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COMBININGABILITY AND HETEROSISFORSEED YIELD AND YIELD RELATED TRAITS IN CANOLA UNDER DIFFERENT NITROGEN LEVELS

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ABSTRACT

Seven divergent canola genotypes were crossed using a half diallel mating design to determine the mean performance, types of combining abilities, and heterosis under different nitrogen levels for agronomic traits, in Ismailia Agricultural Research Stations, Agricultural Research Center, Egypt. The parents and their F_1 crosses were evaluated using a randomized complete block design with three replicates. The GCA/SCA ratio at different nitrogen levels revealed a predominance of additive gene action for the all of the investigated traits. Under all nitrogen levels, P1 for seed weight per plant and P7 for seed oil content were the best general combiners. The generated combinations (P2 × P3) at 30 kg/feddan nitrogen level, (P3 × P5) under 45 kg/feddan nitrogen level, and (P1× P4) under 60 kg/feddan nitrogen level had high and positive SCA effects and mid parent heterosis for seed weight per plant. Moreover, under all nitrogen levels, the combination (P5×P7) had high and positive SCA effects and mid parent heterosisfor seed oil content.

Key words**:** ***Canola (Brassica napus L.), performance, combining ability, mid parent heterosis.***

INTRODUCTION

On the Egyptian agricultural scene, canola is one of the most promising oil crops. This is owing to its abilities, which allow it for growing on nutrient-deficient fields, particularly nitrogen-deficient lands.The lack of nutrients in the soil, however, has a significant impact on its productivity. Accordingly, canola breeders must create strains and cultivars that are appropriate for growth at low nitrogen levels.

The half diallel mating design was one of the best mating designs that canola breeders could use to create new hybrids that are superior than their parents. In this regard, various studies have used the design to estimate of gene action (additive, dominance and their ratio). In that context, of Ali *et al* (2015) and Xie *et al* (2018) revealed that additive gene action predominated in the inheritance of most examined traits, with a minor role of dominance. In contrast, *Hassan et al (2018), Ashish et al (2019), Inayat et al (2019), Dezfouli et al (2019), Abdelsatar et al (2020*) and *Abdelsatar et al (2021*) found that both additive and non-additive gene actions were significant in the expression of examined traits, with a predominance of non-additive gene action for most traits. Furthermore, genetic divergence among canola genotypes has been regarded as the initial stage in the effectiveness of breeding programs in obtaining more new divergent recombinations. In this context, in the research of Luo *et al* (2019) and Wolko *et al* (2019), genetic divergence amongst canola genotypes provided valuable heterosis and genetic variability.

As a consequence, precise genetic information on yield and yield-related traits inherited in these breeding materials provides the best opportunity for designing efficient breeding program and/or selection techniques to improve these traits in canola.

MATERIALS AND METHODS

Plant materials

In the 2019/20 winter growing season at Ismailia Agricultural Research Station, Agricultural Research Center (ARC), Egypt, seven genetically divergent parental canola genotypes (Table 1) were crossed in a half-diallel mating design to generate 21 single-cross combinations. These parental canola genotypes were labeled as N.A.36 (P1), N.A.52 (P2), N.A.81 (P3), N.A.109 (P4), N.A.122 (P5), Pactol (P6), and Serw 4 (P7).

Table 1. Names, origin, and characteristics of the seven rape seed.

No.	Parental variety	Origin	Oil%
P1	N.A.36	Canada	41.0
P2	N.A.52	FAO	42.3
P3	N.A.81	Ireland	44.7
P4	N.A.109	Canada	41.6
P5	N.A.122	FAO	43.6
P6	Pactol	France	44.4
P7	Serw 4	Egypt	40.6

The Oil Crops Research Department of the Field Crops Research Institute of the ARC in Egypt provided these breeding materials. According to *Jackson (1973)*, soil samples were analyzed to determine their compositions and chemical properties, as shown in Table 2.

Experimental design and agricultural practices

At Ismailia Agricultural Research Stations, ARC, Egypt, the parents and their F_1 crosses were evaluated in a field experiment at three levels of nitrogen, i.e. 30, 45, and 60 kg nitrogen per feddan, using a randomized complete block design with three replications in the winter season of 2020/21.Nitrogen fertilization applications were added in six equal portions prior to each irrigation in accordance with the treatment variables. Two rows, each 5 m long and 60 cm wide, were used in the experiment, with individual plants spaced 10 cm apart. Parents' seeds, as well as their F_1 crosses, were planted by hand on adjacent plots. The seedlings were thinned to maintain each hill at one plant. Oil Crops Research Department, Field Crops Research Institute, ARC, Egypt recommended the other cultural practices. Peanut was the preceding crop, which was planted in the summer season of 2020.

Table 2. The upper 30 cm of the experimental soil field station's soil composition and chemical properties.

Properties	**2020/21**
Coarse sand %	75.28
Fine sand	15.23
Silt	2.54
Clay	6.95
Texture class	Sandy
pH (1:2.5 Soil : Water)	8.15
EC dS/m(1:2.5 Soil : Water)	0.08
CaCO3%	1.42
Organic matter %	0.32
Ca++	3.54
Mg++	1.2
Na+	10.82
K+	0.21
CO3--	0
HCO3 --	2.75
Cl--	9.72
SO4--	3.24
Available macro and micro- nutrients mg/kg soil	
N	12.15
P	3.24
K	32.56
Fe	3.52
Mn	3.16
Zn	0.72
B	0.21
Cu	0.23
Fe	2.95
Mn	2.89
Zn	0.78
B	0.31
Cu	0.38

Data collection

Ten plants were randomly selected from each plot to measure stem length (cm), number of branches plant^{-1}, number of siliquae plant^{-1} and seed weight per plant (g) with seed moisture adjusted to 15.5 percent. During the flowering stage, a Model: SPAD-502, Minolta Sensing Ltd., Hangzhou, Japan (SPAD metre) was used to measure CHLC from the highest completely developed leaves on the main stem. AOAC technique 920 was used to determine seed N content using the Kjeldahl procedure (AOAC 1990).Fresh samples of the leaves and edible organs were maintained in a freezer for nitrate reductase (NR) activity assay, as described by *Andrews et al* (1984).On a plot-by-plot basis, traits of days to first flower appearance and days to 50% flowering were determined. After drying the seeds at 70°C for 48 hours, the Soxhlet extraction procedure with diethyl ether was used to determine the seed oil content (AOAC, 1990).

Statistical analysis

All traits were subjected to an analysis of variance for combining ability using Griffing (1956) model 1, method 2 for each nitrogen level. After confirming homogeneity from the error variance as indicated by Steel *et al*. (1997) combined analysis was used to determine nitrogen effects on genetic variation and its components. For each nitrogen level, general (GCA) and specific (SCA) combining ability effects, heterotic effects were used to determine the best parents and crosses for seed weight plant^{-1} and its related traits.

RESULTS AND DISCUSSION

1- Analysis of variance

For all evaluated variables, there are considerable significant differences among canola genotypes and among nitrogen rates, as well as their interaction (Table 3). This suggested that there was a sufficient amount of genetic variability among the investigated materials, allowing for the estimation of genetic parameters to improve all of the studied traits. *Elnenny et al (2015), Hassan et al (2018), Ashish et al (2019),Gul et al (2019), Dezfouli et al (2019), Abdelsatar et al (2020) and Abdelsatar et al (2021)*all reported similar findings. Nitrogen rates and their interactions with genotypes were shown to have highly significant mean squares.

Table 3. Mean squares of canola genotypes, nitrogen levels and their interaction for earliness, yield and its attributes in 2020/21 season.

SOV	df	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
Blocks	2	4.75	5.53	13.69	0.005	0.79	2.31	0.015	3.00	7.78	0.001
Genotypes (G)	27	628.63 **	1452.04 **	2977.41 **	7.422 **	20363.79 **	356.46 **	303.53 **	1077.98 **	0.82 **	0.24 **
Nitrogen	2	1545.14 **	2545.62 **	9927 **	3.71 **	35126.82 **	7060.37 **	387.90 **	5074.22 **	4.73 **	1.99 **
G*N	54	93.83 **	29.41 **	381.26 **	0.35 **	811.61 **	35.57 **	1.35 **	22.02 **	0.01 **	0.029 *
Error	166	2.77	2.07	5.31	0.07	2.19	0.29	0.03	0.48	0.001	0.001

V1: Days to first flower, V2: 50% flowering, V3: Stem length, V4: Number of branches, V5: Number of siliquae per plant, V6: Seed weight per plant, V7: Oil%, V8: SPAD, V9: N% and V10: Nitrate Reductae.

This revealed that the evaluated nitrogen rates differed enough to cause varied responses of the investigated genotypes under different nitrogen levels.

Mean performance

For all studied variables, the mean performance of the seven parental canola genotypes and their 21 F_1 crosses are presented in Table (4).With increasing nitrogen application from 30 to 45 and 60 kg nitrogen, the values of all traits for all evaluated genotypes gradually increased, as previously reported by Teilep *et al* (2014).P3, and the F_1 of (P1× P4) were the earliest canola genotypes in the first flowering and days to 50% flowering under the three nitrogen rates. This meant that the genes that cause earliness might have inherited to their F_1 crosses. When it came to stem length, the shortest genotypes were P1 and the F_1 of (P1× P5) under all the three nitrogen levels, indicating that dwarf genes from the parents had been inherited to their F1 crosses. Under the three nitrogen rates, the promising parents in terms of number of branches per plant were P3 and the F_1 of (P3× P6). This could be due to genes that have a positive effect on the number of branches per plant when they are transformed into F_1 crosses.

Table 4. Mean performance of seven parental canola genotypes and their 21 F_1 cross combinations for earliness, yield and its attributes under different nitrogen levels in 2020/21 season.

Genotypes	Days to first flower				50% flowering				Stem length			
	Nitrogen levels (kg/fed)				Nitrogen levels (kg /fed)				Nitrogen levels (kg/fed)			
	30	45	60	Mean	30	45	60	Mean	30	45	60	Mean
p1	53.33	59.00	67.67	60.00	92.00	94.33	100.67	95.67	82.67	98.63	135.63	105.64
p2	81.33	90.67	83.67	85.22	126.00	120.00	125.67	123.89	135.37	140.07	77.27	117.57
p3	47.33	55.33	60.33	54.33	80.00	84.33	91.33	85.22	161.70	171.93	175.53	169.72
p4	54.00	62.33	68.33	61.55	87.67	91.00	96.00	91.56	147.53	154.87	160.27	154.22
p5	60.67	66.33	70.67	65.89	103.67	106.67	112.33	107.56	121.90	115.83	134.33	124.02
p6	65.33	70.00	76.00	70.44	108.00	109.33	113.00	110.11	129.73	139.57	178.00	149.10
P7	67.67	70.00	75.00	70.89	105.33	108.67	113.33	109.11	155.60	164.10	176.87	165.52
p1×p2	72.67	97.33	97.33	89.11	106.67	108.00	118.33	111.00	155.10	174.07	177.90	169.02
p1×p3	85.67	62.67	72.67	73.67	111.00	115.67	122.67	116.45	156.13	166.67	180.40	167.73
p1×p4	54.00	53.67	73.00	60.22	87.33	90.33	96.33	91.33	159.20	166.13	169.73	165.02
p1×p5	79.33	79.33	78.00	78.89	119.33	124.33	130.67	124.78	107.60	123.70	126.30	119.20
p1×p6	76.67	75.33	79.00	77.00	117.33	122.33	125.67	121.78	128.97	132.07	144.23	135.09
p1×p7	84.33	77.67	77.67	79.89	125.67	130.00	136.00	130.56	147.33	150.80	161.07	153.07
p2×p3	70.33	92.67	90.67	84.56	105.33	109.33	116.67	110.44	153.80	171.17	175.60	166.86
p2×p4	76.67	76.67	77.33	76.89	109.00	116.33	121.33	115.55	120.23	160.10	164.93	148.42
p2×p5	80.33	81.33	84.33	82.00	130.33	130.33	130.67	130.44	165.23	164.67	175.20	168.37
p2×p6	77.33	77.33	85.33	80.00	112.00	115.00	120.67	115.89	162.10	167.50	174.53	168.04
p2×p7	62.33	69.67	74.00	68.67	95.00	102.67	109.33	102.33	159.47	164.37	173.33	165.72
p3×p4	60.67	68.33	72.67	67.22	87.33	90.67	97.67	91.89	145.80	160.80	181.93	162.84
p3×p5	79.00	79.00	77.67	78.56	118.00	121.33	128.33	122.55	140.53	164.13	173.53	159.40
p3×p6	67.00	71.33	75.00	71.11	90.67	110.33	116.00	105.67	154.20	163.57	170.07	162.61
p3×p7	82.33	82.33	82.00	82.22	115.00	119.67	125.33	120.00	149.50	164.90	174.97	163.12
p4×p5	67.33	66.33	71.00	68.22	90.33	103.33	110.33	101.33	109.07	129.47	138.57	125.70
p4×p6	61.33	74.00	81.00	72.11	109.33	116.33	122.00	115.89	145.47	162.20	175.03	160.90
p4×p7	55.67	76.33	80.33	70.78	89.00	93.00	101.00	94.33	146.27	158.23	167.97	157.49
p5×p6	68.00	77.00	80.67	75.22	92.67	100.67	106.33	99.89	138.03	167.47	173.77	159.76
p5×p7	65.33	72.00	77.33	71.55	96.67	113.67	121.00	110.45	124.53	147.30	170.93	147.59
P6×p7	75.33	75.33	82.67	77.78	121.67	121.67	131.33	124.89	142.80	152.80	164.23	153.28
GX`	68.98	73.55	77.55		104.73	109.62	115.71		140.92	153.47	162.58	
L.S.D ≤5%	G = 1.54 N =0.50 G*N =0.68				G = 1.34 N = 0.43 G*N = 0.57				G = 2.14 N = 0.70 G*N = 1.24			

Table 4. Cont.

Genotypes	Number of branches				Number of siliquae/plant				Seed weight/plant			
	Nitrogen levels (kg/fed)				Nitrogen levels (kg/fed)				Nitrogen levels (kg/fed)			
	30	45	60	Mean	30	45	60	Mean	30	45	60	Mean
p_1	3.83	4.13	5.27	4.41	129.20	150.87	172.87	150.98	17.95	24.58	31.66	24.73
p_2	4.23	4.63	4.63	4.50	147.10	154.33	112.30	137.91	16.24	24.66	13.39	18.10
p_3	6.20	6.13	6.57	6.30	204.17	220.57	231.90	218.88	7.68	16.47	24.64	16.26
p_4	5.47	5.57	6.17	5.74	145.23	185.90	277.57	202.90	8.08	18.10	21.48	15.89
p_5	4.63	5.20	5.43	5.09	118.03	126.97	141.60	128.87	16.83	24.93	32.87	24.88
p_6	4.20	5.07	6.07	5.11	162.77	178.63	222.97	188.12	12.07	22.86	27.99	20.97
P7	5.67	5.47	6.40	5.85	187.67	197.20	215.73	200.20	7.19	16.56	25.35	16.37
$p_1 \times p_2$	4.43	4.57	4.67	4.56	241.43	251.43	282.33	258.40	18.62	28.27	32.60	26.50
$p_1 \times p_3$	6.07	6.13	6.33	6.18	247.80	259.13	266.60	257.84	17.55	28.86	34.63	27.01
$p_1 \times p_4$	5.13	5.23	4.73	5.03	197.33	207.53	220.80	208.55	26.66	34.93	55.75	39.11
$p_1 \times p_5$	5.27	5.23	5.70	5.40	270.87	298.27	318.90	296.01	26.24	32.45	43.14	33.94
$p_1 \times p_6$	4.57	4.67	4.60	4.61	179.90	209.67	221.97	203.85	23.75	33.10	41.91	32.92
$p_1 \times p_7$	5.27	6.17	6.00	5.81	170.20	186.90	214.60	190.57	27.52	33.98	51.23	37.58
$p_2 \times p_3$	5.23	5.43	5.50	5.39	266.50	272.20	285.33	274.68	23.03	32.88	44.66	33.52
$p_2 \times p_4$	4.67	5.13	5.33	5.04	206.07	219.47	219.10	214.88	15.50	29.87	32.99	26.12
$p_2 \times p_5$	5.33	5.27	5.40	5.33	190.77	208.37	237.50	212.21	17.08	27.00	37.90	27.33
$p_2 \times p_6$	6.17	6.03	6.13	6.11	171.17	193.23	223.10	195.83	14.00	31.08	40.86	28.65
$p_2 \times p_7$	6.23	6.60	6.43	6.42	232.27	263.13	294.87	263.42	18.10	26.01	34.07	26.06
$p_3 \times p_4$	6.20	6.13	6.13	6.15	152.37	194.00	202.30	182.89	9.75	18.47	29.31	19.18
$p_3 \times p_5$	6.17	6.13	6.17	6.16	204.00	218.73	221.23	214.65	21.58	36.12	46.76	34.82
$p_3 \times p_6$	9.07	9.50	8.70	9.09	329.50	345.77	381.33	352.20	17.86	26.18	32.75	25.60
$p_3 \times p_7$	5.63	6.13	6.50	6.09	217.87	223.50	258.77	233.38	13.30	25.85	37.40	25.52
$p_4 \times p_5$	6.13	6.17	5.23	5.84	171.43	181.90	201.53	184.95	21.99	31.82	41.63	31.81
$p_4 \times p_6$	6.20	6.20	7.00	6.47	214.93	235.83	273.90	241.55	11.25	24.20	37.73	24.39
$p_4 \times p_7$	6.23	6.63	6.57	6.48	210.87	221.73	244.77	225.79	20.15	29.50	38.19	29.28
$p_5 \times p_6$	5.70	6.07	6.17	5.98	228.43	257.73	343.07	276.41	19.15	27.44	36.75	27.78
$p_5 \times p_7$	5.13	5.40	6.77	5.77	211.37	226.43	240.50	226.10	12.48	21.95	31.28	21.90
$P_6 \times p_7$	5.23	5.40	5.47	5.37	198.30	211.87	221.80	210.66	22.20	33.72	37.71	31.21
GX`	5.51	5.73	5.93		200.27	217.90	241.04		17.28	27.21	35.59	
L.S.D ≤5%	G = 0.24 N = 0.80 G*N = 0.32				G = 1.38 N = 0.45 G*N = 0 .97				G = 0.50 N = 0.16 G*N = 0.39			

Table 4. Cont.

Genotypes	Oil %				SPAD				N%			
	Nitrogen levels (kg /fed)				Nitrogen levels (kg /fed)				Nitrogen levels (kg /fed)			
	30	45	60	Mean	30	45	60	Mean	30	45	60	Mean
p_1	38.57	39.78	41.63	39.99	55.48	66.22	69.73	63.81	1.99	2.41	3.05	2.48
p_2	33.03	34.07	34.16	33.75	63.48	70.93	80.04	71.48	1.81	2.01	1.77	1.86
p_3	35.92	37.42	38.77	37.37	54.59	67.80	85.85	69.41	2.33	2.72	3.14	2.73
p_4	28.17	29.25	31.15	29.52	35.97	43.01	45.25	41.41	2.09	2.40	2.66	2.38
p_5	37.26	39.16	41.80	39.41	36.10	43.17	46.84	42.04	2.05	2.38	2.85	2.43
p_6	32.97	34.70	37.31	34.99	61.67	80.15	84.06	75.29	2.22	2.92	3.39	2.84
P7	44.50	45.71	47.59	45.93	58.37	78.47	86.35	74.40	1.88	2.16	2.53	2.19
$p_1 \times p_2$	41.65	44.21	45.78	43.88	76.77	90.56	99.98	89.10	2.37	2.72	3.11	2.73
$p_1 \times p_3$	40.90	42.53	44.85	42.76	49.20	64.53	76.45	63.39	2.50	2.66	2.97	2.71
$p_1 \times p_4$	41.11	43.49	46.55	43.72	51.31	66.71	74.99	64.34	2.38	2.66	2.93	2.66
$p_1 \times p_5$	42.48	45.54	48.36	45.46	63.61	73.24	84.65	73.83	2.66	3.01	3.34	3.00
$p_1 \times p_6$	40.29	42.48	45.96	42.91	64.91	71.17	86.35	74.14	2.92	3.21	3.53	3.22
$p_1 \times p_7$	47.50	49.97	53.01	50.16	61.56	77.77	88.50	75.94	2.30	2.65	2.92	2.62
$p_2 \times p_3$	40.31	41.99	45.39	42.56	48.92	57.21	68.60	58.24	2.51	2.97	3.36	2.95
$p_2 \times p_4$	38.44	39.78	42.74	40.32	49.35	57.65	62.21	56.40	2.51	2.83	3.23	2.86
$p_2 \times p_5$	47.75	48.84	50.69	49.09	62.12	75.38	95.48	77.66	2.20	2.55	2.93	2.56
$p_2 \times p_6$	35.53	37.59	40.52	37.88	59.88	75.77	82.84	72.83	2.71	3.14	3.45	3.10
$p_2 \times p_7$	45.85	46.57	48.30	46.91	58.97	78.30	85.00	74.09	2.14	2.38	2.65	2.39
$p_3 \times p_4$	38.25	41.19	43.02	40.82	33.99	45.55	47.51	42.35	3.06	3.27	3.51	3.28
$p_3 \times p_5$	39.08	41.58	44.65	41.77	53.79	64.47	78.31	65.52	3.06	3.33	3.57	3.32
$p_3 \times p_6$	38.09	39.76	41.82	39.89	63.95	79.83	90.41	78.06	2.42	2.86	3.19	2.82
$p_3 \times p_7$	46.17	47.98	50.70	48.28	57.45	68.14	71.15	65.58	2.52	2.89	3.15	2.85
$p_4 \times p_5$	40.69	43.62	46.66	43.66	59.22	73.89	83.56	72.22	2.45	2.78	3.13	2.79
$p_4 \times p_6$	35.63	36.80	39.70	37.38	57.79	66.50	71.58	65.29	2.53	2.90	3.22	2.88
$p_4 \times p_7$	31.14	34.70	37.90	34.58	56.96	64.74	74.94	65.55	2.34	2.69	3.00	2.68
$p_5 \times p_6$	38.86	41.27	43.98	41.37	61.60	78.58	89.75	76.64	2.61	2.99	3.28	2.96
$p_5 \times p_7$	54.18	57.19	59.54	56.97	56.68	76.70	91.14	74.84	2.37	2.72	3.09	2.73
$P_6 \times p_7$	46.40	48.45	50.26	48.37	68.00	80.25	92.97	80.41	2.71	3.09	3.45	3.08
GX`	40.03	41.99	44.39		56.49	69.17	78.37		2.42	2.76	3.09	
L.S.D 0.05	G = 2.16 N = 0.75 G*N =1.35				G =2.36 N = 1.56 G*N =1.18				G =0.12 N =0.14 G*N =1.12			

Table 4. Con.

Genotypes	Nitrate reductae			
	Nitrogen levels (kg/fed)			
	30	45	60	mean
p_1	0.46	0.66	0.80	0.64
p_2	0.85	0.76	0.33	0.65
p_3	0.21	0.37	0.41	0.33
p_4	0.27	0.37	0.45	0.36
p_5	0.41	0.77	0.89	0.69
p_6	0.62	0.94	1.06	0.87
P7	0.62	0.81	1.28	0.90
$p_1 \times p_2$	0.61	0.91	1.23	0.92
$p_1 \times p_3$	0.32	0.62	0.82	0.59
$p_1 \times p_4$	0.44	0.73	0.91	0.69
$p_1 \times p_5$	0.63	0.82	0.94	0.80
$p_1 \times p_6$	0.42	0.76	0.93	0.70
$p_1 \times p_7$	0.51	0.90	1.40	0.94
$p_2 \times p_3$	0.37	0.63	0.77	0.59
$p_2 \times p_4$	0.32	0.64	0.96	0.64
$p_2 \times p_5$	0.51	0.42	1.21	0.71
$p_2 \times p_6$	0.76	0.92	1.15	0.94
$p_2 \times p_7$	0.46	0.74	0.95	0.72
$p_3 \times p_4$	0.32	0.46	0.54	0.44
$p_3 \times p_5$	0.34	0.63	0.83	0.60
$p_3 \times p_6$	0.27	0.44	0.73	0.48
$p_3 \times p_7$	0.42	0.72	0.86	0.67
$p_4 \times p_5$	0.38	0.64	0.86	0.63
$p_4 \times p_6$	0.48	0.62	0.91	0.67
$p_4 \times p_7$	0.63	0.91	1.01	0.85
$p_5 \times p_6$	0.63	0.92	1.39	0.98
$p_5 \times p_7$	0.63	0.92	1.00	0.85
$P_6 \times p_7$	0.34	0.64	0.83	0.60
GX`	0.47	0.70	0.91	
L.S.D 0.05	G =0.11 N = 0.18 G*N =0.32			

The highest number of siliquae per plant was found in the parent P3 at 30 and 45 kg/feddan nitrogen levels, P4 at 60 nitrogen levels, and the F_1 of (P3 × P6) at all nitrogen levels, as genes from parents with a good effect might have passed to F_1 crosses. Besides, P1 under 30 nitrogen level, P5 under 45 nitrogen level, and P5 at 60 nitrogen level hadthe highest seed weight per plant, but (P1× P7) under 30 nitrogen level, the F_1 of (P3× P5) under 45 nitrogen level, the F_1 of (P1× p4) at 60 nitrogen level had the highest cross combination. This meant that the parents' genes had passed down to their respective F_1 crosses with a good consequence. It is observes that the cross (P5× P7), and the parent P7 had the highest proportion of seed oil. This meant that the genes for seed oil content were passed down from parent towards the respective cross.The largest levels of SPAD were found in P2 under 30 nitrogen level, P6 under 45 kg/feddan nitrogen level, and P7 under 60 kg/feddan nitrogen level. Under all the three nitrogen levels, the highest cross combination values of SPAD were found in (P1× P2). Under 30 kg/feddan nitrogen level, P3 had the largest proportion of nitrogen as well as P6 under both 45 and 60 nitrogen levels. (P3× P4) under 30 nitrogen level and(P3× P5) under both 45 and 60 nitrogen levels were shown to be the most promising cross combinations. Under all nitrogen levels, P1 had the greatest nitrate reductase values of the parents. In addition, (P2× P7) had the highest nitrate reductase values under both 30 and 45 kg/feddan nitrogen levels, and (P2× P3) had the highest nitrate reductase levels under 60 kg/feddan nitrogen level.

2-Determination of genes controlling traits

Combining ability analysis is a frequent method for identifying genes that control the traits being studied. This was demonstrated by dividing genetic differences into general combining ability (GCA), which relates to additive gene effects, and specific combining ability (SCA), which refers to non-additive gene effects (Matzinger *et al* 1959).In all analyzed traits for individual nitrogen level (Table 5), considerable significant differences owing to GCA and SCA were found, demonstrating the major importance of both additive and non-additive gene effects in the expression of all studied traits.

Table 5. Mean squares of general (GCA) and specific (SCA) combining abilities for earliness, yield and its attributes under different nitrogen levels in 2020/21 season.

N levels (kg/fed)	Parameters	df	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
30	G.C.A	6	140.32	317.2	684.89	1.76	1611.22	45.33	73	210.78	0.11	0.06
	S.C.A	21	104.47	159.96	292.79	0.78	2267.96	28.98	19.85	56.67	0.09	0.01
	Error	54	1.38	1.27	0.99	0.01	1.51	0.08	0.12	0.18	0.005	0.001
	G.C.A/S.C.A		1.34	1.98	2.34	2.26	0.71	1.56	3.68	3.72	1.22	6
45	G.C.A	6	206.58	241.82	739.16	1.61	1350.31	23.78	76.65	325.76	0.17	0.07
	S.C.A	21	76.89	135.36	239.77	0.76	2290	33.23	20.93	79.01	0.08	0.02
	Error	54	0.93	0.55	3.96	0.008	0.13	0.11	0.004	0.15	0.003	0.001
	G.C.A/S.C.A		2.69	1.79	3.08	2.12	0.59	0.72	3.66	4.12	2.13	3.5
60	G.C.A	6	95.96	226.15	751.27	1.66	1721.57	58.24	76.28	411.12	0.27	0.15
	S.C.A	21	41.67	127.84	448.7	0.49	3526.54	84.66	23.02	142.61	0.1	0.047
	Error	54	0.43	0.28	0.35	0.052	0.57	0.09	0.02	0.21	0.007	0.001
	G.C.A/S.C.A		2.3	1.77	1.67	3.39	0.49	0.69	3.31	2.88	2.7	3.19

V1: Days to first flower, V2: 50% flowering, V3: Stem length, V4: Number of branches, V5: Number of siliquae per plant, V6: Seed weight per plant, V7: Oil %, V8: SPAD, V9: N% and V10: Nitrate reductae.

However, under both individual nitrogen levels, a GCA/SCA ratio greater than unity was found for all studied traits, indicating that the inheritance of these traits was governed by additive and additive× additive gene effects, with dominance and over-dominance gene effects also contributing to the genetic system of control of these traits. Hassan *et al* (2018), Ashish et al (2019), and Dezfouli *et al* (2019) reported similar findings, stating that both additive and non-additive gene actions were important in the expression of investigated traits, but with a prevalence of non-additive gene action for most traits.

Combining ability effects

General combining ability effects

General combining ability (GCA) effects estimated for the parental canola genotypes and specific combining ability (SCA) effects for F_1 crosses are presented in Table 6. In that respect, P4 under 30 and 45 kg/feddan nitrogen level, as well as P3 at 60 kg/feddan nitrogen levels, were the strongest combiners for earliness in days to first flower, with extremely significant and negative GCA effects.

Table 6. General combining ability effects for earliness, yield and its attributes under different nitrogen levels in 2020/21 season.

Genotypes	N levels	P1	P2	P3	P4	P5	P6	P7	GCA (j)
V1	30	0.84 *	5.61 **	-1.35 **	-7.57 **	0.98 **	0.50 ns	0.98 **	0.33
	45	-2.71 **	9.77 **	-2.38 **	-5.38 **	-0.08 ns	0.22 ns	0.55 ns	0.29
	60	-0.82 **	6.22 **	-3.23 **	-3.15 **	-1.12 **	1.70 **	0.40 ns	0.20
V2	30	1.50 **	8.06 **	-5.61 **	-10.02**	1.87 **	2.43 **	1.76 **	0.35
	45	0.26 ns	4.97 **	-4.59 **	-9.44 **	3.34 **	3.12 **	2.34 **	0.23
	60	0.59 **	4.74 **	-4.04 **	-9.45 **	2.92 **	2.48 **	2.77 **	0.16
V3	30	-11.97 **	6.59 **	10.66 **	-0.70 *	-10.95 **	0.40 ns	5.97 **	0.31
	45	-13.00 **	6.03 **	11.93 **	2.10 **	-11.04 **	-0.33 ns	4.32 **	0.61
	60	-7.75 **	-11.62 **	11.88 **	2.01 **	-8.18 **	6.36 **	7.29 **	0.18
V4	30	-0.63 **	-0.39 **	0.74 **	0.16 **	-0.12 **	0.14 **	0.11 **	0.03
	45	-0.62 **	-0.39 **	0.66 **	0.09 **	-0.13 **	0.24 **	0.16 **	0.03
	60	-0.54 **	-0.52 **	0.56 **	-0.01 ns	-0.13 ns	0.31 **	0.34 **	0.07
V5	30	-4.02 **	0.03 ns	24.91 **	-17.63 **	-9.91 **	5.07 **	1.56 **	0.38
	45	-3.17 **	-2.97 **	23.47 **	-12.33 **	-10.87 **	7.57 **	-1.70 **	0.11
	60	-6.38 **	-17.95 **	16.78 **	-1.20 **	-9.16 **	20.31 **	-2.40 **	0.23
V6	30	4.22 **	0.07 ns	-2.20 **	-1.86 **	1.55 **	-0.65 **	-1.12 **	0.09
	45	2.56 **	0.75 **	-1.82 **	-1.41 **	1.00 **	0.42 **	-1.50 **	0.10
	60	4.20 **	-3.88 **	-1.11 **	-0.69 **	2.05 **	-0.12 ns	-0.46 **	0.10
V7	30	1.21 **	-0.51 **	-0.62 **	-4.29 **	1.93 **	-2.16 **	4.45 **	0.11
	45	1.32 **	-0.97*	-0.67 *	-4.20 *	2.27 *	-2.24 *	4.49 *	0.02
	60	1.41 **	-1.48 **	-0.79 **	-4.02 **	2.49 **	-2.02 **	4.42 **	0.05
V8	30	2.93 **	3.45 **	-3.94 **	-7.93 **	-2.52 **	5.28 **	2.72 **	0.13
	45	2.56 **	2.60 **	-4.22 **	-10.25 **	-2.75 **	6.56 **	5.50 **	0.12
	60	2.60 **	3.02 **	-2.54 **	-13.52 **	-1.16 **	6.11 **	5.49 **	0.14
V9	30	-0.02 **	-0.14 **	0.16 **	0.02 *	0.01 *	0.11 **	-0.13 **	0.006
	45	-0.04 **	-0.16 **	0.15 **	-0.02 **	0.01 ns	0.21 **	-0.15 **	0.01
	60	0.02 **	-0.27 **	0.15 **	-0.04 **	0.04 **	0.24 **	-0.15 **	0.01
V10	30	0.01 *	0.11 **	-0.14 **	-0.08 **	0.02 **	0.04 **	0.05 **	0.003
	45	0.05 **	0.02 **	-0.15 **	-0.10 **	0.03 **	0.06 **	0.09 **	0.001
	60	0.06 **	-0.04 **	-0.21 **	-0.13 **	0.08 **	0.09 **	0.15 **	0.01

V1: Days to first flower, V2: 50% flowering, V3: Stem length, V4: Number of branches, V5: Number of siliquae per plant, V6: Seed weight per plant, V7: Oil%, V8: SPAD, V9: N% and V10: Nitrate reductae.

Ns: non-significant, *, ** significant at 0.05 and 0.01 level of probability, respectively.

Furthermore, P4 revealed to be a good combiners in the desirable direction under all nitrogen levels, with highly significant and negative GCA effects toward earliness in days to 50% flowering. P1 under 30 and 45 kg/feddan nitrogen levels and P2 at 60 kg/feddan nitrogen level were the best combiners, with highly significant and negative GCA effects for stem length. P2 was the best combiner at all nitrogen levels, with highly significant and negative GCA effects for nitrogen content. As a result, these parents were thought to be good general combiners for these traits, and they might be employed in breeding program to develop earliness in flowering and short cultivars. GCA effects on seed weight per plant and its components should be in a positive direction. The best GCA effects were found in P3 at all nitrogen levels for the number of branches per plant, P3 at both 30 and 45 kg/feddan nitrogen levels, and P6 at 60 kg/feddan nitrogen level for the number of siliquae per plant, P1 under all nitrogen levels for seed weight per plant, P7 under all nitrogen levels for seed oil content, P6 under all nitrogen levels for SPAD, and P3 under all nitrogen levels for nitrogen reductae.

Specific combining ability effects

The created combinations showed a large variation in the SCA effects (Table 7) either in the desired or undesired direction under all nitrogen levels.As a result, there is a possibility of selecting for desired effects, such as a negative effect on days to first flower, days to 50% flowering, plant height, and nitrogen content, but a positive effect on seed weight per plant and its components.

For earliness in days to first flower appearance, high significant and negative SCA effects were detected in P2× P7 at all nitrogen levels. The generated cross combination (P2× P7) under 30 kg/feddan nitrogen level, P5× P6 at both 45 and 60 kg/feddan nitrogen levels, and (P2× P7) under 30 kg/feddan nitrogen level had both high significant and negative SCA effects for earliness in days to 50% flowering. For stem length, the desired cross combinations are (P2× P4) under 30 kg/feddan nitrogen, (P4× P5) under 45kg/feddan nitrogen, and (P1× P5) under 60 kg/feddan nitrogen.

Table 7. Specific combining ability effects for earliness, yield and its attributes under different nitrogen levels in 2020/21 season.

Cross	V1			V2			V3		
	N 30	N 45	N 60	N 30	N 45	N 60	N 30	N 45	N 60
p1×p2	-2.76 **	16.72 **	14.39 **	-7.62 **	-6.85 **	-2.70 **	19.56 **	27.58 **	34.69 **
p1×p3	17.20 **	-5.80 **	-0.83 **	10.38 **	10.37 **	10.41 **	16.51 **	14.28 **	13.69 **
p1×p4	-8.24 **	-11.80 **	-0.57 *	-8.88 **	-10.11 **	-10.52 **	30.94 **	23.57 **	12.89 **
p1×p5	8.54 **	8.57 **	2.39 **	11.23 **	11.11 **	11.44 **	-10.40 **	-5.72 **	-20.35 **
p1×p6	6.35 **	4.28 **	0.57 *	8.68 **	9.33 **	6.89 **	-0.39 ns	-8.06 **	-16.96 **
p1×p7	13.54 **	6.28 **	0.54 *	17.68 **	17.78 **	16.93 **	12.41 **	6.02 **	-1.06 **
p2×p3	-2.91 **	11.72 **	10.13 **	-1.84 **	-0.67 *	0.26 ns	-4.37 **	-0.26 ns	12.76 **
p2×p4	9.65 **	-1.28 **	-3.28 **	6.23 **	11.19 **	10.33 **	-26.58 **	-1.50 ns	11.97 **
p2×p5	4.76 **	-1.91 **	1.69 **	15.68 **	12.41 **	7.30 **	28.68 **	16.21 **	32.43 **
p2×p6	2.24 **	-6.20 **	-0.13 ns	-3.21 **	-2.70 **	-2.26 **	14.19 **	8.34 **	17.21 **
p2×p7	-13.24 **	-14.20 **	-10.17 **	-19.55 **	-14.26 **	-13.89 **	5.99 **	0.55 ns	15.09 **
p3×p4	0.61 ns	2.54 **	1.50 **	-1.77 **	-4.93 **	-4.56 **	-5.09 **	-6.70 **	5.46 **
p3×p5	10.39 **	7.91 **	4.46 **	17.01 **	12.96 **	13.74 **	-0.10ns	9.78 **	7.26 **
p3×p6	-1.13 *	-0.06 ns	-1.02 **	-10.88 **	2.19 **	1.85 **	2.21**	-1.50 ns	-10.76 **
p3×p7	13.72 **	10.61 **	7.28 **	14.12 **	12.30 **	10.89 **	-8.06**	-4.81 **	-6.79 **
p4×p5	4.94 **	-1.76 **	-2.28 **	-6.25**	-0.19 ns	1.15 **	-20.20**	-15.07 **	-17.84 **
p4×p6	-0.57 ns	5.61 **	4.91 **	12.19**	13.04 **	13.26 **	4.84**	6.96 **	4.09 **
p4×p7	-6.72 **	7.61 **	5.54 **	-7.47**	-9.52 **	-8.04 **	0.07ns	-1.65 *	-3.91 **
p5×p6	-2.46 **	3.31 **	2.54 **	-16.36**	-15.41 **	-14.78 **	7.66**	25.37 **	13.01 **
p5×p7	-5.61 **	-2.02 **	0.50 ns	-11.69**	-1.63 **	-0.41 ns	-11.40**	0.55 ns	9.25 **
P6×p7	4.87 **	1.02 *	3.02 **	12.75**	6.59 **	10.37 **	-4.50**	-4.65 **	-12.00 **
sca(ii)	1.00	0.87	0.59	1.01	0.67	0.48	0.89	1.79	0.53
sca(ij)	0.00	0.39	0.27	0.46	0.30	0.22	0.41	0.81	0.24

Table 7. Cont.

Cross	V4			V5			V6		
p1×p2	-0.05 ns	-0.15 **	-0.20 *	45.16 **	39.67 **	65.62 **	-2.95 **	-2.26 **	-3.32 **
p1×p3	0.45 **	0.37 **	0.39 **	26.64 **	20.93 **	15.16 **	-1.75 **	0.91 **	-4.06 **
p1×p4	0.10 *	0.03 ns	-0.64 **	18.72 **	5.13 **	-12.66 **	7.02 **	6.56 **	16.64 **
p1×p5	0.51 **	0.25 **	0.44 **	84.54 **	94.41 **	93.39 **	3.19 **	1.68 **	1.29 **
p1×p6	-0.45 **	-0.68 **	-1.09 **	-21.41 **	-12.63 **	-33.00 **	2.90 **	2.91 **	2.23 **
p1×p7	0.28 **	0.90 **	0.27 **	-27.61 **	-26.13 **	-17.67 **	7.14 **	5.71 **	11.89 **
p2×p3	-0.63 **	-0.56 **	-0.46 **	41.29 **	33.80 **	45.46 **	7.89 **	6.74 **	14.05 **
p2×p4	-0.61 **	-0.29 **	-0.06 ns	23.40 **	16.86 **	-2.80 **	0.02 ns	3.32 **	1.96 **
p2×p5	0.34 **	0.06 ns	0.12 ns	0.38 ns	4.31 **	23.56 **	-1.81 **	-1.96 **	4.13 **
p2×p6	0.91 **	0.46 **	0.42 **	-34.20 **	-29.27 **	-20.30 **	-2.69 **	2.70 **	9.26 **
p2×p7	1.01 **	1.10 **	0.68 **	30.41 **	49.90 **	74.17 **	1.87 **	-0.44 **	2.82 **
p3×p4	-0.21 **	-0.34 **	-0.34 **	-55.18 **	-35.05 **	-54.32 **	-3.46 **	-5.51 **	-4.49 **
p3×p5	0.03 ns	-0.12 **	-0.19 *	-11.27 **	-11.77 **	-27.43 **	4.95 **	9.73 **	10.22 **
p3×p6	2.68 **	2.87 **	1.91 **	99.25 **	96.82 **	103.20 **	3.44 **	0.37 **	-1.62 **
p3×p7	-0.73 **	-0.41 **	-0.33 **	-8.88 **	-16.18 **	3.34 **	-0.66 **	1.96 **	3.38 **
p4×p5	0.59 **	0.48 **	-0.56 **	-1.29 *	-12.80 **	-29.15 **	5.02 **	5.02 **	4.67 **
p4×p6	0.39 **	0.14 **	0.78 **	27.23 **	22.69 **	13.75 **	-3.51 **	-2.02 **	2.94 **
p4×p7	0.46 **	0.66 **	0.31 **	26.67 **	17.85 **	7.32 **	5.86 **	5.20 **	3.74 **
p5×p6	0.17 **	0.23 **	0.06 ns	33.01 **	43.13 **	90.87 **	0.97 **	-1.18 **	-0.78 **
p5×p7	-0.37 **	-0.36 **	0.62 **	19.45 **	21.10 **	11.01 **	-5.23 **	-4.75 **	-5.90 **
P6×p7	-0.53 **	-0.73 **	-1.11 **	-8.60 **	-11.91 **	-37.15 **	6.69 **	7.59 **	2.70 **
sca(ii)	0.10	0.08	0.21	1.1044	0.33	0.68	0.2574	0.30	0.28
sca(ij)	0.04	0.04	0.09	0.5024	0.15	0.31	0.1171	0.14	0.13

Table 7. Cont.

Cross	V7			V8			V9		
	N 30	N 45	N 60	N 30	N 45	N 60	N 30	N 45	N 60
p1×p2	0.93 **	1.87 **	1.47 **	13.89 **	16.23 **	15.99 **	0.11 **	0.16 **	0.27 **
p1×p3	0.29 *	-0.11 **	-0.16 *	-6.28 **	-2.98 **	-1.98 **	-0.05 **	-0.21 **	-0.29 **
p1×p4	4.16 **	4.38 **	4.78 **	-0.19 ns	5.23 **	7.54 **	-0.02 **	-0.04 **	-0.14 **
p1×p5	-0.68 **	-0.04 ns	0.07 ns	6.71 **	4.25 **	4.84 **	0.26 **	0.28 **	0.19 **
p1×p6	1.22 **	1.41 **	2.19 **	0.20 ns	-7.12 **	-0.73 **	0.41 **	0.27 **	0.18 **
p1×p7	1.82 **	2.18 **	2.79 **	-0.58 **	0.54 **	2.03 **	0.04 **	0.08 **	-0.04 **
p2×p3	1.41 **	1.65 **	3.28 **	-7.08 **	-10.33 **	-10.25 **	0.09 **	0.22 **	0.40 **
p2×p4	3.21 **	2.97 **	3.86 **	-2.66 **	-3.86 **	-5.66 **	0.23 **	0.25 **	0.45 **
p2×p5	6.31 **	5.56 **	5.30 **	4.70 **	6.36 **	15.24 **	-0.09 **	-0.05 **	0.08 **
p2×p6	-1.82 **	-1.18 **	-0.36 **	-5.34 **	-2.56 **	-4.67 **	0.32 **	0.33 **	0.38 **
p2×p7	1.89 **	1.07 **	0.97 **	-3.68 **	1.03 **	-1.88 **	-0.00 ns	-0.07 **	-0.01 ns
p3×p4	3.14 **	4.08 **	3.45 **	-10.63 **	-9.14 **	-14.80 **	0.47 **	0.38 **	0.31 **
p3×p5	-2.25 **	-2.01 **	-1.43 **	3.76 **	2.27 **	3.63 **	0.47 **	0.41 **	0.30 **
p3×p6	0.84 **	0.68 **	0.25 **	6.11 **	8.33 **	8.46 **	-0.26 **	-0.26 **	-0.29 **
p3×p7	2.31 **	2.17 **	2.68 **	2.18 **	-2.31 **	-10.17 **	0.08 **	0.13 **	0.06 **
p4×p5	3.02 **	3.56 **	3.81 **	13.18 **	17.73 **	19.86 **	0.01 ns	0.03 **	0.04 **
p4×p6	2.06 **	1.25 **	1.36 **	3.94 **	1.02 **	0.61 **	-0.01 ns	-0.06 **	-0.07 **
p4×p7	-9.04 **	-7.57 **	-6.88 **	5.68 **	0.32 *	4.60 **	0.04 **	0.10 **	0.10 **
p5×p6	-0.93 **	-0.75 **	-0.87 **	2.35 **	5.60 **	6.42 **	0.07 **	0.01 ns	-0.09 **
p5×p7	7.78 **	8.44 **	8.25 **	-0.00 ns	4.78 **	8.44 **	0.07 **	0.10 **	0.12 **
P6×p7	4.09 **	4.21 **	3.48 **	3.51 **	-0.98 **	2.99 **	0.31 **	0.27 **	0.27 **
sca(ii)	0.32	0.06	0.14	0.39	0.35	0.41	0.02	0.02	0.02
sca(ij)	0.15	0.03	0.06	0.18	0.16	0.19	0.01	0.01	0.01

Table 7. Cont.

Cross	V10		
p1×p2	0.03 **	0.14 **	0.29 **
p1×p3	-0.02 **	0.02 **	0.06 **
p1×p4	0.04 **	0.08 **	0.07 **
p1×p5	0.13 **	0.04 **	-0.12 **
p1×p6	-0.10 **	-0.06 **	-0.14 **
p1×p7	-0.02 **	0.06 **	0.28 **
p2×p3	-0.06 **	0.06 **	0.11 **
p2×p4	-0.18 **	0.01 **	0.22 **
p2×p5	-0.08 **	-0.33 **	0.26 **
p2×p6	0.14 **	0.14 **	0.19 **
p2×p7	-0.17 **	-0.07 **	-0.07 **
p3×p4	0.07 **	0.01 ns	-0.02 ns
p3×p5	-0.01 ns	0.04 **	0.05 **
P3×p6	-0.09 **	-0.17 **	-0.05 **
P3×p7	0.04 **	0.08 **	0.01 ns
p4×p5	-0.04 **	0.01 ns	-0.00 ns
p4×p6	0.04 **	-0.04 **	0.05 **
p4×p7	0.18 **	0.21 **	0.08 **
p5×p6	0.10 **	0.13 **	0.31 **
p5×p7	0.09 **	0.09 **	-0.14 **
P6×p7	-0.21 **	-0.22 **	-0.31 **
sca(ii)	0.01	0.01	0.03
sca(ij)	0.00	0.00	0.01

V1: Days to first flower, V2: 50% flowering, V3: Stem length, V4: Number of branches, V5: Number of siliquae per plant, V6: Seed weight per plant, V7: Oil %, V8: SPAD, V9: N% and V10: Nitrate reductae, Ns: non-significant, *, ** significant at 0.05 and 0.01 level of probability, respectively.

Under all nitrogen levels, the promising generated combinations for number of branches per plant and number of capsules per plant were detected in (P3× P6), with high and positive SCA effects. The generated combinations (P2× P3) under 30 kg/feddan nitrogen level, (P3× P5) under 45 kg/feddan nitrogen level, and (P1× P4) under 60 kg/feddan nitrogen level had high significant and positive SCA effects on seed weight per plant. Under all nitrogen levels, the created combination (P5× p7) had a high significant and positive SCA effect on seed oil content. The desirable created SPAD combinations were (P1× P2) under 30kg/feddan nitrogen level and (P4× P5) under both 45 and 60 kg/feddan nitrogen levels as they had high significant and positive SCA effects. As they had high significant and negative SCA effects, the desired generated combination was found in (P3× P6) at both 30 and 45 kg/feddan nitrogen level and (P1× P3) under 60 kg/feddan nitrogen levels for nitrogen content. In addition, (P4× P7) under both 30 and 45 kg/feddan nitrogen level, as well as (P5× P6) under 60 kg/feddan nitrogen levels, had the best direction of SCA effects on nitrate reductae. Inayat *et al.* (2019) and pointed out that combining ability had a favorable effect on seed weight plant^{-1} and seed oil content.

Heterotic effects

To find the best cross combinations, heterosis relative to mid parents heterosis (MPH) was estimated(Table 8).The desired goal was a negative MPH for early flowering to produce a high yield in a short period of time, as well as a short statured plant that could be harvested mechanically and was resistant to lodging. Accordingly,(P2× P7) relative to MPH at all nitrogen levels for earliness in days to first flower and days to 50% flowering, (P4× P5) relative to MPH under both 30 and 45kg/feddan nitrogen levels, and (P1× P6) under 60 kg/feddan nitrogen level for short statured plants were shown to be the best cross combinations.

Cross combinations with a positive direction, on the other hand, are ideal for seed weight per plant and its components. As a result, the best cross combinations for number of branches per plant were found in (P3× P6) under all nitrogen levels and (P1x P5) under all nitrogen levels relative to MPH for number of siliquae per plant,(P4× P7) under 30 kg/feddan nitrogen level, (P3× P5) under 45 kg/feddan nitrogen level and(P2× P3) under 60 kg/feddan nitrogen level over MPH for seed weight per plant, (P2× P5) under 30 and 60 kg/feddan nitrogen level as well as (P5× P6) under 40 kg/feddan nitrogen level over MPH for seed oil content, (P4 × P5) under all nitrogen levels over MPH for SPAD, (P3 × P6) under both 30 and 45 kg/feddan nitrogen levels as well as (P1× P3) under 60 kg/feddan nitrogen levels in MPH for nitrogen content and (P1× P5) under 30 kg/feddan nitrogen level, (P4× P7) under 45 kg/feddan nitrogen level and (P2× P4) under 60 kg/feddan nitrogen level for nitrate reductae. These findings are similar to some extent those of Hassan *et al* (2018), Ashish *et al* (2019) and *Abdelsatar et al (2020*)

Table 8. Mid parent heterosis for earliness, yield and its attributes under different nitrogen levels in 2020/21 season.

Cross	V1			V2			V3		
	N 30	N 45	N 60	N 30	N 45	N 60	N 30	N 45	N 60
p1×p2	7.92**	30.07 **	28.63 **	-2.14 ns	0.78 ns	4.57 **	42.27 **	45.85 **	67.12 **
p1×p3	70.20**	9.62 **	13.54 **	29.07 **	29.48 **	27.78 **	27.78 **	23.20 **	15.95 **
p1×p4	0.62ns	-11.54 **	7.35 **	-2.78 ns	-2.52 *	-2.03 **	38.31 **	31.07 **	14.72 **
p1×p5	39.18**	26.60 **	12.77 **	21.98 **	23.71 **	22.69 **	5.19 **	15.36 **	-6.43 **
p1×p6	29.21**	16.80 **	9.98 **	17.33 **	20.13 **	17.63 **	21.43 **	10.89 **	-8.02 **
p1×p7	39.39**	20.41 **	8.88 **	27.36 **	28.08 **	27.10 **	23.67 **	14.79 **	3.08 **
p2×p3	9.33**	26.94 **	25.93 **	2.27 ns	7.01 **	7.53 **	3.55 **	9.72 **	38.92 **
p2×p4	13.30**	0.22 ns	1.75 ns	2.03 ns	10.27 **	9.47 **	-15.00 **	8.57 **	38.87 **
p2×p5	13.15**	3.61 *	9.29 **	13.50 **	15.00 **	9.80 **	28.45 **	28.70 **	65.60 **
p2×p6	5.45**	-3.73 *	6.89 **	-4.27 **	0.29 ns	1.12 *	22.29 **	19.80 **	36.75 **
p2×p7	-16.33**	-13.28 **	-6.72 **	-17.87 **	-10.20 **	-8.51 **	9.61 **	8.08 **	36.41 **
p3×p4	19.74**	16.15 **	12.95 **	4.17 *	3.42 **	4.27 **	-5.70 **	-1.59 ns	8.36 **
p3×p5	46.30**	29.86 **	18.58 **	28.49 **	27.05 **	26.02 **	-0.89 ns	14.07 **	12.01 **
p3×p6	18.93**	13.83 **	10.02 **	-3.55 *	13.94 **	13.54 **	5.82 **	5.02 **	-3.79 **
p3×p7	43.19**	31.38 **	21.18 **	24.10 **	24.01 **	22.48 **	-5.77 **	-1.85 ns	-0.70 ns
p4×p5	17.44**	3.11 ns	2.16 ns	-5.57 **	4.55 **	5.92 **	-19.04 **	-4.35 *	-5.93 **
p4×p6	2.79ns	11.84 **	12.24 **	11.75 **	16.14 **	16.75 **	4.93 **	10.18 **	3.49 **
p4×p7	-8.49**	15.37 **	12.09 **	-7.77 **	-6.84 **	-3.50 **	-3.50 **	-0.78 ns	-0.36 ns
p5×p6	7.94**	12.96 **	10.00 **	-12.44 **	-6.79 **	-5.62 **	9.71 **	31.14 **	11.27 **
p5×p7	1.82ns	5.62 **	6.18 **	-7.50 **	5.57 **	7.24 **	-10.25 **	5.24 **	9.85 **
P6×p7	13.28**	7.62 **	9.49 **	14.06 **	11.62 **	16.05 **	0.09 ns	0.64 ns	-7.44 **

Table 8. Cont.

Cross	V4			V5			V6		
p1×p2	9.92**	4.18 ns	-5.72 ns	74.76 **	64.77 **	98.01 **	8.92 **	14.82 **	44.73 **
p1×p3	20.93**	19.48 **	7.04 ns	48.67 **	39.53 **	31.73 **	36.94 **	40.60 **	23.01 **
p1×p4	10.39**	7.90 **	-17.20 **	43.81 **	23.25 **	-1.96 **	104.84 **	63.67 **	109.81 **
p1×p5	24.41**	12.14 **	6.54 ns	119.12 **	114.71 **	102.82 **	50.91 **	31.08 **	33.69 **
p1×p6	13.69**	1.45 ns	-18.82 **	23.23 **	27.26 **	12.15 **	58.25 **	39.54 **	40.52 **
p1×p7	10.88**	28.47 **	2.86 ns	7.43 **	7.39 **	10.45 **	118.91 **	65.19 **	79.71 **
p2×p3	0.32ns	0.93 ns	-1.79 ns	51.74 **	45.21 **	65.80 **	92.56 **	59.87 **	134.89 **
p2×p4	-3.78ns	0.65 ns	-1.23 ns	40.98 **	29.01 **	12.40 **	27.46 **	39.70 **	89.22 **
p2×p5	20.30**	7.12 **	7.28 ns	43.90 **	48.15 **	87.08 **	3.31 ns	8.89 **	63.87 **
p2×p6	46.25**	24.40 **	14.64 **	10.48 **	16.07 **	33.09 **	-1.12 ns	30.82 **	97.49 **
p2×p7	25.93**	30.69 **	16.62 **	38.76 **	49.71 **	79.78 **	54.43 **	26.21 **	75.92 **
p3×p4	6.29**	4.84 *	-3.66 ns	-12.78 **	-4.54 **	-20.58 **	23.75 **	6.86 **	27.11 **
p3×p5	13.85**	8.24 **	2.78 ns	26.63 **	25.88 **	18.46 **	76.09 **	74.49 **	62.61 **
p3×p6	74.36**	69.64 **	37.73 **	79.60 **	73.23 **	67.67 **	80.86 **	33.15 **	24.43 **
p3×p7	-5.06*	5.75 **	0.26 ns	11.20 **	7.00 **	15.62 **	78.84 **	56.49 **	49.63 **
p4×p5	21.45**	14.55 **	-9.77 *	30.24 **	16.28 **	-3.84 **	76.51 **	47.91 **	53.19 **
p4×p6	28.28**	16.61 **	14.44 **	39.57 **	29.39 **	9.44 **	11.66 **	18.17 **	52.53 **
p4×p7	11.98**	20.24 **	4.51 ns	26.68 **	15.76 **	-0.76 *	163.84 **	70.23 **	63.09 **
p5×p6	29.06**	18.18 **	7.25 ns	62.70 **	68.67 **	88.21 **	32.51 **	14.87 **	20.76 **
p5×p7	-0.32ns	1.25 ns	14.37 **	38.28 **	39.70 **	34.61 **	3.87 ns	5.82 **	7.46 **
P6×p7	6.08 *	2.53 ns	-12.30 **	13.17 **	12.75 **	1.12 **	130.42 **	71.08 **	41.41 **

Table 8. Cont.

Cross	V7			V8			V9		
	N 30	N 45	N 60	N 30	N 45	N 60	N 30	N 45	N 60
p1×p2	16.36 **	19.70 **	20.82 **	29.07 **	32.06 **	33.51 **	24.60 **	22.98 **	29.36 **
p1×p3	9.83 **	10.18 **	11.56 **	-10.60 **	-3.71 **	-1.72 *	15.68 **	3.83 **	-3.99 **
p1×p4	23.20 **	26.00 **	27.91 **	12.22 **	22.14 **	30.44 **	16.83 **	10.74 **	2.74 *
p1×p5	12.06 **	15.38 **	15.92 **	38.92 **	33.90 **	45.24 **	31.74 **	25.59 **	13.24 **
p1×p6	12.65 **	14.06 **	16.44 **	10.82 **	-2.75 **	12.30 **	38.67 **	20.28 **	9.68 **
p1×p7	14.37 **	16.90 **	18.82 **	8.15 **	7.50 **	13.39 **	18.86 **	15.83 **	4.48 **
p2×p3	16.90 **	17.48 **	24.49 **	-17.14 **	-17.52 **	-17.29 **	21.87 **	25.35 **	37.09 **
p2×p4	25.60 **	25.63 **	30.89 **	-0.75 ns	1.19 ns	-0.70 ns	29.28 **	28.25 **	45.97 **
p2×p5	35.86 **	33.40 **	33.47 **	24.76 **	32.13 **	50.50 **	14.09 **	16.15 **	27.17 **
p2×p6	7.65 **	9.32 **	13.39 **	-4.31 **	0.30 ns	0.97 ns	34.83 **	27.38 **	33.68 **
p2×p7	18.27 **	16.73 **	18.16 **	-3.21 **	4.82 **	2.17 **	16.20 **	14.22 **	23.32 **
p3×p4	19.37 **	23.57 **	23.07 **	-24.93 **	-17.80 **	-27.52 **	38.42 **	27.73 **	21.08 **
p3×p5	6.81 **	8.60 **	10.84 **	18.62 **	16.19 **	18.03 **	39.57 **	30.37 **	19.27 **
p3×p6	10.56 **	10.26 **	9.95 **	10.01 **	7.92 **	6.43 **	6.53 **	1.48 ns	-2.40 *
p3×p7	14.81 **	15.43 **	17.42 **	1.71 ns	-6.84 **	-17.36 **	19.97 **	18.44 **	10.98 **
p4×p5	24.37 **	27.54 **	27.93 **	64.34 **	71.48 **	81.46 **	18.26 **	16.10 **	13.61 **
p4×p6	16.56 **	15.08 **	15.98 **	18.37 **	7.98 **	10.71 **	17.65 **	9.09 **	6.50 **
p4×p7	-14.27 **	-7.42 **	-3.73 **	20.76 **	6.58 **	13.88 **	17.88 **	17.98 **	15.38 **
p5×p6	10.66 **	11.77 **	11.17 **	26.02 **	27.45 **	37.14 **	22.09 **	12.83 **	5.18 **
p5×p7	32.53 **	34.77 **	33.22 **	20.00 **	26.11 **	36.86 **	20.17 **	19.74 **	15.05 **
P6×p7	19.79 **	20.51 **	18.40 **	13.29 **	1.19 *	9.11 **	32.30 **	21.86 **	16.31 **

Table 8. Cont.

Cross	V10		
p1×p2	-7.07 **	28.94 **	116.47 **
p1×p3	-6.86 ns	21.04 **	36.09 **
p1×p4	21.46 **	42.86 **	45.60 **
p1×p5	42.97 **	14.69 **	10.41 *
p1×p6	-22.60 **	-5.02 **	-0.72 ns
p1×p7	-4.94 ns	22.35 **	34.94 **
p2×p3	-30.43 **	11.83 **	109.05 **
p2×p4	-42.43 **	13.35 **	146.35 **
p2×p5	-19.16 **	-44.54 **	97.82 **
p2×p6	2.49 ns	8.48 **	65.87 **
p2×p7	-37.56 **	-5.51 **	18.26 **
p3×p4	33.79 **	24.89 **	27.34 **
p3×p5	7.94 ns	9.36 **	27.18 **
P3×p6	-34.14 **	-31.97 **	0.68 ns
P3×p7	1.60 ns	21.91 **	2.18 ns
p4×p5	10.78 *	12.61 **	27.86 **
p4×p6	9.09 **	-4.62 *	21.06 **
p4×p7	42.64 **	54.37 **	16.44 **
p5×p6	21.43 **	7.63 **	42.91 **
p5×p7	22.98 **	15.97 **	-7.83 *
P6×p7	-43.63 **	-27.24 **	-28.86 **

V1: Days to first flower, V2: 50% flowering, V3: Stem length, V4: Number of branches, V5: Number of siliquae per plant, V6: Seed weight per plant, V7: Oil %, V8: SPAD, V9: N% and V10: Nitrate reductae.

Ns: non-significant, *, ** significant at 0.05 and 0.01 level of probability, respectively.

CONCLUSION

The study found more of promising combinations for increasing canola production at different nitrogen fertilizer levels. Simultaneously, the study found that additive gene action governed seed yield and its related traits, allowing selection in early segregating generations within created combinations to improve seed yield and its components under different nitrogen levels.

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القدرة علي التالف و قوة الهجين لمحصول البذور و الصفات المتعلقة به في الكانولا تحت مستويات مختلفة من التسميد النيتروجيني

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تم تهجين سبعة من التراكيب الوراثية المتباعدة وراثيا من الكانولا بطريقةالتزاوج النصف حلقي لتحديد متوسط السلوك، و نوعي القدرة علي التألف و قوة الهجين تحت مستويات مختلفة من التسميد النيتروجيني للصفات المحصولية في الموسم الشتوي ٢٠٢٠/٢٠١٩. و تم تقييم الاباء و هجنها في الجيل الاول في محطة البحوث الزراعية بالإسماعيلية، مركز البحوث الزراعية، مصر باستخدام القطاعات الكاملة العشوائية في ثلاث مكررات في موسم الشتوي ٢٠٢١/٢٠٢٠. و أشارت النسبة بين القدرة العامة الي القدرة الخاصة علي التالف الي سيادة الفعل الجيني المضيف في وراثة كل الصفات المدروسة تحت مستويات التسميد النيتروجيني المختلفة. كان الاب الاول لمحصول البذور للنبات و الاب السابع لمحتوي البذور من الزيت من أفضل الاباء قدرة عامة علي التالف. و من افضل التوليفات الناتجة P2× P3 لمستوي التسميد ب٣٠ كجم نيتروجين، P3× P5 لمستوي التسميد ب ٤٥ كجم نيتروجين و P1× P4 لمستوي التسميد ب٦٠ كجم نيتروجين للفدان حيث كانت ذات قدرة خاصة علي التالف و قوة هجين عالية و موجبة لمحصول البذور للنبات. علاوة علي ذلك، كان الهجين P5× p7 من افضل التوليفات قدرة خاصة علي التالف و قوة هجين عالية و موجبة لمحتوي البذور من الزيت.

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