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HETEROSIS AND COMBINING ABILITY OF SOME GRAIN SORGHUM GENOTYPES UNDER NITROGEN STRESS CONDITIONS

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ABSTRACT

Thirty grain sorghum genotypes [twenty F_1 crosses, nine parents and a commercial check hybrid H-306] were assessed under two levels of nitrogen (100 kg. N/fed. as a recommended level and 60 kg. N/fed. as a stress level, one feddan = 4200 m^2). These crosses and their parental lines were evaluated in the summer seasons of 2017 and 2018 at Shandaweel Agric. Res. Station. The obtained data showed significant differences between years for all the studied traits. Likewise, highly significant differences between the two levels of fertilizer and among genotypes. As well, the differences among crosses, lines, tester, lines × tester and parents were highly significant for all the studied traits in the two seasons except the lines effects for days to 50% flowering and panicle length in 2017 season. Beside, highly significant differences were obtained for crosses vs. parents for all the studied traits in the two seasons, reflecting the presence of heterosis for all the studied traits. A number of crosses was earlier than their parents and several crosses were heavier in 1000- grain weight than the best parents. Moreover, most of the crosses were taller and higher in grain yield per plant than the best parents under the two levels of nitrogen fertilizer and combined across the two seasons. Additionally, decreasing nitrogen fertilizer from 100 kg N/ fed., to 60 kg N/ fed resulted in a decline in plant height, panicle length, 1000 grain weight and grain yield/plant. Decreasing nitrogen fertilizer from 100 kg N/fed. to 60 kg N/ fed led to increasing the days to 50% flowering. Results indicated that the best crosses were (Ash-33 xRsh-76), (Ash-32 xRsh-38) and (Ash-32 x ICSR-92003) each of them gave the highest grain yield / plant across the two seasons under both nitrogen levels. Also, these crosses significantly out-yielded the check hybrid H-306. The female line Ash-32 and the male line ICSR - 92003 were good combiner for grain yield per plant. Thus, these two lines can be used in sorghum breeding program for improving grain yield. Moreover, some crosses showed positive and highly significant SCA for grain yield per plant and 1000 grain weight under both nitrogen levels.

key words: ***Sorghum, Heterosis, Line × Tester, Nitrogen fertilizer.***

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is one of the world leading cereal crops, providing food, feed, fiber, fuel, chemical/biofuels and feed-stocks across a range of environments and production systems. Its remarkable ability to produce a crop under adverse conditions, in particular, with much less of water and nitrogen fertilizer than most of other grain crops. The cultivated area was about 147,961 hectares produced about 727648 tons of grains (FAO 2017). Seventy percent of this area is located in Assiut and Sohag governorates.

Heterosis is the fraction of F_1 hybrid that falls out side the range of the parents with respect to such characters as vigor, growth, size and yield. Amir (1999) stated that most of the crosses were earlier, taller, longer in panicle length and wider in panicle width, 1000- grain weight and grain yield/plant than the better parent. Besides, most of crosses had positive and highly significant heterosis for all studied traits except for days to 50% flowering. He added that grain yield/ feddan was positively and significantly correlated with each of plant height, panicle length, 1000-grain weight, grain yield/plant and panicle width. Similarly, Haussmann *et al* (1999) they pointed out that the relative hybrid mean superiority compared with the mid parents values was highest for grain yield followed by plant height and above ground dry matter. Hybrid vigor was expressed in a higher harvest index, earlier anthesis and less green leaves at 95 days after planting. Heterosis for the number of kernels per head and 1000 grain weight contributed most to heterosis for grain yield. Ali (2000) presented that the correlation between grain yield/plant and each of plant height, panicle length, panicle width, panicle weight and1000-grain weight was positive and highly significant. Hovny (2000) established that the crosses had highly significant differences among all studied traits at two successive growing seasons and combined across the two seasons. Moreover, Hovny *et al* (2001), Mahmoud (2002) and Abd El Halim (2003) described that some of F_1 crosses were earlier, taller, higher in 1000 grain weight and higher in grain yield per plant compared with their parents. Amir (2004) and Mahmoud (2007) mentioned that some crosses were earlier than the parents and most the crosses were heavier in 1000-grain weight than best parents. In addition, all the crosses were taller, higher in number of grains per panicle and higher in grain yield per plant than best parents. In addition, correlation between grain yield/plant with each of plant height, number of green leaves, panicle length and panicle width was positive and highly significant, By contrast, it was negative and highly significant with days to 50% flowering and 1000-grain weight. Al-Niggar *et al* (2006) pointed out N levels and genotypes x N levels interactions were highly significant for all studied traits.

Low-N as a stress factor caused a significant reduction in grain yield/plant of 17.9 and 15.2% for parental lines and their F_1's, respectively. The lines B-91003, R- 93002 and RTX-86 and the crosses (A-1 x R-89022), (A-47 x R-90001) and (A-91003 x RTX-86) had maximum low-N tolerance. Abo- Zaid (2007) and Abd El- Mottaleb (2009) stated that decreasing nitrogen fertilizer from 100 kg N/ fed., to 50 kg N/fed caused a drop in plant height, panicle length, panicle width, 1000 grain weight and grain yield/plant. While, falling nitrogen fertilizer from 100 kg N/fed., to 50 kg N/fed led to increasing the days to 50% flowering.

El-Dardeer (2011) assessed heterosis in 49 grain sorghum crosses, their parents and hybrid check shandweel-1. He mentioned that the cross (ICSA-610 x ICSR-31) had highest positive significant heterosis for grain yield (66.97%). Crosses (ICSA-364 x ICSR-66), (ICSA-364 x ICSR-66) and (ICSA-490 x ICSR-66) had higher grain yield than the check shandweel-1 and it should be produced commercially after tested on a large scale. Mahdi *et al* (2011) revealed that heterosis was found for more than half of the hybrids studied. Several cross combinations showed significant positive 1000-grain weight heterosis, significant negative days to heading heterosis and good performance. They showed that selection of grain sorghum hybrids in their study should be based on high grain yield, early maturing, taller plants and heavier grain weight. They added that information on general and specific combining ability and heterosis for those four traits could contribute to more efficient breeding program. Mahmoud (2011) decided that some crosses were earlier than their parents and most the crosses were heavier in 1000 grain weight than the best parents. Moreover, most the crosses were taller, had higher panicle length, and higher in grain yield per plant than the best parents under two levels of nitrogen fertilizer and their combined across the two levels in 2007 and 2008 seasons. In addition, decreasing nitrogen fertilizer from 100 kg N/fed., to 60 kg N/ fed caused decline in plant height, panicle length, 1000 grain weight and grain yield/plant. On the other hand, decreasing nitrogen fertilizer from 100 kg N/fed. to 60 kg N/ fed led to increasing days to 50% flowering. Abd-Elrheem (2012) evaluated 36 grain sorghum hybrids derived from six male sterile and six restorer lines and their parental lines with the check shandaweel-6 (Sh-6). He revealed that most of the crosses were earlier, taller, longer in panicle length and higher in panicle width, 1000-grain weight and grain yield/plant than the best parent. Also, most of the crosses had positive and highly significant heterosis for all studied traits except for days to 50 % flowering. He added that nine crosses significantly out yielded the highest check Shandaweel-6.

Mohamed (2014) found that most of the crosses were taller, had higher green leaves/plant, higher panicle length, higher panicle width and higher in grain yield per plant than the best parents over two seasons under two nitrogen levels. He mentioned that all of two types of crosses had positive and highly significant heterosis across the two seasons under the two levels of nitrogen, indicating that these crosses gave higher grain yield per plant than the highest parents. Sayed *et al* (2016) stated that, significant differences among genotypes were found for all studied traits. The interaction of genotypes with each of years and NPK levels used were significant in most studied traits. The analysis of variance for combining ability revealed that the mean squares due to entries, parents, parents *vs*. crosses, crosses, lines, testers, lines × testers turned up significant for all studied characters and suggesting that the experimental materials possessed considerable variability that both general and specific combining ability were involved in the genetic expression of these characters. He added, that the female line ICSB610 showed significant and negative general combining ability (GCA) effects for days to 50% heading and panicle length and positive for grain yield and plant height. In their opinion, these entries may be used to develop high yielding, early flowering, and tall hybrids with short panicles. For specific combining ability (SCA), effects, the crosses ICSA613 × ICSR89028 and ICSA20 × ICSR53 gave positive and highly significant SCA effects which indicated that these crosses can be considered desirable combiners. These crosses had also high grain yield per se and one of the parents has highest GCA effects.

The objective of this study was to examine the expression of specific adaptation of F_1 crosses to nitrogen stress conditions. Also, quantify the effect of N on genetic response and decrease the quantity of N with using stressed N tolerant genotypes to conditions in order to increase the farmer's income and to overcome the expected increase in the price of fertilizers.

MATERIALS AND METHODS

The experiments were conduct at Shandaweel Agric. Res. Station, Sohag, Egypt, during 2016, 2017 and 2018 seasons. In season 2016 twenty grain sorghum crosses were developed from five introduced cytoplasmic male sterile lines (A-lines) and four restorer lines (R-lines). The origin and some agronomic characters of the five male sterile lines (CMS- lines) and the four restorer lines (R- lines) are presented in Table (1). The heads of both parents (A-lines and R-lines) were bagged at flowering time and before anthesis. The pollen was collected from each of the four restorer lines and stigmas of the five male sterile lines (A-lines) were pollinated with the collected pollen to produce the twenty crosses seeds.

In 2017 and 2018 seasons, twenty crosses, their parents and one check hybrid (H-306) were evaluated at Shandaweel Station Farm under two levels of nitrogen fertilizer (100 and 60 kg/fed. of nitrogen as a normal (N1) and stress nitrogen fertilizer (N2), respectively). A randomized complete block design (RCBD) with three replications were used for each nitrogen level. The experimental unit was one row, four meter along and 60 cm. apart and the sowing was done with 20 cm. between hills. Two plants/hill were left after thinning. Sowing date in both of the 2017 and 2018 seasons was on 21st and 25th June, respectively. The recommended cultural practices of sorghum production in the two years were implemented except the amount of nitrogen added.

Table 1. Origin and agronomic characteristics of (CMS lines) and R-lines used.

No	Lines	Origin	Days to 50% flowering	Plant height cm
Male sterile (C. M. S.) lines				
1	BSH-17	Shandaweel	70	143
2	BSH-20	Shandaweel	71	142
3	BSH-22	Shandaweel	68	126
4	BSH-32	Shandaweel	67	135
5	BSH-33	Shandaweel	67	125
Restorer (R) lines				
1	RSH-10	Shandaweel	70	152
2	RSH-38	Shandaweel	68	163
3	RSH-76	Shandaweel	71	152
4	ICSR92003	India	69	168

Data were recorded on days from sowing date to 50% flowering (days), plant height (cm.), panicle length (cm.), 1000-grain weight (gm.) and grain yield per plant (gm.). Grain yield was adjusted with grains moisture to 14% moisture.

Data of each season and combined across the two seasons under different nitrogen fertilizer levels were subjected to a regular analysis of variance of a randomized complete blocks design according to Gomez and Gomez (1984). Line × tester analysis was performed according to Kembthorn (1957).

Lines were considered fixed, because they were selected, but, the replications and years were considered random. Moreover, the nitrogen fertilizer levels were considered fixed. In this analysis the mean squares for male and female parents are considered independent estimates of general combining ability (GCA) and the male × female interaction mean squares provides an estimate of specific combining ability (SCA). According to Singh and Chaudary (1985) general and specific combining ability (GCA & SCA) effect were estimated.

Heterosis (H) was calculated as the percentage of deviation from better parent according to following formulas:

$$H = \frac{\overline{F_1} - \overline{B.P}}{\overline{B.P}} x100$$

Where: Bp two parents mean, F_1 average of cross and its significant was tested by LSD test Stress susceptibility index (S.S.I.):

Stress susceptibility index was calculated according to Fischer and Maurer (1978) equation:

SSI = (1 – YS/YN)/(1 - YMS/YMN)

Where YS is the yield under nitrogen stress (60 kg. nitrogen)

YN is the non-nitrogen stressed yield (100 kg. nitrogen)

YMS is the yield means for all genotypes under 60 kg. nitrogen.

YMN is the mean yield for all 100 kg. N genotypes.

S.S.I values >1.0 indicate relatively stress susceptible genotype and <1.0 indicate relatively stress tolerance genotype.

Results and Discussion

Twenty F_1 grain sorghum crosses, their parental lines (five cytoplasmic male sterile and four restorer lines) along with the check hybrid Shandaweel-306 (H-306), were evaluated under two nitrogen levels (100 and 60 Kg N/ fed) at two successive seasons, 2017 and 2018 for days to 50 % flowering, plant height, Panicle length, 1000- grain weight and grain yield / plant to identify the best parental lines in order to produce nitrogen tolerant crosses. Also, to study heterotic effects for yield and its components.

The combined analysis of variance across the two years is presented in Table (2). The anova Table showed significant differences between seasons for all the studied traits reflecting the sensitivity of genotypes to fluctuation of climate factors.

Table 2. Mean squares values of combined analysis across two seasons and two levels of nitrogen fertilizer for studied traits.

SOV	df	Mean square				
		Days to50% flowering	Plant height	Panicle length	1000 grain weight	Grain yield per plant
Years (Y)	1	9.501**	213.14*	67.60**	30.45*	495.85**
Rep./Years (Ea)	4	2.03	33.56	2.16	2.48	11.08
Nitrogen (N)	1	1727.91**	23216.34**	4987.78**	1597.28**	13258.10**
Y × N	1	1.38	148.23	2.84	57.36*	44.87
Error (b)	4	042	20.31	2.08	3.26	7.02
Entries (E)	29	25.01**	4880.80**	305.63**	72.78**	2958.15**
Y × E	29	5.29**	59.72**	15.66**	20.38**	32.36**
N × E	29	1.86	72.40**	10.24**	2.54	20.78**
Y × N × E	29	1.10	52.99**	1.31	2.81	12.43*
Error (c)	232	1.74	21.91	2.63	1.89	7.25

***, ** significant at 0.5 and 0.01 probability levels, respectively.**

Also, highly significant differences were found between N levels and among genotypes for all the studied traits. But, the interaction between seasons × N levels showed significance for only 1000-grain weight. Moreover, the genotypes were highly significant for all studied traits. Beside, that the interactions between genotypes × seasons were highly significant for all the studied traits. The interactions between genotypes × N levels were highly significant for all the studied traits except days to 50 % flowering and 1000-grain weight. Highly significant differences between N levels and genotypes were obtained at each seasons Tables (3, 4) for all the studied traits indicating that genotypes responded differently to the quantity of N applied and the variability among crosses and their parents. Also, the contrast between crosses and their parents was highly significant.

Table 3. Combined analysis of variance of 20 F1's and 9 parents across the two levels of nitrogen fertilizer in 2017seasons.

SOV	df	Mean square				
		Days to 50% flowering	Plant height	Panicle length	1000 grain weight	Grain yield/plant
Nitrogen (N)	1	908.08**	9357.33**	2302.81**	1087.65**	5687.51**
error a	4	0.46	9.25	2.41	2.86	8.29
Genotypes(G)	28	15.23**	2434.64**	145.82**	36.38**	1620.05**
Crosses (C)	19	15.87**	561.45**	35.37**	42.48**	285.95**
Female effects(F)	4	2.93	148.46**	4.97	55.31**	167.09**
Male Effects(M)	3	25.23**	401.79**	189.54**	92.94**	516.73**
F×M	12	17.84**	739.03**	6.97**	25.59**	267.88**
Parents (P)	8	13.49**	1176.39**	38.13**	17.76**	438.63**
C *vs.* P	1	17.05**	48091.19**	3105.96**	69.51**	36419.33**
G × N	28	1.84	50.05**	5.35**	1.71	12.93*
C × N	19	1.96	64.87**	4.90**	1.07	12.13
F × N	4	0.36	72.37**	0.20	1.34	22.53*
M × N	3	2.62	72.16**	7.23*	1.44	4.55
F × M × N	12	2.33	60.54**	5.89**	2.26	10.55
P×N	8	0.39	20.89	1.02	2.76	14.62
C *vs.* P × N	1	1.02	1.72	48.38**	5.49	14.84
Error b	112	1.79	19.88	2.03	1.72	7.42

***, ** significant at 0.5 and 0.01 probability levels, respectively.**

Table 4. Combined analysis of variance of 20 F1's and 9 parents across the two levels of nitrogen fertilizer in 2018 seasons.

SOV	df	Mean square				
		Days to 50% flowering	Plant height	Panicle length	1000 grain weight	Grain yield/plant
Nitrogen (N)	1	802.60**	12469.71**	2541.52**	431**	7131.26**
error a	4	2.08	24.29	3.06	3.09	7.46
Genotypes(G)	28	15.59**	2685.02**	182.60**	50.89**	1435.44**
Crosses (C)	19	15.94**	616.32**	49.72**	47.18**	322.34**
Female effects(F)	4	12.21**	87.41***	23.72**	37.03**	24.32*
Male Effects(M)	3	12.0611**	489.3**	229.14**	46.59**	517.44**
F×M	12	18.13**	824.38**	13.54**	50.71**	372.9**
Parents (P)	8	11.81**	1326.89**	83.75**	41.86**	401.8**
C *vs.* P	1	39.30**	52855.43**	3498.02**	193.64**	30853.59**
G × N	28	1.37	75.56**	6.59**	5.95**	21.35**
C × N	19	1.55	99.85**	5.41	6.78**	26.79**
F × N	4	1.16	121.28**	2.11	10.01**	16.17
M × N	3	1.18	48.03*	11.79*	4.67	11.25
F × M × N	12	1.77	105.66***	4.92	6.23**	34.22**
P × N	8	1.11	26.78	1.02	1.85	10.22
C *vs.* P ×N	1	0.01	4.44	73.67**	23.14**	6.97
Error b	112	1.74	17.38	3.24	2.21	7.24

***, ** significant at 0.5 and 0.01 probability levels, respectively.**

Mean performance

Mean performance of the 20 F_1 crosses, their parents and the check hybrid H-306 in the two studied seasons under two nitrogen levels and combined across seasons is presented in Tables 4, 5 and 6

The combined data across the two seasons (Table 5) indicated that days to 50% flowering for the parental lines under 60 kg N level ranged from 72.15 (BSH-32) to 75.55 (BSH-20) with an average of 73.91 days. Moreover, for the crosses it ranged from 71.45 (ASH-32×RSH-76) to 76.33 (ASH-33×RSH-10) with an average of 73.14 days.

Days to 50% flowering for the parental lines under 100 kg N level ranged from 67.38 days (BSH-33) to 71.78 days (RSH-76) with an average of 69.58 days.

Table 5. Mean performance of 20 F1's and their parents for days to 50% flowering and plant height under two levels of nitrogen fertilizer in the two seasons and their combined.

Genotypes	Days to 50% flowering						Plant height					
	100Kg			60Kg			100Kg			60Kg		
	2017	2018	Comb	2017	2018	Comb	2017	2018	Comb	2017	2018	Comb
ASH-17 × RSH-10	66.17	68.33	67.25	71.77	72.00	71.88	185.67	184.33	185.00	178.33	176.33	177.33
ASH-20 × RSH-10	67.87	65.67	66.77	72.00	71.17	71.58	182.33	180.00	181.17	177.33	174.33	175.83
ASH-22× RSH-10	68.33	70.80	69.57	73.17	74.00	73.58	183.67	194.67	189.17	174.33	172.67	173.50
ASH-32 × RSH-10	66.90	65.67	66.28	72.63	71.00	71.82	177.00	176.67	176.83	162.00	166.67	164.33
ASH-33× RSH-10	71.27	73.33	72.30	76.00	76.67	76.33	175.00	177.33	176.17	151.67	155.00	153.33
ASH-17 × RSH-38	69.33	67.67	68.50	73.50	72.57	73.03	172.67	172.33	172.50	157.67	160.00	158.83
ASH-20 × RSH-38	69.10	67.33	68.22	73.90	71.87	72.88	180.00	171.33	175.67	164.00	159.00	161.50
ASH-22× RSH-38	69.73	65.33	67.53	74.33	71.67	73.00	158.00	188.33	173.17	157.33	154.00	155.67
ASH-32 × RSH-38	68.40	71.10	69.75	75.33	73.57	74.45	176.00	176.67	176.33	155.00	159.67	157.33
ASH-33× RSH-38	66.83	68.03	67.43	71.67	72.73	72.20	186.00	190.00	188.00	173.00	176.67	174.83
ASH-17 × RSH-76	66.57	67.67	67.12	71.23	72.27	71.75	179.67	181.33	180.50	167.00	178.33	172.67
ASH-20 × RSH-76	66.37	67.27	66.82	72.47	72.77	72.62	190.00	205.00	197.50	163.67	182.33	173.00
ASH-22× RSH-76	70.60	68.00	69.30	75.67	72.33	74.00	179.67	175.00	177.33	160.33	162.00	161.17
ASH-32 × RSH-76	68.43	68.10	68.27	70.90	72.00	71.45	174.00	176.67	175.33	160.00	163.33	161.67
ASH-33× RSH-76	67.57	68.00	67.78	73.33	72.67	73.00	203.33	205.00	204.17	180.33	177.33	178.83
ASH-17 ×ICSR-92003	72.67	70.67	71.67	76.00	74.03	75.15	179.67	182.33	181.00	165.67	161.67	163.67
ASH-20 ×ICSR-92003	71.90	70.67	71.28	74.90	74.10	74.50	171.00	170.00	170.50	153.67	158.00	155.83
ASH-22×ICSR-92003	68.10	68.00	68.05	73.77	73.23	73.50	178.00	176.67	177.33	167.00	161.67	164.33
ASH-32 ×ICSR-92003	70.00	68.23	69.12	74.00	72.10	73.05	208.33	214.00	211.17	186.00	183.67	184.83
ASH-33×ICSR-92003	69.77	70.33	70.05	72.77	73.23	73	176.33	180.00	178.17	166.00	160.67	163.33
Average	68.74	68.41	68.58	73.47	72.80	73.14	180.82	183.88	182.35	166.02	167.17	166.59
BSH-17	70.40	70.33	70.37	74.07	74.17	74.12	145.67	142.00	143.83	126.33	127.00	126.67
BSH-20	71.57	71.10	71.33	76.33	74.77	75.55	142.67	141.33	142.00	128.00	128.33	128.17
BSH-22	69.00	68.33	68.67	73.00	73.67	73.33	124.67	129.00	126.83	114.67	115.67	115.17
BSH-32	67.33	68.00	67.67	71.97	72.33	72.15	137.33	134.00	135.67	125.33	121.00	123.17
BSH-33	68.43	66.33	67.38	73.43	72.33	72.88	122.00	128.00	125.00	110.00	105.00	107.50
RSH-10	71.00	70.83	70.92	75.00	75.17	75.08	148.33	156.00	152.17	135.33	133.00	134.17
RSH-38	68.33	69.00	68.67	72.33	73.00	72.67	160.67	166.00	163.33	148.67	144.33	146.50
RSH-76	71.67	71.90	71.78	75.67	75.10	75.38	153.67	152.00	152.83	138.67	135.33	137.00
ICSR-92003	69.00	69.90	69.45	74.00	74.00	74.00	167.00	170.67	168.83	145.67	152.67	149.17
Average	69.64	69.53	69.58	73.98	73.84	73.91	144.67	146.56	145.61	130.30	129.15	129.72
H-306	70.33	71.00	70.67	73.00	74.20	73.60	179.00	178.67	178.84	161.00	156.00	158.50
LSD 0.05	2.60	2.39	2.50	1.66	1.92	1.79	7.61	9.54	8.58	7.13	6.23	6.68

While for the crosses it ranged from 66.28 days (ASH-32× RSH-10) to 72.30 days (ASH-33× RSH-10) with an average of 68.58 days. Moreover, The data showed that increase in an average of days to 50% flowering across the two seasons for the parental lines and crosses by decreasing nitrogen fertilizer from 100 to 60 Kg N/fed was 4.33 and 4.56 days, respectively. The results indicated that 9 and 4 out of 20 crosses were significantly earlier compared to the check hybrid H-306 in a combined analysis across the two seasons under two nitrogen levels (100 and 60 Kg N/fed) respectively.

The plant height for the parent lines across the two seasons Table (5) under 60 kg N level varied from 107.50 cm (BSH-33) to 149.17 cm (ICSR-92003) with an average of 129.72 cm. Moreover, for the crosses it ranged from 153.33cm (ASH-33×RSH-10) to 184.83cm (ASH-32×ICSR-92003) with an average of 166.59 cm Plant height under 100 kg N level for the parent lines varied from 125.00 cm (BSH-33) to 168.83cm (ICSR-92003) with an average of 145.61cm. Moreover, the crosses varied from 170.50 cm (ASH-20× ICSR-92003) to 211.17 cm (ASH-32×ICSR-92003) with an average of 182.35 cm. The reduction in the average of plant height for the parent lines and crosses under 60 kg N level was 15.89 and 15.76 cm, respectively.

Most of the crosses were taller than its parents in all cases (across the two seasons and under the two N levels), reflecting the presence of hybrid vigor for this character.

Moreover, the tallest cross was (ASH-32×ICSR-92003) under the two nitrogen levels in the two seasons and combined across them. Five and 8 out of the 20 crosses were significantly taller compared to the check hybrid H-306 across two seasons under two N levels (100 and 60 Kg N/fed), respectively.

Highly significant differences between N levels were obtained at each season and across the two seasons, indicating that panicle length responded differently to the quantity of N fertilizer applied. Mean squares for genotypes were highly significant at each season and across the two seasons, indicating the presence of variability among the crosses and their parents.

Panicle length data are presented in (Table 6). Data showed that most of the crosses were significant in panicle length across the parental lines under the two levels of nitrogen combined in the two seasons. This reflecting the presence of hybrid vigor. Moreover, the tallest panicle cross was (ASH-17×ICSR-92003) under 100kg nitrogen level, and cross (ASH-33×ICSR-92003) under the 60kg nitrogen level. Five and 1 out of 20 crosses had significantly longer panicl length compared to the check hybrid H-306 across the two seasons under two N levels (100 and 60 Kg N/ fed) respectively.

Regarding to 1000-grain weight data (Table 6) for the parental lines under the two levels of nitrogen across the two seasons under 60 kg N varied from 21.50 (BSH-20) to 29.32 (ICSR-92003) with an average of 24.68 g. While, under 100kg N, it ranged from 26.16 (BSH-20) to 33.15 (ICSR-92003) with an average of 28.47 g. Wherase, 1000- grain weight of the crosses across the two levels and across seasons for 60 kg N and 100 kg N varied from15.16, 21.99 g. (ASH-33× ICSR- 92003) to 25.81, 30.12 g (ASH-33× RSH-76) with an average 22.60, 27.00 g., respectively. The reduction in the average of 1000-grain weight for the parental lines and crosses under 60 kg N level across two seasons were 3.79 and 4.40 g respectively. Whereas, in a combined over two seasons 11 and 10 out of the 20 crosses had highly significant 1000-grain weight compared to the check hybrid H-306 under the two nitrogen levels, respectively.

The grain yield/plant under the two levels of nitrogen across the two seasons is shown in (Table 7). Grain yield\plant for the parent lines under 60 and 100 kg N levels ranged from 30.45, 41.40 (BH-20) to 52.05 , 66.79 (RSH-38) with an average of 40.17, 53.02 gm respectively. Wherase, the crosses under 60 kg N level ranged from 53.06 (ASH-22 × RSH-10) to 78.62 (ASH-32×RSH-38) with an average of 70.73gm. Moreover, grain yield/plant under 100 kg N level for the crosses ranged from 70.46 (ASH-33 × RSH-38) to 90.10 (ASH-33×RSH-76) with an average 82.52gm. The reductions in the average of parent lines and crosses under 60kg N level across the two seasons were 12.85 and 11.79 gm respectively. The female line ASH-32 gave the highest crosses compared with the other female lines across the two seasons.

Table 6. Mean performance of 20 F_1's and their parents for panicle length and 1000 -grain weight under two levels of nitrogen fertilizer in two seasons and across two seasons.

Genotypes	Panicle length (cm.)						1000 grain weight (g)					
	100Kg			60Kg			100Kg			60Kg		
	2017	2018	Comb	2017	2018	Comb	2017	2018	Comb	2017	2018	Comb
ASH-17 × RSH-10	37.00	39.67	38.33	31.00	29.00	30.00	26.00	27.11	26.56	21.73	22.13	21.93
ASH-20 × RSH-10	36.00	39.33	37.67	30.33	28.00	29.17	28.41	28.18	28.30	22.73	23.91	23.32
ASH-22× RSH-10	39.33	37.33	38.33	32.00	30.00	31.00	28.79	26.12	27.46	22.58	21.54	22.06
ASH-32 × RSH-10	36.33	38.67	37.50	28.67	31.00	29.83	27.73	26.55	27.14	23.73	22.06	22.90
ASH-33× RSH-10	40.33	42.33	41.33	28.67	30.67	29.67	25.60	24.12	24.86	19.83	18.62	19.23
ASH-17 × RSH-38	34.00	36.33	35.17	26.67	29.00	27.83	28.60	27.23	27.92	24.90	23.54	24.22
ASH-20 × RSH-38	35.00	32.67	33.83	28.00	25.67	26.83	29.62	18.17	23.90	25.94	13.82	19.88
ASH-22× RSH-38	33.33	31.00	32.17	27.00	24.67	25.83	30.73	28.90	29.82	26.00	25.13	25.57
ASH-32 × RSH-38	33.67	35.67	34.67	26.00	28.00	27.00	28.40	27.23	27.82	24.52	23.69	24.11
ASH-33× RSH-38	34.33	31.33	32.83	27.67	24.67	26.17	29.73	26.79	28.26	25.73	22.96	24.34
ASH-17 × RSH-76	35.00	38.00	36.50	28.00	31.33	29.67	23.95	25.58	24.76	19.47	22.63	21.05
ASH-20 × RSH-76	35.33	38.33	36.83	26.00	28.33	27.17	30.01	30.23	30.12	24.63	26.98	25.81
ASH-22× RSH-76	34.67	37.33	36.00	27.67	30.33	29.00	29.88	28.45	29.16	24.70	25.50	25.10
ASH-32 × RSH-76	36.00	39.00	37.50	26.67	29.67	28.17	30.73	28.50	29.62	25.73	25.32	25.52
ASH-33× RSH-76	32.33	36.33	34.33	25.33	29.33	27.33	25.52	25.84	25.68	21.91	21.03	21.47
ASH-17 ×ICSR-	41.00	44.00	42.50	30.33	33.33	31.83	27.20	26.16	26.68	23.17	22.31	22.74
ASH-20 ×ICSR-	39.33	42.00	40.67	30.00	32.67	31.33	29.10	28.12	28.61	24.49	23.26	23.88
ASH-22×ICSR-	42.67	40.00	41.33	30.67	28.00	29.33	23.98	21.63	22.81	18.64	20.74	19.69
ASH-32 ×ICSR-	40.67	38.67	39.67	33.00	31.00	32.00	27.35	29.84	28.60	21.53	26.69	24.11
ASH-33×ICSR-	38.00	41.00	39.50	31.00	34.00	32.50	20.95	23.03	21.99	15.38	14.94	15.16
Average	36.72	37.95	37.33	28.73	29.43	29.08	27.61	26.39	27.00	22.87	22.34	22.60
BSH-17	27.00	29.00	28.00	20.67	22.67	21.67	30.40	25.59	27.99	21.79	21.95	21.87
BSH-20	25.00	22.67	23.83	21.00	18.67	19.83	27.73	24.59	26.16	22.58	20.42	21.50
BSH-22	24.33	22.33	23.33	18.33	16.33	17.33	27.88	27.54	27.71	23.14	26.03	24.59
BSH-32	22.33	24.33	23.33	16.00	18.00	17.00	27.58	27.41	27.50	23.57	26.74	25.16
BSH-33	24.67	23.67	24.17	19.00	18.00	18.50	30.45	28.08	29.26	24.67	26.29	25.48
RSH-10	30.67	32.67	31.67	24.00	26.00	25.00	29.33	26.53	27.93	23.57	24.78	24.18
RSH-38	28.00	30.67	29.33	23.00	25.67	24.33	29.70	28.24	28.97	25.42	26.59	26.01
RSH-76	27.67	26.00	26.83	22.33	20.67	21.50	27.79	27.41	27.60	22.51	25.54	24.02
ICSR-92003	28.33	30.33	29.33	22.33	24.33	23.33	33.57	32.73	33.15	27.41	31.23	29.32
Average	26.44	26.85	26.65	20.74	21.15	20.94	29.38	27.57	28.47	23.85	25.51	24.68
H-306	35.33	38.33	36.83	28.33	31.33	29.83	25.47	24.43	24.95	19.39	21.54	20.47
LSD 0.05	2.38	3.04	2.71	2.29	2.91	2.60	2.00	2.59	2.30	2.34	2.08	2.21

Table 7. Mean performance of 20 F1's and their parents for grain yield/plant under two levels of nitrogen fertilizer in two seasons and across the two seasons and stress susceptible index.

Genotypes	Grain yield per plant						
	100Kg			60Kg			SSI
	2017	2018	Comb	2017	2018	Comb	
ASH-17 × RSH-10	82.00	87.87	84.94	76.66	78.38	77.52	0.61
ASH-20 × RSH-10	85.00	85.34	85.17	78.23	75.46	76.85	0.68
ASH-22× RSH-10	68.00	73.67	70.83	54.56	51.55	53.06	1.76
ASH-32 × RSH-10	73.29	72.65	72.97	60.56	64.55	62.56	1.00
ASH-33× RSH-10	82.00	85.03	83.52	70.90	79.25	75.08	0.71
ASH-17 × RSH-38	79.00	76.24	77.62	68.90	65.95	67.43	0.92
ASH-20 × RSH-38	72.00	73.52	72.76	59.36	59.17	59.27	1.30
ASH-22× RSH-38	79.00	81.58	80.29	65.10	74.13	69.62	0.93
ASH-32 × RSH-38	88.58	89.15	88.86	79.57	77.67	78.62	0.81
ASH-33× RSH-38	68.00	72.92	70.46	56.59	54.87	55.73	1.46
ASH-17 × RSH-76	82.30	83.78	83.04	71.44	65.07	68.26	1.25
ASH-20 × RSH-76	80.00	83.92	81.96	67.64	70.20	68.92	1.11
ASH-22× RSH-76	85.00	90.02	87.51	71.00	74.33	72.67	1.19
ASH-32 × RSH-76	87.00	85.69	86.34	78.57	74.67	76.62	0.79
ASH-33× RSH-76	86.83	93.37	90.10	74.97	82.25	78.61	0.89
ASH-17 ×ICSR-92003	86.83	88.69	87.76	73.33	73.00	73.17	1.16
ASH-20 ×ICSR-92003	82.66	85.74	84.20	75.32	73.50	74.41	0.81
ASH-22×ICSR-92003	86.55	92.08	89.31	70.06	81.55	75.81	1.06
ASH-32 ×ICSR-92003	89.22	86.72	87.97	77.45	78.25	77.85	0.81
ASH-33×ICSR-92003	84.44	85.02	84.73	76.63	68.50	72.57	1.00
Average	81.39	83.65	82.52	70.34	71.11	70.73	
BSH-17	45.00	47.86	46.43	36.53	35.73	36.13	0.92
BSH-20	39.56	43.24	41.40	28.60	32.31	30.45	1.09
BSH-22	40.23	45.58	42.91	28.33	33.87	31.10	1.14
BSH-32	47.56	53.91	50.74	28.53	38.53	33.53	1.40
BSH-33	50.67	57.24	53.96	37.67	40.00	38.83	1.16
RSH-10	61.23	65.75	63.49	48.20	52.25	50.23	0.86
RSH-38	64.66	68.92	66.79	50.57	53.53	52.05	0.91
RSH-76	52.23	57.37	54.80	43.20	48.23	45.72	0.68
ICSR-92003	55.56	57.82	56.69	44.32	42.63	43.48	0.96
Average	50.74	55.30	53.02	38.44	41.90	40.17	
H-306	81.23	85.86	83.55	69.90	72.53	71.22	
LSD 0.05	3.86	2.66	3.26	5.06	5.60	5.33	

The male line ICSR-92003 gave the highest crosses compared with the other male lines followed by RSH-76 across the two seasons under the two N levels. It can be concluded that 6 crosses(No. 9, 13, 15, 16, 18 and 19) produced significantly higher grain yield/plant compared to the check Sh-306 across two seasons under 100 Kg N level. Morevere, 6 crosses (No. 1, 2, 9, 14, 15 and 19 produced significantly higher grain yield/plant compared to the check H-306 across the two seasons under 60 Kg N level.

Generally, the best crosses (ASH-33× RSH-76), (ASH-32× RSH-38) and (ASH-32× ICSR-92003) gave the highest yield under the two levels of nitrogen. Also, these crosses are nitrogen tolerant and significantly out yielded the check H-306. fertilizer in 2017 and 2018 seasons and over two seasons.

These crosses can be used in sorghum production under low nitrogen level after testing them in a large scale. Also, the male lines which was used for proudcing these crosses can be considered the best tolerant restorer line and it can be used in crossing with more female lines. These results are in harmony with those obtained by Hovny and El-Dsouky (2007) they reported that twenty two crosses out of twenty eight studied crosses had high NTI more than the check Sh-6. Abd El- Mottaleb (2009) fond that the best crosses (SPDM-94002-A x ICSV-273), (SPDM-94002-A x ZSV-14), (SPDM-94021-A x ICSR-90012) and (SPAN-94037-A x ICSV-273) gave the highest yield in 2006, 2007 and over two seasons under both nitrogen levels. Also, these crosses are nitrogen tolerant and significantly out yielded the check Shandaweel-6.

Stress Susceptibility Indexes (SSI)

The results of stress susceptibility index for grain yield/plant (Table 6) cleared that the different genotypes (lines and crosses) differed greatly in their response to nitrogen stress, some genotypes scored stress susceptibility index >1.0 indicate relatively stress susceptible and some genotypes scored stress susceptibility index <1.0 indicate relatively nitrogen stress tolerance. For example the best parent lines were BSh-17 0.92, RSH-10 0.86, RSH-38 0.91 and RSH-76 0.68. Moreover, the best three crosses were (ASH-17×RSH-10) 0.61 (ASH-20 ×RSH -10) 0.68, (ASH-33× RSH-10) 0.71. The tolerant lines and hybrids scored the lowest stress susceptibility index and selection should be for high yielding genotypes at severe nitrogen which showed SSI lower than the unity. In general, most of the nitrogen stress tolerance crosses were developed from one or two nitrogen stress tolerance lines. Also, restorer lines BSh-17, RSH-10 RSH-76 and ICSR-92003 had good nitrogen stress tolerance. These results are in harmony with these obtained by Mahmoud (2002), El-Abd (2003) and Amir (2008).

Heterosis

Estimates of heterosis for days to 50% flowering, plant height, panicle length,1000-grain weight and grain yield per plant for 20 crosses as a percentage of the better parent under two levels of nitrogen fertilizer (100 and 60 Kg N/levels) in 2017 and 2018 seasons and combined across the two seasons are presented in Tables (8, 9 and 10).

The combined data across the two seasons under 60 Kg N level (Table 8) showed that heterosis for days to 50% flowering ranged from -4.66 (ASH-20× RSH-10) to 4.73% (ASH-33×RSH-10). Four crosses out of twenty crosses had negative and highly significant heterosis (earliness). Whereas, under 100 Kg N level heterosis values for days to 50% flowering ranged from -6.33 (ASH-20×RSH-76) to 7.33 % (ASH-33×RSH-10) and four crosses out of the twenty crosses had negative and significant or highly significant heterosis. Generally, negative significantly heterosis values means that these crosses had favorable gene action for earliness compare to the earlier parent.

Under nitrogen stress condition heterosis for plant height (Table 8) ranged from 4.47 (ASH-20× ICSR-92003) to 32.17% (ASH-17× RSH-10) and all the crosses had positive and significant or highly significant heterosis. On the other hand, under optimum nitrogen level across the two seasons heterosis values for plant height ranged from 0.99 (ASH-20× ICSR-92003) to 33.59% (ASH-33× RSH-76) and nineteen crosses had positive and significant or highly significant heterosis. Most of the crosses were significantly taller than the better parent and the heterosis of ninteen crosses were highly significant across the two seasons under two nitrogen levels. Generally, positive and significant heterosis values means that these crosses had favorable gene action for tallness.

Table 8. Heterosis of days to 50% flowering and plant height in percentage from the better parent under two levels of nitrogen fertilizer and combined over two levels of nitrogen in 2017 and 2018 seasons.

No.	F1 cross	Days to 50% flowering					
		100Kg			60Kg		
		2017	2018	Comb	2017	2018	Comb
1	Ash-17 ×R-sh-10	-6.01**	-2.84**	-4.43*	-3.11**	-2.92**	-3.01**
2	Ash-20 ×R-sh-10	-4.41**	-7.29**	-5.85**	-4.00**	-4.81**	-4.66**
3	Ash-22×R-sh-10	-0.97	3.61**	1.31	0.23	0.45	0.34
4	Ash-32 ×R-sh-10	-0.64	-3.43**	-2.04	0.93*	-1.84**	-0.46
5	Ash-33×R-sh-10	4.14**	10.55**	7.30**	3.5**	5.99**	4.73**
6	Ash-17 ×R-sh-38	1.46*	-1.93**	-0.24	1.61**	-0.59	0.50
7	Ash-20 ×R-sh-38	1.12	-2.42**	-0.66	2.17**	-1.55**	0.30
8	Ash-22×R-sh-38	2.05**	-4.39**	-1.65	2.76**	-1.83**	0.46
9	Ash-32 ×R-sh-38	1.58*	4.56**	3.08	4.68**	1.71**	3.19*
10	Ash-33×R-sh-38	-2.20**	2.56**	0.07	-0.92*	0.55	-0.64
11	Ash-17 ×R-sh-76	-5.45**	-3.79**	-4.62*	-3.83**	-2.56**	-3.19*
12	Ash-20 ×R-sh-76	-7.27**	-5.39**	-6.33**	-4.23**	-2.67**	-3.67**
13	Ash-22×R-sh-76	2.32**	-0.49	0.92	3.65**	-1.81**	0.91
14	Ash-32 ×R-sh-76	1.63*	0.15	0.89	-1.48**	-0.46	-0.97
15	Ash-33×R-sh-76	-1.27	2.51**	0.59	-0.14	0.46	0.16
16	Ash-17 ×ICSR-92003	5.31**	1.10	3.19	2.70**	0.05	1.37
17	Ash-20 ×ICSR-92003	4.20**	1.10	2.64	1.22**	0.14	0.68
18	Ash-22×ICSR-92003	-1.30*	-0.49	-0.9	1.05**	-0.59	0.23
19	Ash-32 ×ICSR-92003	3.96**	0.34	2.14	2.83**	-0.32	1.25
20	Ash-33×ICSR-92003	1.95**	6.03**	3.96*	-0.91*	1.24**	0.16

Table 8. Cont.

No.	F1 cross	Plant height					
		100Kg			60Kg		
		2017	2018	Comb	2017	2018	Comb
1	Ash-17 ×R-sh-10	25.17**	18.16**	21.58**	31.77**	32.58**	32.17**
2	Ash-20 ×R-sh-10	22.92**	15.38**	19.06**	31.03**	31.08**	31.06**
3	Ash-22×R-sh-10	23.82**	24.79**	24.32**	28.82**	29.82**	29.32**
4	Ash-32 ×R-sh-10	19.33**	13.25**	16.21**	19.7**	25.31**	22.48**
5	Ash-33×R-sh-10	17.98**	13.68**	15.77**	12.07**	16.54**	14.29**
6	Ash-17 ×R-sh-38	7.47**	3.82**	5.61*	6.05**	10.85**	8.42**
7	Ash-20 ×R-sh-38	12.03**	3.21**	7.55**	10.31**	10.16**	10.24**
8	Ash-22×R-sh-38	-1.66*	13.45**	6.02*	5.83**	6.70**	6.26**
9	Ash-32 ×R-sh-38	9.54**	6.43**	7.96**	4.26**	10.62**	7.39**
10	Ash-33×R-sh-38	15.77**	14.46**	15.10**	16.37**	22.40**	19.34***
11	Ash-17 ×R-sh-76	16.92**	19.3**	18.10**	20.43**	31.77**	26.03**
12	Ash-20 ×R-sh-76	23.64**	34.87**	29.23**	18.03**	34.73**	26.28**
13	Ash-22×R-sh-76	16.92**	15.13**	16.03**	15.63**	19.70**	17.64**
14	Ash-32 ×R-sh-76	13.23**	16.23**	14.72**	15.38**	20.69**	18.00**
15	Ash-33×R-sh-76	32.32**	34.87**	33.59**	30.05**	31.03**	30.54**
16	Ash-17 ×ICSR-92003	7.58**	6.84**	7.21**	13.73**	5.90**	9.72**
17	Ash-20 ×ICSR-92003	2.40**	-0.39	0.99	5.49**	3.49**	4.47*
18	Ash-22×ICSR-92003	6.59**	3.52**	5.03*	14.65**	5.9**	10.17**
19	Ash-32 ×ICSR-92003	24.75**	25.39**	25.07**	27.69**	20.31**	23.91**
20	Ash-33×ICSR-92003	5.59**	5.47**	5.53*	13.96**	5.24**	9.50**

***, ** Significant at 0.05 and 0.01 probability levels, respectively**

For panicle length (Table 9), heterosis vaules uner 100 kg N level in 2017, 2018 seasons showed that all the crosses exhibited significant or highly significant positive heterosis the highest cross vaules is 44.89% (ASH-17 × ICSR-92003). Whereas, under stress levels of nitrogen fertilizer (combined across the two seasons heterosis vaules ranged from 6.16% (ASH-22× RSH-38) to 39.29% (ASH-33× ICSR-92003), 17 crosses were significantly or highly significantly positive under stress levels of nitrogen fertilizer.

Table 9. Heterosis of panicle length and 1000 grain weight in percentage from the better parent under the two levels of nitrogen fertilizer and combined.

No.	F_1 cross	panicle length					
		100Kg			60Kg		
		2017	2018	Comb	2017	2018	Comb
1	Ash-17 ×R-sh-10	20.65**	21.43**	21.05**	29.17**	11.54**	20.00**
2	Ash-20 ×R-sh-10	17.39**	20.41**	18.95**	26.39**	7.69**	16.67**
3	Ash-22×R-sh-10	28.26**	14.29**	21.05**	33.33**	15.38**	24.00**
4	Ash-32 ×R-sh-10	18.48**	18.37**	18.42**	19.44**	19.23**	19.33**
5	Ash-33×R-sh-10	31.52**	29.59**	30.53**	19.44**	17.95**	18.67**
6	Ash-17 ×R-sh-38	21.43**	18.48**	19.89**	15.94**	12.99**	14.38*
7	Ash-20 ×R-sh-38	25.00**	6.52**	15.34**	21.74**	0.00	10.27
8	Ash-22×R-sh-38	19.05**	1.09	9.66*	17.39**	-3.90*	6.16
9	Ash-32 ×R-sh-38	20.24**	16.3**	18.18**	13.04**	9.09**	10.96*
10	Ash-33×R-sh-38	22.62**	2.17	11.93*	20.29**	-3.9*	7.53
11	Ash-17 ×R-sh-76	26.51**	31.03**	30.36**	25.37**	38.24**	36.92**
12	Ash-20 ×R-sh-76	27.71**	47.44**	37.27**	16.42**	37.1**	26.36**
13	Ash-22×R-sh-76	25.30**	43.59**	34.16**	23.88**	46.77**	34.88**
14	Ash-32 ×R-sh-76	30.12**	50.00**	39.75**	19.40**	43.55**	31.01**
15	Ash-33×R-sh-76	16.87**	39.74**	27.95**	13.43**	41.94**	27.13**
16	Ash-17 ×ICSR-92003	44.71**	45.05**	44.89**	35.82**	36.99**	36.43**
17	Ash-20 ×ICSR-92003	38.82**	38.46**	38.64**	34.33**	34.25**	34.29**
18	Ash-22×ICSR-92003	50.59**	31.87**	40.91**	37.31**	15.07**	25.71**
19	Ash-32 ×ICSR-92003	43.53**	27.47**	35.23**	47.76**	27.40**	37.14**
20	Ash-33×ICSR-92003	34.12**	35.16**	34.66**	38.81**	39.73**	39.29**

Table 9. Cont.

No.	F_1 cross	1000 grain weight					
		100Kg			60Kg		
		2017	2018	Comb	2017	2018	Comb
1	Ash-17 ×R-sh-10	-14.47**	2.17	-5.14	-7.78**	-10.69**	-9.27
2	Ash-20 ×R-sh-10	-3.14**	6.22**	1.31	-3.54*	-3.51*	-3.52
3	Ash-22×R-sh-10	-1.86	-5.14**	-1.71	-4.20*	-17.26**	-10.28*
4	Ash-32 ×R-sh-10	5.47**	-3.15*	-2.84	0.69	-17.5**	-8.98
5	Ash-33×R-sh-10	-15.92**	-14.09**	-15.04**	-19.59**	-29.17**	-24.53**
6	Ash-17 ×R-sh-38	-5.92**	-3.58*	-3.64	-2.06	-11.47**	-6.87
7	Ash-20 ×R-sh-38	-0.26	-35.66**	-17.51**	2.03	-40.51**	-19.71**
8	Ash-22×R-sh-38	3.48**	2.34	2.92	2.27	-5.47**	-1.69
9	Ash-32 ×R-sh-38	-4.37**	-3.56*	-3.98	-3.55*	-11.4**	-7.30
10	Ash-33×R-sh-38	-2.35*	-5.13**	-3.42	1.21	-13.65**	-6.39
11	Ash-17 ×R-sh-76	-21.22**	-6.7**	-11.54**	-13.51**	-11.38**	-12.38*
12	Ash-20 ×R-sh-76	7.99**	10.27**	9.12*	9.08**	5.63**	7.42
13	Ash-22×R-sh-76	7.15**	3.30*	5.24	6.76**	-2.06	2.09
14	Ash-32 ×R-sh-76	10.58**	3.98*	7.30	9.18**	-5.33**	1.46
15	Ash-33×R-sh-76	-16.19**	-7.98**	-12.25**	-11.18**	-20.01**	-15.73**
16	Ash-17 ×ICSR-92003	-18.98**	-20.08**	-19.52**	-15.47**	-28.55**	-22.44**
17	Ash-20 ×ICSR-92003	-13.31**	-14.09**	-13.69**	-10.65**	-25.51**	-18.56**
18	Ash-22×ICSR-92003	-27.58**	-33.9**	-30.7**	-32.00**	-33.6**	-32.85**
19	Ash-32 ×ICSR-92003	-18.51**	-27.89**	-23.14**	-21.45**	-14.53**	-17.76**
20	Ash-33×ICSR-92003	-37.59**	-29.62**	-33.65**	-43.88**	-52.15**	-48.29**

***, ** Significant at 0.05 and 0.01 probability levels, respectively**

Under nitrogen stress, heterosis values for 1000-grain weight (Table 9) across the two seasons heterosis ranged from -33.65 (ASH-33 × ICSR-92003) to 9.12% (ASH-20× RSH-76) and from -48.29 (ASH-33× ICSR-92003) to 7.42% (ASH-20× RSH-76) under optimum nitrogen fertilizer, respectively. Most of the crosses had negative and highly significant heterosis for 1000-grain weight. This indicates that the increase in grain yield may be attributed to the increased number of grains.

For grain yield per plant (Table 10, most of the crosses showed positive and highly significant heterosis in 2017 and 2018 under the two levels of nitrogen and their combined, indicating that these crosses had higher grain yield per plant than the highest parents. The respective superiority of these hybrids in grain yield per plant from the highest parents may be due to the superiority of 1000 grain weight and number of grains per panicle.

In general, some crosses were earlier, taller plant height and heavier in 1000 grain weight than the best parents. Moreover, most of the crosses were higher in grain yield per plant than the best parents in 2017, 2018 seasons under two levels of nitrogen and combined over two seasons. These results are in harmony with those obtained by Mahmoud (1997), Amir (1999), Hovny *et al* (2001), Mahmoud(2002) and Abd El Halim (2003) they concluded that most of the F1 crosses were earlier, taller, heavy grain weight and higher grain yield compared than their parents. Mahdi *et al* (2011) concluded that heterosis was found for more than half of the hybrids studied. Several cross combinations showed significant positive 1000grain weight heterosis, significant negative days to heading heterosis and good performance. Mahmoud (2011) concluded that some crosses were earlier than the parents and most of the crosses were heavier in 1000 grain weight than the best parents. Moreover, most the crosses were taller, higher panicle length, and higher in grain yield per plant than best parents under two levels of nitrogen fertilizer and combined over two levels in 2017 and 2018 seasons. In addition, decreasing nitrogen fertilizer from 100 kg N/ fed., to 60 kg N/ fed decline in plant height, panicle length, 1000 grain weight and grain yield/plant. While, decreasing nitrogen fertilizer from 100 kg N/fed. to 60 kg N/ fed led to increasing the days to 50% flowering.

Table 10. Heterosis of grain yield per plant in percentage from the better parent under two levels of nitrogen fertilizer and their combined.

No.	F_1 cross	Grain yield/plant					
		100Kg			60Kg		
		2017	2018	Comb	2017	2018	Comb
1	ASH-9× RSH-14	33.92**	33.65**	33.78**	59.05**	50.02**	54.35**
2	A-SH-11 RSH-14	38.82**	29.79**	34.15**	62.3**	44.42**	53.00**
3	ASH-12× RSH-14	11.06**	12.04**	11.57**	13.2**	-1.34	5.63
4	ASH-13× RSH-14	19.7**	10.5**	14.94**	25.64**	23.54**	24.55**
5	ASH-18× RSH-14	33.92**	29.33**	31.54**	47.10**	51.67**	49.48**
6	ASH-9× RSH-39	22.18**	10.63**	16.22**	36.26**	23.19**	29.54**
7	A-SH-11× RSH-39	11.35**	6.68**	8.94**	17.4**	10.52**	13.86**
8	ASH-12× RSH-39	22.18**	18.38**	20.22**	28.74**	38.48**	33.75**
9	ASH-13× RSH-39	36.99**	29.35**	33.05**	57.35**	45.08**	51.04**
10	ASH-18× RSH-39	5.17**	5.80**	5.49**	11.92**	2.49	7.07*
11	ASH-9× RSH-79	57.57**	46.04**	51.54**	65.38**	34.9**	49.3**
12	A-SH-11× RSH-79	53.17**	46.28**	49.56**	56.58**	45.54**	50.76**
13	ASH-12× RSH-79	62.74**	56.91**	59.69**	64.35**	54.11**	58.95**
14	ASH-13× RSH-79	66.57**	49.36**	57.56**	81.87**	54.8**	67.59**
15	ASH-18× RSH-79	66.25**	62.74**	64.41**	73.53**	70.53**	71.95**
16	ASH-9× ICSR93001	56.28**	53.39**	54.81**	65.46**	71.23**	68.29**
17	A-SH-11× ICSR93001	48.78**	48.30**	48.53**	69.94**	72.4**	71.15**
18	ASH-12× ICSR93001	55.78**	59.26**	57.55**	58.08**	91.28**	74.36**
19	ASH-13× ICSR93001	60.58**	49.99**	55.18**	74.75**	83.54**	79.06**
20	ASH-18× ICSR93001	51.98**	47.05**	49.47**	72.91**	60.67**	66.91**

***, ** Significant at 0.05 and 0.01 probability levels, respectively**

Combining ability

General and specific combining ability GCA & SCA effects for days to 50% flowering, plant height, panicle length, 1000-grain weight and grain yield\plant are presented in Tables 11&12.

Table 11. Combined data across the two seasons to estimate general combining ability for all studied traits of five females and four restorer lines under two nitrogen levels.

No.	Genotypes	Days to 50%heading		Plant height (cm)		Pnicle length (cm)		1000- Grain yield (g)		Grain yield/plant (g)	
		100%	60%	100%	60%	100%	60%	100%	60%	100%	60%
Female lines											
1	A-SH-17	-0.02	-0.21	-2.60	1.53	0.79	0.75	-0.38	-0.17	0.82	0.86
2	A-SH-20	-0.38	-0.24	-1.14	-0.05	-0.08	-0.46	0.88*	0.82*	-1.50*	-0.87
3	A-SH-22	-0.04	0.39	-3.10*	-2.93*	-0.38	-0.29	0.50	0.45	-0.53	-2.94**
4	A-SH-*32*	-0.30	-0.44	2.57	0.45	0.01	0.17	0.66	1.51**	1.52*	3.18**
5	A-SH-33	0.74	0.50	4.28**	0.99	-0.33	-0.17	-1.66**	-2.60**	-0.32	-0.23
S.E (gi)		0.44	0.32	1.33	1.15	0.47	0.46	0.40	0.41	0.59	0.94
S.E.(g_i-g_j)		0.62	0.45	1.88	1.63	0.67	0.66	0.57	0.57	0.83	1.32
Male lines											
1	R-SH-10	-0.22	-0.09	-0.68	2.28*	1.30**	0.85*	0.01	-0.77*	-3.03**	-1.72*
2	R-SH-38	-0.37	-0.02	-5.22**	-4.96**	-3.60**	-2.35**	0.69	1.17**	-4.52**	-4.60**
3	R-SH-76	-0.80*	-0.57*	4.62**	2.88**	-1.10*	-0.82	1.01**	1.14**	3.27**	2.29**
4	ICSR-92003	1.38**	0.68*	1.28	-0.19	3.40**	2.32**	-1.71**	-1.54**	4.28**	4.03**
S.E (gi)		0.39	0.28	1.19	1.03	0.42	0.41	0.36	0.36	0.53	0.84
S.E.(g_i-g_j)		0.56	0.40	1.68	1.46	0.60	0.59	0.51	0.51	0.74	1.18

***, ** significant at the 0.05 and 0.01 levels, respectively.**

For number of days to 50% flowering, the male line RSH- 76 had negative and significant GCA under combined data. These lines had favorable genes and would be good combiners for earliness. Whereas, the male line ICSR-92003 had positive and significant or highly significant GCA under the two levels of nitrogen fertilizer and combined across the two seasons. Specific combining ability (SCA) effects for days to 50% flowering Table (10) showed that crosses No. (4 and 18) under 100 Kg N level and crosses No. (10 and 20) under 60 Kg N combined across the two seasons had negative and significant means. These crosses would be considered as good combiners for earliness. These results are in harmony with those obtained by Ali (2000), Biradar *et al* (2000), Kenga *et al* (2004), Bakheit *et al* (2004), Hovny *et al* (2005), Mohamed (2007) and Eatemad (2015).

Table 12. Estimate of specific combining ability (SCA) effects for all the studied traits of the twenty F1 crosses across the two seasons under two nitrogen levels.

No.	Genotypes	Days to 50%heading		Plant height (cm)		Panicle length (cm)		1000-Grain Weight (g)		Grain yield / plant (g)	
		100%	60%	100%	60%	100%	60%	100%	60%	100%	60%
1	Ash-17 ×R-sh-10	-1.16	-0.95	5.93*	6.93**	-1.09	-0.68	0.07	0.21	4.63**	7.65**
2	Ash-20 × R-sh-10	-1.29	-1.22	0.64	7.02**	-0.88	-0.31	0.56	0.62	7.18**	8.70**
3	Ash-22× R-sh-10	1.17	0.16	10.60**	7.56*	0.08	1.36	0.10	-0.28	-8.12**	-13.01**
4	Ash-32 × R-sh-10	-1.85*	-0.78	-7.40**	-4.98*	-1.13	-0.27	-0.38	-0.50	-8.03**	-9.64**
5	Ash-33× R-sh-10	3.13**	2.79**	-9.78**	-16.53**	3.03**	-0.10	-0.35	-0.06	4.35**	6.30**
6	Ash-17 × R-sh-38	0.23	0.13	-2.03	-4.33	0.64	0.35	0.75	0.56	-1.20	0.43
7	Ash-20 × R-sh-38	0.31	0.01	-0.33	-0.08	0.18	0.56	-4.52**	-3.76**	-3.75**	-5.10**
8	Ash-22× R-sh-38	-0.71	-0.50	-0.87	-3.04	-1.19	-0.61	1.78*	1.29	2.82*	6.43**
9	Ash-32 × R-sh-38	1.76	1.78**	-3.37	-4.75*	0.93	0.10	-0.38	-1.22	9.34**	9.30**
10	Ash-33× R-sh-38	-1.59	-1.41*	6.59*	12.21**	-0.57	-0.40	2.38**	3.12**	-7.22**	-10.17**
11	Ash-17 × R-sh-76	-0.72	-0.60	-3.87	1.67	-0.53	0.65	-2.73**	-2.57**	-3.57**	-5.62**
12	Ash-20 × R-sh-76	-0.66	0.29	11.68**	3.58	0.68	-0.64	1.38	1.20	-2.34	-3.22
13	Ash-22× R-sh-76	1.48	1.05	-6.53*	-5.38*	0.14	1.03	0.80	0.86	2.25	2.60
14	Ash-32 × R-sh-76	0.71	-0.67	-14.20**	-8.25**	1.27	-0.27	1.09	0.23	-0.97	0.42
15	Ash-33× R-sh-76	-0.81	-0.06	12.93**	8.38**	-1.57	-0.77	-0.53	0.28	4.62**	5.83**
16	Ash-17 × ICSR-92003	1.65	1.42*	-0.03	-4.27	0.98	-0.32	1.91*	1.79*	0.14	-2.46
17	Ash-20 × ICSR-92003	1.63	0.92	-11.99**	-10.52**	0.02	0.39	2.59**	1.94*	-1.10	0.52
18	Ash-22× ICSR-92003	-1.94*	-0.70	-3.20	0.86	0.98	-1.76	-2.67**	-1.88*	3.05*	3.99*
19	Ash-32 × ICSR-92003	-0.62	-0.32	24.97**	17.98**	-1.07	0.43	-0.33	1.49	-0.34	-0.09
20	Ash-33× ICSR-92003	-0.72	-1.31*	-9.74**	-4.06	-0.90	1.27	-1.50	-3.35**	-1.75	-1.96
$SE_{(sij)}$		0.88	0.63	2.66	2.31	0.95	0.93	0.81	0.81	1.18	1.87
S.E.(s_{ij}-s_{kl})		1.25	0.89	3.77	3.27	1.34	1.31	1.14	1.15	1.66	2.65

***, ** significant at the 0.05 and 0.01 levels, respectively.**

CMS-line ASH-33 under 100 Kg N and R-lines RSH-10 under 60 Kg N across the two seasons had positive and significant or highly significant GCA effect for plant height. These lines had favor gene action for tallness. While, the crosses No.1, 3, 10, 15 and 19 had positive and significant SCA effect for plant height under the two nitrogen levels across the two seasons. These results are in agreement with those obtained by Hovny and El-Dsouky (2007), Abd-El-Mottaleb (2009) and Amir (2015). They found that both additive and non-additive gene action were involved in the inheritance of plant height.

For the panicle length under the two levels of nitrogen across the two seasons the parent lines RSH-10 and ICSR-92003 had positive and significant or highly significant GCA effect for panicle length. These lines had favor gene action for panicle length. Whereas the cross No. 5 under 100Kg N level across the two seasons only had positive and highly significant SCA. It may be considered as the best combiner for panicle length.

For 1000-grain weight, the female parent ASH-20 and the male parent RSH-76 displayed significant or highly significant positive GCA effects under the two levels of nitrogen across the two seasons. These parents are considered to be good combiners for grain weight. The crosses No. 10, 16 and 17 under both nitrogen levels and combined across the two seasons and the cross No. 8 combined across the two seasons under 100 Kg N had positive and significant SCA effect for 1000-grain weight. These crosses were considered as the best combinations for 1000-grain weight. Similar results were obtained by Bakheit *et al* (2004), Hovny *et al* (2005), Mohamed (2007), Essa (2009) and Eatemad (2015). They found that general and specific combining ability were significant for 1000-grain weight. Sayed *et al* (2016) supposed that, specific combining ability (SCA), effects, the crosses ICSA613 × ICSR89028 and ICSA20 × ICSR53 gave positive and highly significant SCA effects which indicated that these crosses can be considered desirable combinations. These crosses had also high grain yield per se and one of the parents with highest GCA effects (*i.e.* good combiner parent).

Parental lines such as the female line ASH-32 and the male lines RSH-76 and ICSR-92003 had positive and highly significant GCA effects for grain yield across the nitrogen levels and the two seasons. These lines had favor gene action and considered the best combiners for grain yield. It could be expected these two parents could show better heterosis in F_1 hybrids and produce earlier and high yielding genotypes. These results are in harmony with those obtained by Ali (2000), Biradar *et al* (2000), Kenga *et al* (2004), Bakheit *et al* (2004), Hovny *et al* (2005), Mohamed (2007), Essa (2009) and Hussien (2015).

The crosses No. 1, 2, 5, 8, 9, 15 and 18 had positive and significant SCA effect under nitrogen levels across the two seasons and would be considered as the best combinations for grain yield / plant. Moreover, the crosses (ASH-20 x RSH-10) and (ASH-32 x RSH-38) had positive and highly values and would be considered a good combinations for grain yield/plant under optimum and stress conditions. These results are in line with those reported by Haussmann *et al* (1999), Mahmoud (2002), Amir (2004), Mahmoud (2007), Amir *et al* (2015) and Eatemad (2015).

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قوة الهجين والقدرة على الائتلاف في بعض التراكيب الوراثية للذرة الرفيعة للحبوب تحت ظروف نقص النيتروجين

يوسف محمد يوسف القاضي و محمد السيد محمد الصغير

قسم بحوث الذرة الرفيعة ــ معهد بحوث المحاصيل الحقلية ــ مركز البحوث الزراعية

تم إنتاج عدد ٢٠ هجين من ذرة الحبوب الرفيعة باستخدام ٥ سلالات عقيمة A lines و عدد ٤ أباء معيدة للخصوبة R- lines و ذلك في موسم ٢٠١٦ . في موسمي ٢٠١٧ و ٢٠١٨ تم تقييم عدد ٣٠ تركيب وراثي (٢٠ هجين، ٩ أباء بالإضافة إلى هجين ٣٠٦ للمقارنة) في محطة بحوث شندويل تحت مستويين من التسميد النيتروجيني (١٠٠ كجم للفدان كمعدل امثل و ٦٠ كجم للفدان كمعدل منخفض). أظهرت النتائج اختلافات عالية المعنوية بين السنوات بالنسبة لجميع الصفات محل الدراسة. كذلك أظهرت النتائج اختلافات عالية المعنوية بين معدلي التسميد النيتروجيني وبين التراكيب الوراثية و كذلك بين كلاً من الآباء و الأمهات و كان التباين الراجع للتفاعل بين الآباء و الأمهات عالي المعنوية لجميع الصفات موضع الدراسة. كما كان التباين بين الاباء والهجن عالي المعنوية خلال الموسمين وبالنسبة لجميع الصفات محل الدراسة مما يعطى مؤشرا عن وجود قوة الهجين. كانت بعض الهجن مبكرة مقارنة بالآباء و قد كانت معظم الهجن اقل من الآباء في وزن الألف حبة كذلك كانت معظم الهجن أطول و اعلى في طول القنديل ,واعلى في محصول الحبوب لكل نبات مقارنة بأحسن الابوين و ذلك خلال موسمي التقييم وتحت مستويي التسميد النيتروجيني وتحت متوسط معدلى التسميد في موسمي التقييم. ادى انخفاض معدل التسميد النيتروجيني من ١٠٠ كجم نيتروجين للفدان الى ٦٠ كجم نيتروجين للفدان الى انخفاض في طول النباتات و طول القنديل ووزن الالف حبة ومحصول الحبوب لكل نبات بينما ادى لزيادة عدد الايام من الزراعة وحتى التزهير. اظهرت النتائج ان افضل الهجن في محصول النبات الفردي وتحت مستويي التسميد النيتروجيني هي Ash-33 xRsh-76 و Ash-32 xRsh-38 و Ash-32 x ICSR-92003. علاوة علي ذلك تفوقت تلك الهجن علي هجين المقارنة هجين ٣٠٦ بالنسبة لمحصول النبات الفردي. أظهرت السلالة الأم Ash-32 والسلالة الأب ICSR-92003 قدرة ائتلافية عالية بالنسبة لصفة محصول النبات الفردي ويدل ذلك أنه يمكن استعمال هذه الآباء في برنامج التربية لتحسين محصول الحبوب. علاوة على ذلك أظهرت بعض الهجن قدرة ائتلافية خاصة عالية موجبة و معنوية بالنسبة لصفة محصول الحبوب لكل نبات و صفة وزن الالف حبة تحت مستويي التسميد النيتروجيني.

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