolerance in said crop. Potential parents found on the basis of GCA were ZMR-2, Dunkled and Garchi under control and drought stress conditions. Best cross combinations having positive significant values for SCA were ZMR2 × ZMR18, Winner x ZMM12 and Garchi × ZMR 18 under control and drought stress treatment T_1. While G51 × ZMR 18, Dunkled × ZMR 18 and DGL × ZMR 18 were best performing cross combinations under drought stress treatment T_2. So, these crosses can be used for hybrid development programs. Variance due to GCA was more than SCA variance which shows prepondrance of additive gene action. It is suggested that the selected crosses should be used for future crop improvement programmes.

5. ACKNOWLEDGMENT

None.

6. CONFLİCT OF INTEREST

None.

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