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COMBINING ABILITY FOR YIELD AND RESISTANCE TO MIDGE STENODIPLOSIS SORGHICOLA (COQUILLETT) IN SORGHUM (SORGHUM BICOLOR (L.) MOENCH)

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ABSTRACT

Sorghum plays an important role in both animals and humans feeding. However, sorghum midge is one of limiting factors in sorghum production. This study was conducted to estimate combining ability for grain yield, and resistance to sorghum midge. Two introduced cytoplasmic male sterile lines were crossed to 25 F5 inbred lines in line by tester design to produce 50 hybrids. The parents and F1 hybrids were evaluated in two different planting dates at a location considered to be a sorghum midge hot spot in Niger. Line by testers analysis was performed to estimate combining ability for yield and midge resistance as well as other sorghum traits among parental lines and the hybrids. The analysis of variance for combining ability shows that mean sum of square due to lines, testers and the interaction between lines and testers in both planting date was significant for most of the characters under study. Additive gene action was predominant for all traits in both planting dates. Non additive gene action was also predominant for plant height, days to 50% flowering, grain yield and resistance to midge. Based on GCA and SCA effects, some lines and hybrids have been identified with good yield potential and resistance to sorghum midge.

Keywords: Sorghum, midge, combining ability, resistance, yield.

INTRODUCTION

Sorghum is an important food crop and feed for animals in the tropics. In Niger, sorghum is one of the major cereals crops produced. It ranks second most produced cereal after millet (FAOSTAT 2013). In West Africa, both abiotic and biotic constraints account for about 50% reductions in sorghum yield (Waddington et al., 2010). Sorghum midge, Stenodiplosis sorghicola (Coquillett 1898), is one of the most damaging pests of grain sorghum (Sharma et al., 1993). Globally, losses due to sorghum midge are thought to approximate 10-15% of the world sorghum crop production (Sharma & Teetes, 1995). In Niger yield reduction is about 55.8% to 67.3% (Kadi Kadi et al., 2005). In Niger, early planting is used as control measure. However, timing of rainy seasons in the Sahel is unpredictable. Hence the use of genetic resistance may be a solution. Exploiting heterosis or hybrid vigor can increase sorghum yield. From the 1960s to the 1990s sorghum grain productivity has increased by 47% in China and 50% in India and this is due to the adoption of hybrids in these countries (Reddy et al., 2006). Studies in Niger and Mali on 40 hybrids showed significant yield increase of hybrids of about 40% over well-adapted landrace varieties (Reddy et al., 2006) indicating the huge potential for hybrids development in the Sahelian regions. The objectives of this study were to (i) identify parental lines for resistance to sorghum midge and yield related traits,(ii) identify sorghum hybrids for resistance to sorghum midge and yield related traits and (iii) assess gene action governing midge resistance and yield related traits in sorghum.

MATERIALS AND METHOD

A field experiment was conducted during the year 2015 at the research station of INRAN at Konni, in Niger Republic. 25 F5 recombinant inbred lines were crossed to two male sterile lines in line by tester fashion to

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produce 50 hybrids during the dry season of 2015. The 50 hybrids, their parents and two local checks were sown in the rainy season of the year 2015 in α-lattice arrangement with 3 replications in two different planting dates. Each genotype was grown in a single plot of 3 meters row. The intra and inter row spacing was 0.20m x 0.80m, respectively. Three panicles in each plot were selfed to estimate sorghum midge damage. Data were collected from an average of 3 plants/plot on the following traits: days to 50% flowering, plant height (cm), 1000 grain weight (gm), grain yield (gm/m^2), seedling vigor and midge damage. Midge damage was estimated as a percentage of yield loss as described by Sharma et al (1992). Analysis of variance for grain yield, midge resistance and secondary traits were performed in SAS 9.3 software using the model described by (Kempthorne 1957). Genotypes were considered fixed effects, while replications and environments were considered random effects.

RESULTS

In the first planting date data mean square due to replication was significant for all the characters. Lines were significant for all the traits except for time to 50% flowering. Testers were significant for all traits except 1000 seeds weight and grain yield. The interaction line x testers was significant for all the characters except for seedling vigor. Variance due to SCA was higher than that of GCA for all traits except seedling vigor and 1000 seeds weight (Table 1). In the second planting date, the mean square due to replication was significant for all characters. Lines were significant for all characters except midge damage, while testers were significant for days to 50% flowering, grain yield per panicle and midge damage rating. The interaction Line x testers was significant for all the characters under study except for seedling vigor. Variance due to SCA was greater than that of GCA for all the traits except for seedling vigor and 1000 seeds weight (Table 2). Genetic analysis of planting date one data showed that seventeen lines had significant GCA estimates of line and testers for plant height with nine lines being negative and 8 positive. Fourteen lines were significantly different for days to 50% flowering; seven were negative and seven were positive. Sixteen lines displayed significant 1000 seeds weight differences; ten lines were negative while 6 lines were positive. Fourteen lines exhibited significance for grains yield per plant; five were negative and nine were positive. Eight lines had negative and significant GCA effect for midge damage while 13 had positive and significant GCA effect (Table 3). The mean value for seedling vigor varied from 0.45 to 0.10 for lines and from 0.29 to 0.26 for testers. The line L9 had the highest mean value for lines while the lowest was observed for L18. Among testers, TX640 had the highest mean value, and the lowest QL33. Plant heights mean values varied from 293.33 cm for L8 to 215.17 cm for L19. The tester TX640 had a mean value of 263.25 cm compared to QL33 which was 244.26 cm tall. The mean value for the days to 50% flowering varied from 67.83 DAP to 59.83 DAP for lines and 63.71 DAP and 64.48 DAP for testers. L11 had the highest mean value while L3 had the lowest. Among testers, Ql33 had the highest value and TX640 had the lowest mean value for days to 50% flowering. For 1000 seeds weight, the mean values ranged from 22.99 to 15.99 for lines. The mean value of the line L18 was the highest while that of line L19 was the lowest. Among testers, 1000 seeds weight mean values ranged from the 20.53 for QL33 and 20.39 for TX640. The mean performance of grain yield ranged from 272.29 g/cm2 to 114.81 g/cm2 for lines, and from 224.80 g/cm2 to 213.76 g/cm2 for testers. Among lines, L7 displayed the highest mean value and L8 had the lowest. Tester QL33 had the highest mean value for grain yield per panicle while TX640 had the lowest. Mean performance for midge damage varied from 0.69% to 0.24% for lines whereas the mean performance of testers ranged from of 0.23% to 0.20%. L21 was the highest and L13 and L20 the lowest lines whereas tester TX640 was the highest and QL33 the lowest in terms of mean value (Table 4). In the second planting date, the general combining ability estimates of 1000 seeds weight indicated that 9 lines were negative and significant while 11 lines displayed positive and significant GCA. The estimates of general combining ability of plant height in the planting date two showed that 9 lines exhibited negative and significant GCA effect and 11 lines had positive and significant GCA effect. The general combing ability of days to 50% flowering showed that 9 exhibited negative and significant GCA effects whereas 10 were positive and significant. Twelve lines displayed negative and significant GCA effects for grain yield per plant; 9 were positive and significant. For midge damage, 6 lines were negative and significant while 9 had positive and significant GCA effects. The general combining ability for midge damage revealed that 6 lines were negative and significant while 9 lines were positive and significant (Table 5).

Table 1. ANOVA for planting date one.

Source of variation	d.f.	S_vigor	Plant Height	50% Flowering	1000_seed weight	Grain Yield	Midge Damages
Rep	2	0.247*	4994.42*	18.914*	456.37**	12654.49*	0.088*
Lines	24	0.036*	2233.04*	19.711^{NS}	34.36*	8063.47*	0.108*
Testers	1	0.025*	13036.13*	23.012*	1.015^{NS}	2139.76^{NS}	0.057*
LinesxTesters	24	0.022^{NS}	2284.16*	21.107*	29.820*	12936.73*	0.097*
Residual	97	0.037	1706.06	20.008	33.607	10450.038	0.059
CV		70.103	16.281	6.978	28.33	46.601	50.486
Variance Component Estimate							
σ^2GCA		0.00021	132.1	0.01	0.29	-193.45	-0.00034
σ^2SCA		-0.00500	333.34	0.55	-560.98	1447.52	0.01018
σ^2GCA/σ^2SCA		-0.04198	0.3963	0.0113	-0.00051	-0.1336	-0.0337
σ^2A		0.00084	528.4	0.0248	1.16	-773.8	-0.0013
σ^2D		-0.01000	666.68	1.0952	-1121.96	2895.04	0.0203

Table 2. ANOVA for planting date two.

Source of variation	d.f.	S_vigor	Plant Height	50% Flowering	1000_seed weight	Grain Yield	Midge Damages
Rep	2	0.046*	596.42*	3.795*	138.779*	42540.29*	1.19*
Lines	24	0.013*	1702.13**	8.371*	49.983*	21725.33*	0.05^{ns}
Testers	1	0.0009^{ns}	2444.77^{ns}	36.358*	41.808^{ns}	214220.59**	0.15*
LinesXTesters	24	0.014^{ns}	1327.83*	9.34*	27.215*	10620.12*	0.11*
Residual	97	0.0158	508.85	6.679	28.864	11339.524	0.07
CV		30.064	10.52	3.950	20.740	52.810	49.628
Variance Component Estimate							
σ^2GCA		-0.00017	18.41	0.32	12.78	2650.68	0.0059
σ^2SCA		-0.00060	422.32	4.75	-1445.01	28392.3	0.7782
σ^2GCA/σ^2SCA		0.29012	0.0436	0.0674	-0.00884	0.09336	0.0076
σ^2A		-0.0007	73.64	1.28	51.12	10602.7	0.0237
σ^2D		-0.0012	844.64	1.5	-2890.02	56784.5	1.54

Table 3: General combining ability of lines and testers of planting date one.

Genotypes / Lines	Plant Height	50% Flowering	1000_seed weight	Grain Yield	Midge Damages
L1	-12.03**	-1.27**	0.70^{ns}	-39.28**	0.053**
L2	-5.365^{ns}	-2.60**	-1.87**	-8.95^{ns}	0.187**
L3	4.6353^{ns}	-4.27**	-0.81^{ns}	6.27^{ns}	-0.224**
L4	-2.031^{ns}	0.57^{ns}	5.49**	13.09^{ns}	0.071**
L5	19.635**	0.57^{ns}	2.82**	-1.61^{ns}	-0.017^{ns}
L6	29.635**	1.57**	1.43**	-7.02^{ns}	0.116**
L7	16.302**	0.90**	5.20**	52.93**	0.132**
L8	39.635**	1.90**	2.52**	-104.55**	0.165**
L9	11.302^{ns}	2.90**	-2.33**	-42.40**	0.046*
L10	2.9687^{ns}	0.07^{ns}	-0.25^{ns}	9.51^{ns}	-0.115**

L11	-8.698**	3.73**	-2.10**	37.10**	0.033^{ns}
L12	19.635**	-0.27^{ns}	-2.46**	23.99**	0.100**
L13	-37.03**	-1.60**	0.86^{ns}	41.73**	-0.233**
L14	-18.7**	-2.93**	0.13^{ns}	16.32^{ns}	-0.108**
L15	2.9687^{ns}	0.57^{ns}	-1.04**	-6.55^{ns}	0.107**
L16	-5.365^{ns}	-0.10^{ns}	-1.51**	22.56**	-0.016^{ns}
L17	-3.698^{ns}	-0.77*	0.76^{ns}	11.89^{ns}	0.040*
L18	11.302**	-0.43^{ns}	1.88**	25.95**	-0.037^{ns}
L19	-38.53**	1.40**	-4.48**	40.98**	-0.112**
L20	-25.36**	-0.43^{ns}	-2.05**	7.07^{ns}	-0.237**
L21	22.969**	-1.27**	0.69^{ns}	-67.18**	0.203**
L22	-10.36**	2.40**	-2.90**	20.83*	-0.174**
L23	-8.698**	-0.27^{ns}	0.68^{ns}	17.43*	0.055*
L24	-15.36**	0.07^{ns}	-0.37^{ns}	-77.31**	0.121**
L25	12.302**	-0.50^{ns}	-1.20**	4.29^{ns}	-0.208**
Testers					
TX640	9.5588^{ns}	-0.38^{ns}	-0.07^{ns}	-5.59^{ns}	0.0270^{ns}
QL33	-9.431^{ns}	0.38^{ns}	0.07^{ns}	5.44^{ns}	-0.025^{ns}
S.E (GCA for line)	3.37	0.36	0.47	8.35	0.02
S.E (GCA for Tester)	16.52	1.79	2.32	40.89	0.098

^{ns}= non-significant; *= significant at 5%; **= significant at 1%.

Table 4. Mean performance of lines and testers in the planting date one.

Genotypes	S_vigor	Plant Height (cm)	50% Flowering DAP	1000_seed weight (g)	Grain Yield (g/m^{2})	Midge Damages
L1	0.23^{b}	241.67^{a}	62.83^{d}	21.16^{c}	180.09^{d}	0.54^{e}
L2	0.34^{b}	248.33^{b}	61.50^{f}	18.60^{c}	210.41^{d}	0.67^{a}
L3	0.33^{b}	258.33^{f}	59.83^{g}	19.65^{c}	225.64^{d}	0.26^{k}
L4	0.29^{b}	251.67^{e}	64.67^{d}	25.96^{a}	232.46^{c}	0.56^{d}
L5	0.31^{b}	273.33^{e}	64.67^{d}	23.28^{c}	217.75^{d}	0.47^{g}
L6	0.18^{b}	283.33^{e}	65.67^{c}	21.89^{c}	212.35^{d}	0.60^{b}
L7	0.37^{b}	270.00^{d}	65.00^{c}	25.67^{b}	272.30^{a}	0.62^{b}
L8	0.26^{b}	293.33^{d}	66.00^{c}	22.99^{c}	114.81^{g}	0.65^{b}
L9	0.45^{a}	265.00^{d}	67.00^{b}	18.13^{f}	176.97^{d}	0.53^{f}
L10	0.26^{b}	256.67^{e}	64.17^{d}	20.22^{c}	228.87^{d}	0.37^{h}
L11	0.34^{b}	245.00^{f}	67.83^{a}	18.36^{e}	256.46^{c}	0.52^{g}
L12	0.23^{b}	273.33^{d}	63.83^{d}	18.00^{g}	243.35^{c}	0.58^{c}
L13	0.24^{b}	216.67^{i}	62.50^{e}	21.32^{c}	261.09^{b}	0.25^{l}
L14	0.21^{c}	235.00^{g}	61.17^{f}	20.59^{c}	235.68^{c}	0.38^{h}
L15	0.29^{b}	256.67^{e}	64.67^{d}	19.43^{c}	212.81^{d}	0.59^{b}
L16	0.29^{b}	248.33^{e}	64.00^{d}	18.96^{c}	241.93^{c}	0.47^{g}
L17	0.31^{b}	250.00^{e}	63.33^{d}	21.23^{c}	231.25^{d}	0.52^{g}
L18	0.10^{h}	265.00^{d}	63.67^{d}	22.34^{c}	245.31^{c}	0.45^{g}
L19	0.31^{b}	215.17^{i}	65.50^{c}	15.99^{i}	260.34^{b}	0.37^{h}
L20	0.29^{b}	228.33^{h}	63.67^{d}	18.42^{d}	226.43^{d}	0.25^{m}
L21	0.18^{e}	276.67^{c}	62.83^{d}	21.16^{c}	152.19^{e}	0.69^{a}
L22	0.18^{f}	243.33^{f}	66.50^{d}	17.56^{h}	240.19^{c}	0.31^{i}

L23	0.34^{b}	245.00^{f}	63.83^{d}	21.15^{c}	236.80^{c}	0.54^{e}
L24	0.39^{b}	238.33^{f}	64.17^{d}	20.09^{c}	142.06^{f}	0.61^{b}
L25	0.18^{g}	266.00^{d}	63.60^{d}	19.26^{c}	223.65^{d}	0.28^{j}
TESRTERS						
TX640	0.29^{a}	263.26^{b}	63.72^{a}	20.39^{a}	213.77^{a}	0.23^{a}
QL33	0.26^{a}	244.27^{a}	64.48^{a}	20.53^{a}	224.81^{a}	0.20^{a}
GRAND MEAN	0.27	253.69	64.10	20.46	219.36	0.48
LSD lines	0.22	47.33	5.12	7.43	117.18	0.28
LSD testers	0.06	13.39	1.45	2.10	33.14	0.07

Lines with the same letter are not different; Testers with the same letter are not different.

Table 5. General combining ability of lines and testers for planting date two.

Genotypes/Lines	Plant Height	50% Flowering	1000_seed weight	Grain Yield	Midge Damages
L1	-27.64**	-0.25^{ns}	-0.72^{ns}	-34.61**	-0.009^{ns}
L2	21.69**	0.17^{ns}	3.16**	-47.71**	0.065**
L3	-34.30**	-1.02**	-0.61^{ns}	-35.25**	-0.095**
L4	14.86**	2.24**	-8.21**	111.03**	-0.172**
L5	8.19**	-0.09^{ns}	-1.75**	-49.68**	0.083**
L6	11.52**	1.07**	4.40**	37.37**	-0.062**
L7	21.52**	0.91**	2.01**	31.71**	-0.001^{ns}
L8	10.69**	0.24^{ns}	3.84**	-21.89	0.070**
L9	-3.47^{ns}	1.41**	-3.37**	-78.24**	0.013^{ns}
L10	3.19^{ns}	-2.09**	1.42**	-81.10**	0.036^{ns}
L11	-29.30**	1.07**	2.76**	-42.01**	-0.163**
L12	15.69**	0.07^{ns}	2.25**	-41.95**	0.063**
L13	-0.9^{ns}	0.74**	-0.48**	71.37**	-0.255**
L14	-5.139**	-1.09**	0.22^{ns}	3.23^{ns}	-0.001^{ns}
L15	24.02**	-0.75**	4.68**	17.69*	0.058**
L16	-25.30**	-1.22**	-2.94**	-49.45**	0.054*
L17	-28.47**	0.74**	1.36**	-64.50**	0.072**
L18	23.19**	0.91**	0.76^{ns}	163.98**	-0.051*
L19	-19.30**	-0.82**	-0.69^{ns}	5.04^{ns}	0.028^{ns}
L20	-4.30*	1.97**	4.12**	48.16**	0.068**
L21	10.69**	-1.92**	-1.21**	-14.29^{ns}	0.095**
L22	5.69**	-0.42*	-3.20**	-77.47**	0.036^{ns}
L23	-0.9^{ns}	0.41^{ns}	0.30^{ns}	-27.17**	0.006^{ns}
L24	-26.80**	-3.67**	-4.11**	27.81**	-0.012^{ns}
L25	1.52^{ns}	0.74**	-2.26**	79.08**	0.004^{ns}
TESRTERS					
TX640	4.84^{ns}	0.49^{ns}	-0.71^{ns}	41.50^{ns}	-0.032^{ns}
QL33	-4.37^{ns}	-0.45^{ns}	0.64^{ns}	-37.94^{ns}	0.028^{ns}
S.E (GCA for line)	1.84	0.21	0.439	8.70	0.022
S.E (GCA for Tester)	9.023	1.03	2.149	42.60	0.110

^{ns}= non-significant; *= significant at 5%; **=significant at 1%.

The mean values for seedling vigor in the planting date two ranged from 0.48 to 0.34 for lines and from 0.43 to 0.41 for testers. The highest seedling vigor was seen in lines L3, L4, L5, L9, L11 and L16. The lowest was seen in lines L10, L18 and L22. Tester QL33 had the highest seedling vigor whereas tester TX640 had the lowest. The mean performance of plant height ranged from 238.33 cm for L15 to 180 cm for L3 for lines while testers exhibited mean plant height of 219.15 cm for TX640 and 209.93 for QL33. Days to 50% flowering ranged from 67.66 days after planting (DAP) for L4 to 61.75 DAP for L24. The testers exhibited 65.99 DAP for TX640 and 64.97 DF for QL33. Mean performance for 1000 seeds weight ranged from 30.59 for L15 to 17.70 for L4. For the testers, the highest mean value of 26.54 was seen in QL33 while TX640 had the lowest mean value. Mean value of the yield ranged from 365.62 g/cm2 for L18 to 120.53 g/cm2 for L10 while testers had mean performance of 243.4 g/cm2 for TX640 and 163.69 g/cm2 for QL33. Midge damage mean values ranged from 0.65% for L21 to 0.29% for L13. Testers had mean values of 0.58% for QL33 and 0.52% for TX640 (Table 6).

Table 6. Mean performance of lines and testers in the planting date two.

Genotypes	S. vigor	Plant Height (cm)	50% Flowering (DAP)	1000_seed weight (g)	Grain Yield (g/m^2)	Midge Damages
L1	0.45^a	186.66^a	65.16^e	25.18^f	167.02^g	0.54^b
L2	0.41^a	236^a	65.6^e	29.06^d	153.93^h	0.61^b
L3	0.48^a	180^b	64.4^g	25.30^f	166.38^g	0.45^b
L4	0.48^a	229.16^c	67.66^a	17.70^m	312.66^b	0.37^b
L5	0.48^a	222.5^d	65.33^e	24.16^g	151.95^h	0.63^b
L6	0.45^a	225.83^d	66.5^c	30.31^b	239.01^f	0.48^b
L7	0.40^a	235.83^d	66.3^d	27.91^f	233.35^f	0.55^a
L8	0.36^a	225^d	65.66^e	29.75^c	179.74^g	0.62^b
L9	0.48^a	210.83^g	66.83^c	22.53^k	123.4^j	0.56^b
L10	0.34^a	217.5^d	63.33^i	27.32^f	120.53^j	0.58^b
L11	0.48^a	185^e	66.5^c	28.67^e	159.62^g	0.38^b
L12	0.43^a	230^e	65.5^e	28.15^f	159.68^g	0.61^b
L13	0.45^a	213.33^e	66.16^e	25.42^f	273.01^d	0.29^b
L14	0.37^a	209.16^f	64.33^g	26.12^f	204.87^f	0.55^b
L15	0.45^a	238.33^f	64.66^f	30.59^a	219.33^f	0.61^b
L16	0.48^a	189^d	64.2^g	22.97^i	152.18^h	0.60^b
L17	0.45^a	185.83^h	66.16^e	27.27^f	137.13^i	0.62^b
L18	0.34^a	237.5^i	66.33^d	26.66^f	365.62^a	0.50^b
L19	0.44^a	195^j	64.6^f	25.21^f	206.68^f	0.58^b
L20	0.35^a	210^k	67.4^b	30.03^c	249.80^e	0.62^c
L21	0.40^a	225^k	63.5^h	24.69^f	187.34^g	0.64^b
L22	0.34^a	220^l	65^e	22.70^j	124.16^j	0.58^b
L23	0.40^a	213.33^l	65.83^e	26.21^f	174.46^g	0.55^b
L24	0.43^a	187.5^l	61.75^j	21.79^l	229.45^f	0.53^b
L25	0.42^a	215.83^m	66.16^e	23.64^h	280.72^c	0.55^b
TESRTERS						
TX640	0.41^a	219.154^b	65.9231^b	25.20^a	243.14^a	0.51^a
QL33	0.43^a	209.931^a	64.9722^a	26.54^a	163.69^a	0.58^a
GRAND MEAN	0.418	214.30	65.42	25.90	201.64	0.55
LSD lines	0.14	25.89	2.96	6.42	122.31	0.31
LSD lines	0.04	7.32	0.83	1.81	34.59	0.08

Lines with the same letter are not different; Testers with the same letter are not different.

For planting date one, seven hybrids showed significant SCA for plant height; three had negative and four positive SCA effects. The highest positive SCA for plant height was recorded for the cross L9xQL33 and the lowest was recorded by L20xTX640, while the highest negative SCA was recorded by L9xTX640 and the lowest recorded by L25xTX640. Two crosses were significant for days to 50% flowering. L3xQL33 had negative SCA, and L3xTX640 had positive. L4xTX640 had negative and significant SCA for 1000 seeds weight while L4xQL33 showed positive and significant SCA effect. Four crosses in the planting date one exhibited significant SCA effect for grains yield per plant. The highest positive SCA was recorded by the cross L2xQL33 and the lowest was recorded by the cross L12xTX640. The cross L2xTX640 recorded the highest negative SCA effect for grains yield per plant while the lowest was recorded by the cross L12xQL33. Two lines displayed positive and significant SCA for sorghum midge damage. The cross L13xQL33 had the lowest positive and the cross L14xTX640 had the highest. Five crosses showed negative and significant SCA effect for sorghum midge damage and three showed significant positive differences. The highest negative SCA was recorded by the cross L13xTX640 and the lowest recorded by the cross L12xTX640 (Table 7).

Table 7. Specific combining ability of crosses in the planting date one.

Genotypes	Plant Height	50% Flowering	1000_seed weight	Grain Yield	Midge Damages
TX640 x L1	8.77^{ns}	2.55^{ns}	-0.27^{ns}	-0.483^{ns}	0.150^{ns}
QL33 x L1	-8.90^{ns}	-2.55^{ns}	0.27^{ns}	0.634^{ns}	-0.152^{ns}
TX640 x L2	-11.23^{ns}	2.22^{ns}	1.48^{ns}	-89.775*	0.084^{ns}
QL33 x L2	11.10^{ns}	-2.21^{ns}	-1.48^{ns}	89.926*	-0.086^{ns}
TX640 x L3	8.77^{ns}	4.55*	0.85^{ns}	38.509^{ns}	0.073^{ns}
QL33 x L3	-8.90^{ns}	-4.55*	-0.85^{ns}	-38.358^{ns}	-0.074^{ns}
TX640 x L4	-17.89^{ns}	-0.95^{ns}	-4.62*	27.631^{ns}	-0.09^{ns}
QL33 x L4	17.76^{ns}	0.95^{ns}	4.62*	-27.480^{ns}	0.089^{ns}
TX640 x L5	-26.23^{ns}	-0.95^{ns}	-2.05^{ns}	10.511^{ns}	-0.112^{ns}
QL33 x L5	26.10^{ns}	0.95^{ns}	2.05^{ns}	-10.360^{ns}	0.110^{ns}
TX640 x L6	-12.89^{ns}	-1.62^{ns}	2.06^{ns}	35.004^{ns}	-0.045^{ns}
QL33 x L6	12.76^{ns}	1.62^{ns}	-2.06^{ns}	-34.853^{ns}	0.044^{ns}
TX640 x L7	37.11*	-2.62^{ns}	3.87^{ns}	2.656^{ns}	-0.051^{ns}
QL33 x L7	-37.24*	2.62^{ns}	-3.87^{ns}	-2.505^{ns}	0.050^{ns}
TX640 x L8	10.44^{ns}	0.05^{ns}	-1.17^{ns}	-5.862^{ns}	0.146^{ns}
QL33 x L8	-10.57^{ns}	-0.05^{ns}	1.17^{ns}	11.742^{ns}	-0.234*
TX640 x L9	-37.89*	-0.28^{ns}	1.98^{ns}	-19.580^{ns}	0.102^{ns}
QL33 x L9	37.76*	0.29^{ns}	-1.98^{ns}	19.731^{ns}	-0.104^{ns}
TX640 x L10	-6.23^{ns}	-0.12^{ns}	0.02^{ns}	-49.397^{ns}	0.081^{ns}
QL33 x L10	6.10^{ns}	0.12^{ns}	-0.02^{ns}	49.548^{ns}	-0.083^{ns}
TX640 x L11	2.11^{ns}	-1.78^{ns}	-1.49^{ns}	46.296^{ns}	-0.011^{ns}
QL33 x L11	-2.24^{ns}	1.79^{ns}	1.49^{ns}	-46.145^{ns}	0.0098^{ns}
TX640 x L12	20.44^{ns}	-0.45^{ns}	-2.05^{ns}	87.566*	-0.223*
QL33 x L12	-20.57^{ns}	0.45^{ns}	2.06^{ns}	-87.415*	0.1564^{ns}
TX640 x L13	-16.23^{ns}	-2.45^{ns}	1.91^{ns}	2.611^{ns}	-0.278**
QL33 x L13	16.10^{ns}	2.45^{ns}	-1.91^{ns}	-3.454^{ns}	0.1933*
TX640 x L14	2.11^{ns}	-1.78^{ns}	2.97^{ns}	-24.300^{ns}	0.2485**
QL33 x L14	-2.24^{ns}	1.79	-2.97^{ns}	24.451^{ns}	-0.25*
TX640 x L15	-6.23^{ns}	1.72^{ns}	-0.05^{ns}	22.919^{ns}	-0.018^{ns}
QL33 x L15	6.10^{ns}	-1.71^{ns}	0.05^{ns}	-22.768^{ns}	0.017^{ns}
TX640 x L16	-11.23^{ns}	1.38^{ns}	-0.02^{ns}	-23.465^{ns}	0.039^{ns}
QL33 x L16	11.10^{ns}	-1.38^{ns}	0.02^{ns}	23.616^{ns}	-0.04^{ns}
TX640 x L17	30.44^{ns}	-0.28^{ns}	1.68^{ns}	73.491^{ns}	-0.118^{ns}
QL33 x L17	-30.57^{ns}	0.29^{ns}	-1.68^{ns}	-73.340^{ns}	0.116^{ns}

TX640 x L18	-7.89^{ns}	0.72^{ns}	2.52^{ns}	-1.152^{ns}	-0.241*
QL33 x L18	7.76^{ns}	-0.71^{ns}	-2.52^{ns}	1.303^{ns}	0.239*
TX640 x L19	-4.39^{ns}	3.22^{ns}	1.19^{ns}	32.401^{ns}	-0.009^{ns}
QL33 x L19	4.26^{ns}	-3.21^{ns}	-1.19^{ns}	-23.314^{ns}	0.014^{ns}
TX640 x L20	32.11*	-0.95^{ns}	-1.61^{ns}	-65.867^{ns}	-0.014^{ns}
QL33 x L20	-32.24^{ns}	0.95^{ns}	1.61^{ns}	66.018^{ns}	0.012^{ns}
TX640 x L21	33.77*	1.22^{ns}	-3.82^{ns}	-54.777^{ns}	0.0003^{ns}
QL33 x L21	-33.90*	-1.21^{ns}	3.82^{ns}	54.928^{ns}	-0.001^{ns}
TX640 x L22	-2.89^{ns}	-0.78^{ns}	0.67^{ns}	64.706^{ns}	-0.178^{ns}
QL33 x L22	2.76^{ns}	0.79^{ns}	-0.67^{ns}	-64.555^{ns}	0.176^{ns}
TX640 x L23	-7.89^{ns}	-2.45^{ns}	-3.86^{ns}	-22.850^{ns}	0.010^{ns}
QL33 x L23	7.76^{ns}	2.45^{ns}	3.86^{ns}	23.001^{ns}	-0.012^{ns}
TX640 x L24	5.44^{ns}	1.22^{ns}	-1.73^{ns}	-78.358^{ns}	0.177^{ns}
QL33 x L24	-5.57^{ns}	-1.21^{ns}	1.73^{ns}	78.509^{ns}	-0.179^{ns}
TX640 x L25	-30.56*	-2.22^{ns}	2.00^{ns}	52.737^{ns}	-0.002^{ns}
QL33 x L25	23.43^{ns}	1.35^{ns}	-1.35^{ns}	-36.872^{s}	0.0093^{ns}
SE	16.52	1.78	0.109	40.89	0.09

^{ns}= not significant; *= significant at 5%; **= significant at 1%.

The highest mean performance for seedling vigor in the planting date one was 0.48 for L7xTX640. The lowest mean value was 0.10g shown by L6xTX640, L8xTX640, L18xTX640, L18xQL33 and L22xQL33. The hybrids were generally tall, with height ranging from 303.33 cm to 186.66cm. The tallest hybrid was L7xTX640 while the shortest was L20xQL33. The longest days to 50% flowering was seen for hybrid L3xTX640 with 70.67 DAP and the shortest was hybrid L22xTX640 which had the value of 58.67 DAP. Mean performance for 1000 seeds weight ranged from 30.64g to 14.87g for L4xQL33 and L19xQL33, respectively. The hybrid L2xQL33 had the highest grain yield (305.78 gram/cm2) while hybrid L24xTX640 had the lowest (58.10 gram/cm2). Hybrid L8xTX640 had the highest midge damage percentage (0.82%) and the lowest damage percentage was seen for hybrid L13xTX640, (0%) (Table 8).

Table 8. Mean performance of the crosses in the planting date one.

Genotypes	S_vigor	Plant Height (cm)	50% Flowering (DAP)	1000_seed weight (g)	Grain Yield (g/m^2)	Midge Damages
TX640 x L1	0.26^{d}	260^{g}	65^{g}	20.82^{s}	174.00^{a}	0.715^{c}
QL33 x L1	0.20^{d}	223.33^{l}	60.67^{j}	21.50^{o}	186.16^{b}	0.359^{j}
TX640 x L2	0.32^{d}	246.67^{j}	63.33^{h}	20.01^{z}	115.043^{b}	0.783^{b}
QL33 x L2	0.36^{d}	250.00^{i}	59.67^{k}	17.19^{ar}	305.783^{b}	0.560^{f}
TX640 x L3	0.36^{d}	276.67^{g}	70.67^{a}	20.43^{t}	258.55^{b}	0.359^{j}
QL33 x L3	0.30^{d}	240.00^{k}	62.33^{h}	18.87^{aj}	192.72^{c}	0.159^{n}
TX640 x L4	0.32^{d}	243.33^{k}	63.33^{h}	21.27^{p}	254.493^{c}	0.492^{h}
QL33 x L4	0.26^{d}	260.00^{g}	66.00^{f}	30.65^{a}	210.42^{c}	0.619^{f}
TX640 x L5	0.36^{d}	256.67^{g}	63.33^{h}	21.16^{r}	222.67^{d}	0.382^{j}
QL33 x L5	0.26^{d}	290.00^{e}	66.00^{f}	25.40^{c}	212.837^{d}	0.551^{f}
TX640 x L6	0.10^{h}	280.00^{f}	63.67^{g}	23.88^{h}	241.757^{d}	0.582^{f}
QL33 x L6	0.26^{d}	286.67^{f}	67.67^{e}	19.90^{ac}	182.937^{d}	0.619^{f}
TX640 x L7	0.48^{a}	316.67^{b}	62.00^{h}	29.46^{b}	269.357^{d}	0.592^{f}
QL33 x L7	0.26^{d}	223.33^{l}	68.00^{d}	21.87^{m}	275.233^{e}	0.641^{e}
TX640 x L8	0.10^{i}	313.33^{c}	65.67^{g}	21.75^{n}	103.357^{e}	0.822^{a}
QL33 x L8	0.42^{c}	273.33^{g}	66.33^{e}	24.23^{g}	132^{e}	0.389^{j}

TX640 x L9	0.48^{b}	236.67^{k}	66.33^{e}	20.04^{y}	151.79^{e}	0.660^{d}
QL33 x L9	0.42^{c}	293.33^{d}	67.67^{e}	16.22^{aw}	202.14^{f}	0.401^{i}
TX640 x L10	0.26^{d}	260.00^{g}	63.67^{g}	20.16^{v}	173.877^{f}	0.477^{h}
QL33 x L10	0.26^{d}	253.33^{h}	64.67^{g}	20.27^{u}	283.86^{f}	0.259^{l}
TX640 x L11	0.42^{c}	256.67^{g}	65.67^{g}	16.80^{au}	297.16^{f}	0.534^{g}
QL33 x L11	0.26^{d}	233.33^{l}	70.00^{b}	19.92^{ab}	215.757^{f}	0.501^{g}
TX640 x L12	0.20^{d}	303.33^{d}	63.00^{h}	15.88^{ax}	325.32^{f}	0.389^{j}
QL33 x L12	0.26^{d}	243.33^{k}	64.67^{g}	20.13^{w}	161.377^{f}	0.715^{c}
TX640 x L13	0.32^{d}	210.00^{m}	59.67^{k}	23.16^{j}	258.105^{g}	0^{p}
QL33 x L13	0.16^{e}	223.33^{l}	65.33^{g}	19.49^{ag}	263.077^{g}	0.418^{i}
TX640 x L14	0.16^{f}	246.67^{j}	59.00^{k}	23.49^{i}	205.783^{g}	0.651^{d}
QL33 x L14	0.26^{d}	223.33^{l}	63.33^{h}	17.70^{ao}	265.573^{g}	0.100^{o}
TX640 x L15	0.32^{d}	260.00^{g}	66.00^{f}	19.30^{ah}	230.137^{g}	0.599^{f}
QL33 x L15	0.26^{d}	253.33^{h}	63.33^{h}	19.55^{af}	195.487^{g}	0.582^{f}
TX640 x L16	0.26^{d}	246.67^{j}	65.00^{g}	18.86^{ak}	212.867^{g}	0.534^{g}
QL33 x L16	0.32^{d}	250.00^{i}	63.00^{h}	19.05^{ai}	270.987^{g}	0.401^{i}
TX640 x L17	0.26^{d}	290.00^{e}	62.67^{h}	22.84^{k}	299.147^{g}	0.433^{h}
QL33 x L17	0.36^{d}	210.00^{m}	64.00^{g}	19.62^{ae}	163.353^{g}	0.615^{f}
TX640 x L18	0.10^{j}	266.67^{g}	64.00^{g}	24.79^{f}	238.563^{g}	0.232^{m}
QL33 x L18	0.10^{k}	263.33^{g}	63.33^{h}	19.89^{ad}	252.057^{g}	0.660^{d}
TX640 x L19	0.36^{d}	220.33^{l}	68.33^{c}	17.11^{as}	287.145^{g}	0.389^{j}
QL33 x L19	0.26^{d}	210.00^{m}	62.67^{h}	14.87^{ay}	242.467^{g}	0.359^{j}
TX640 x L20	0.32^{d}	270.00^{g}	62.33^{h}	16.74^{av}	154.967^{g}	0.259^{l}
QL33 x L20	0.26^{d}	186.67^{n}	65.00^{g}	20.10^{x}	297.89^{g}	0.232^{m}
TX640 x L21	0.26^{d}	320.00^{a}	63.67^{g}	17.26^{ap}	91.813^{g}	0.715^{c}
QL33 x L21	0.10^{l}	233.33^{l}	62.00^{h}	25.05^{e}	212.557^{g}	0.660^{d}
TX640 x L22	0.26^{d}	250.00^{i}	58.67^{l}	18.16^{am}	299.3^{h}	0.159^{n}
QL33 x L22	0.10^{m}	236.67^{k}	61.00^{i}	16.96^{at}	181.077^{h}	0.460^{h}
TX640 x L23	0.42^{c}	246.67^{j}	61.00^{i}	17.21^{aq}	208.35^{g}	0.577^{f}
QL33 x L23	0.26^{d}	243.33^{k}	66.67^{e}	25.08^{d}	265.24^{i}	0.501^{g}
TX640 x L24	0.36^{d}	253.33^{h}	65.00^{g}	18.29^{al}	58.103^{j}	0.810^{a}
QL33 x L24	0.42^{c}	223.33^{l}	63.33^{h}	21.89^{l}	226.01^{k}	0.401^{i}
TX640 x L25	0.15^{g}	245.00^{k}	61.00^{i}	21.19^{q}	270.795^{l}	0.301^{k}
QL33 x L25	0.20^{d}	280.00^{f}	65.33^{g}	17.98^{an}	192.223^{m}	0.259^{l}
GRAND MEAN	0.27	253.69	64.10	20.46	219.36	0.48
LSD	0.31	66.93	7.24	10.51	165.72	0.39

Crosses with the same letter are not different.

Eleven crosses were significantly different for plant height in planting date two. Among them, five were negative and six were positive. Cross L20xQL33 had the highest negative SCA and the cross L19xTX640 had the lowest. L24xTX640 had the highest positive SCA and L17xQL33 had the lowest. Ten crosses had significant SCA effects for days to 50% flowering in planting date two, three were negative and seven were positive. L25xTX640 had the highest negative SCA and L11xQL33 had the lowest. L11xTX640 had the highest positive SCA and L2xTX640 had the lowest. Three crosses displayed significant SCA effect for grains yield per panicle. Among these two were negative and one was positive. L19xTX640 had the highest negative SCA value, and L7xQL33 had the lowest negative SCA value. Nine crosses had significant SCA effects for sorghum midge damage. Of these, five were negative and four were positive. The highest negative SCA value was seen for L18xQL33 and the lowest for L2xTX640. The highest positive SCA value was seen in L19xTX640 and the lowest was seen in L4xTX640 (Table 9).

Table 9: Specific combining ability of crosses in the planting date two.

Genotypes	Plant Height	50% Flowering	1000_seed weight	Grain Yield	Midge Damages
TX640 x L1	-1.51^{ns}	-0.67^{ns}	-0.38^{ns}	-2.44^{ns}	0.2146^{ns}
QL33 x L1	1.043^{ns}	0.61^{ns}	0.45^{ns}	-1.11^{ns}	-0.2115^{ns}
TX640 x L2	-0.85^{ns}	1.9*	-1.97^{ns}	-10.09^{ns}	-0.2363*
QL33 x L2	1.709^{ns}	-1.15^{ns}	1.15^{ns}	17.00^{ns}	0.1500^{ns}
TX640 x L3	-9.85^{ns}	1.1^{ns}	-4.11^{ns}	-63.10^{ns}	0.0267^{ns}
QL33 x L3	7.709^{ns}	-0.62^{ns}	2.57^{ns}	52.34^{ns}	-0.0253^{ns}
TX640 x L4	-4.01^{ns}	-0.5^{ns}	2.41^{ns}	-75.20^{ns}	0.2522*
QL33 x L4	3.543^{ns}	0.451^{ns}	-2.34^{ns}	71.64^{ns}	-0.2491*
TX640 x L5	2.653^{ns}	0.5^{ns}	-1.28^{ns}	-59.15^{ns}	0.0157
QL33 x L5	-3.12	-0.55^{ns}	1.35^{ns}	55.59^{ns}	-0.0126^{ns}
TX640 x L6	0.986^{ns}	-0.33^{ns}	0.06^{ns}	43.19^{ns}	-0.2569*
QL33 x L6	-1.46^{ns}	0.284^{ns}	0.01^{ns}	-46.75^{ns}	0.2600*
TX640 x L7	4.319^{ns}	0.167^{ns}	-1.16^{ns}	80.25^{ns}	-0.2595*
QL33 x L7	-4.79^{ns}	-0.22^{ns}	1.23^{ns}	-83.80*	0.2626*
TX640 x L8	11.82^{ns}	0.834^{ns}	-0.70^{ns}	-56.16^{ns}	0.0764^{ns}
QL33 x L8	-12.3^{ns}	-0.88^{ns}	0.77^{ns}	52.60^{ns}	-0.0733^{ns}
TX640 x L9	-34**	-0.33^{ns}	-2.38^{ns}	-43.07^{ns}	0.0074^{ns}
QL33 x L9	33.54**	0.284^{ns}	2.45^{ns}	40.30^{ns}	0.0078^{ns}
TX640 x L10	10.99^{ns}	-1.17^{ns}	3.77^{ns}	-5.07^{ns}	0.0268^{ns}
QL33 x L10	-11.5^{ns}	1.118^{ns}	-3.70^{ns}	1.51^{ns}	-0.0237^{ns}
TX640 x L11	-9.85^{ns}	2^{ns}	4.05^{ns}	79.04^{ns}	0.1199^{ns}
QL33 x L11	9.376^{ns}	-2.05*	-3.98^{ns}	-82.60^{ns}	-0.1168^{ns}
TX640 x L12	-4.85^{ns}	3**	-8.33**	-49.33^{ns}	0.0190^{ns}
QL33 x L12	4.376^{ns}	-0.72^{ns}	2.37^{ns}	40.55^{ns}	-0.0245^{ns}
TX640 x L13	1.819^{ns}	-2.33*	1.72^{ns}	15.18^{ns}	-0.0051^{ns}
QL33 x L13	-2.29^{ns}	2.284*	-1.65^{ns}	-18.74^{ns}	0.0082^{ns}
TX640 x L14	0.986^{ns}	0.834^{ns}	-1.36^{ns}	43.35^{ns}	-0.0588^{ns}
QL33 x L14	-1.46^{ns}	-0.88^{ns}	1.43^{ns}	-46.91^{ns}	0.0619^{ns}
TX640 x L15	-3.18^{ns}	0.5^{ns}	-2.39^{ns}	-23.10^{ns}	0.0403^{ns}
QL33 x L15	2.709^{ns}	-0.55^{ns}	2.46^{ns}	19.55^{ns}	-0.0372^{ns}
TX640 x L16	-11.3^{ns}	1.3^{ns}	1.22^{ns}	47.76^{ns}	0.0528^{ns}
QL33 x L16	8.709^{ns}	-0.75^{ns}	-0.98^{ns}	-21.56^{ns}	-0.0427^{ns}
TX640 x L17	17.65*	-1^{ns}	-0.76^{ns}	-10.35^{ns}	-0.1592^{ns}
QL33 x L17	-18.1*	0.951^{ns}	0.83^{ns}	-8.77^{ns}	0.1623^{ns}
TX640 x L18	-5.68^{ns}	-0.83^{ns}	0.80^{ns}	18.91^{ns}	0.2730*
QL33 x L18	5.209^{ns}	0.784^{ns}	-0.73^{ns}	-22.47^{ns}	-0.2699**
TX640 x L19	-14.8^{ns}	2.9*	0.61^{ns}	-91.80*	0.296**
QL33 x L19	11.04^{ns}	-1.82^{ns}	-0.57^{ns}	54.71^{ns}	-0.1169^{ns}
TX640 x L20	28.49**	-0.9^{ns}	-1.20^{ns}	-17.53^{ns}	-0.0471
QL33 x L20	-45.6**	1.051^{ns}	2.23^{ns}	1.99^{ns}	0.0897^{ns}
TX640 x L21	3.486^{ns}	-2.33*	-1.54^{ns}	48.38ns	-0.023^{ns}
QL33 x L21	-3.96^{ns}	2.284*	1.61^{ns}	-51.93^{ns}	0.0261^{ns}
TX640 x L22	11.82	0.834^{ns}	2.26^{ns}	-27.13^{ns}	-0.0219^{ns}
QL33 x L22	-12.3^{ns}	-0.88^{ns}	-2.19^{ns}	23.57^{ns}	0.0249^{ns}
TX640 x L23	-29.8**	1^{ns}	1.41^{ns}	-3.12^{ns}	-0.0248^{ns}

QL33 x L23	29.38**	-1.05^{ns}	-1.34^{ns}	-0.43^{ns}	0.0279^{ns}
TX640 x L24	57.65**	-0.25^{ns}	8.63**	121.46**	-0.2067^{ns}
QL33 x L24	-16.5^{ns}	0.368^{ns}	-3.28^{ns}	-16.37^{ns}	0.0508^{ns}
TX640 x L25	-19*	-2.67**	0.63^{ns}	60.89^{ns}	-0.0051^{ns}
QL33 x L25	18.54*	2.618*	-0.56^{ns}	-64.45^{ns}	0.0082^{ns}
SE	9.02	1.03	2.14	42.60	0.10

^{ns}= not significant; *= significant at 5%; **= significant at 1%.

L20xTX640 was the tallest hybrid (243.33 cm) and L20xQL33 (160 cm) was the shortest. Days to 50% flowering ranged from 68.33 DAP to 61.66 DAP. The earliest maturing hybrids were L21xTX640 and L24xQL33, while the latest maturing was L25xQL33. Yields ranged from 426.04 gram/cm2 to 39.08 gram/cm2. L18xTX640 had the highest yield while L11xQL33 had the lowest. Midge damage ranged from 0.84% to 0.15%. L19xTX640 and L7xQL33 had the highest damage while L4xQL33 had the lowest (Table 10).

Table 10: Mean performance of crosses in the planting date two.

Genotypes	S_vigor	Plant Height (cm)	50% Flowering (DAP)	1000_seed weight (g)	Grain Yield (g/m^2)	Midge Damages
TX640 x L1	0.42^{b}	190^{o}	65^{j}	24.10^{s}	206.08^{m}	0.725^{b}
QL33 x L1	0.48^{a}	183.33^{p}	65.333^{j}	26.27^{o}	127.97^{r}	0.359^{b}
TX640 x L2	0.48^{a}	240^{c}	68^{c}	26.39^{o}	185.34^{m}	0.349^{b}
QL33 x L2	0.36^{b}	233.33^{e}	64^{l}	30.85^{g}	132.99^{q}	0.796^{b}
TX640 x L3	0.48^{a}	175^{r}	66^{i}	20.48^{ac}	144.79^{q}	0.451^{b}
QL33 x L3	0.48^{a}	183.33^{p}	63.333^{n}	28.51^{m}	180.79^{n}	0.460^{b}
TX640 x L4	0.48^{a}	230^{e}	67.667^{d}	19.40^{ae}	278.97^{j}	0.599^{b}
QL33 x L4	0.48^{a}	228.33^{f}	67.667^{d}	16.00^{ah}	346.37^{e}	0.159^{b}
TX640 x L5	0.48^{a}	230^{e}	66.333^{h}	22.17^{z}	134.31^{q}	0.619^{b}
QL33 x L5	0.48^{a}	215^{i}	64.333^{k}	26.14^{o}	169.61^{o}	0.651^{b}
TX640 x L6	0.42^{b}	231.67^{e}	66.667^{g}	29.66^{k}	323.71^{g}	0.200^{b}
QL33 x L6	0.48^{a}	220^{g}	66.333^{h}	30.96^{f}	154.32^{p}	0.778^{b}
TX640 x L7	0.32^{b}	245^{a}	67^{f}	26.04^{o}	355.11^{d}	0.259^{b}
QL33 x L7	0.48^{a}	226.67^{f}	65.667^{j}	29.78^{i}	111.6^{s}	0.842^{a}
TX640 x L8	0.36^{b}	241.67^{c}	67^{f}	28.34^{n}	165.08^{o}	0.666^{a}
QL33 x L8	0.36^{b}	208.33^{j}	64.333^{k}	31.15^{e}	194.4^{m}	0.577^{b}
TX640 x L9	0.48^{a}	181.67^{p}	67^{f}	19.44^{ad}	121.83^{r}	0.541^{b}
QL33 x L9	0.48^{a}	240^{c}	66.667^{g}	25.62^{o}	125.76^{r}	0.602^{b}
TX640 x L10	0.26^{c}	233.33^{e}	62.667^{o}	30.39^{h}	156.97^{o}	0.582^{b}
QL33 x L10	0.42^{b}	201.67^{m}	64^{l}	24.26^{q}	84.103^{u}	0.592^{b}
TX640 x L11	0.48^{a}	180^{q}	69^{a}	32.01^{c}	280.17^{j}	0.477^{b}
QL33 x L11	0.48^{a}	190^{o}	64^{l}	25.32^{o}	39.08^{v}	0.301^{c}
TX640 x L12	0.48^{a}	230^{e}	69^{a}	19.12^{ag}	151.85^{p}	0.602^{a}
QL33 x L12	0.42^{b}	230^{e}	64.333^{k}	31.16^{d}	162.3^{o}	0.619^{b}
TX640 x L13	0.42^{b}	220^{g}	64.333^{k}	26.43^{o}	329.7^{f}	0.259^{b}
QL33 x L13	0.48^{a}	206.67^{k}	68^{c}	24.41^{p}	216.33^{l}	0.333^{b}
TX640 x L14	0.32^{b}	215^{i}	65.667^{j}	24.06^{t}	289.73^{i}	0.460^{b}
QL33 x L14	0.42^{b}	203.33^{l}	63^{n}	28.18^{o}	120.02^{r}	0.641^{b}
TX640 x L15	0.48^{a}	240^{c}	65.667^{j}	27.49^{o}	237.73^{k}	0.619^{b}
QL33 x L15	0.42^{b}	236.67^{e}	63.667^{m}	33.69^{a}	200.94^{m}	0.602^{b}
TX640 x L16	0.48^{a}	182.5^{p}	66^{i}	23.48^{w}	241.46^{k}	0.627^{c}
QL33 x L16	0.48^{a}	193.33^{n}	63^{n}	22.63^{x}	92.673^{t}	0.592^{b}

TX640 x L17	0.42[b]	208.33[j]	65.667[j]	25.80[o]	168.28[o]	0.433[b]
QL33 x L17	0.48[a]	163.33[t]	66.667[g]	28.73[l]	90.415[t]	0.815[b]
TX640 x L18	0.32[b]	236.67[e]	66[i]	26.75[o]	426.04[a]	0.741[b]
QL33 x L18	0.36[b]	238.33[d]	66.667[g]	26.57[o]	305.2[h]	0.259[b]
TX640 x L19	0.48[a]	185[o]	68[c]	25.12[o]	156.38[p]	0.845[b]
QL33 x L19	0.42[b]	201.67[m]	62.333[p]	25.28[o]	223.45[k]	0.492[b]
TX640 x L20	0.26[d]	243.33[b]	67[f]	28.12[o]	273.77[j]	0.541[b]
QL33 x L20	0.48[a]	160[t]	68[c]	32.90[b]	213.86[l]	0.738[c]
TX640 x L21	0.48[a]	233.33[e]	61.667[r]	22.44[y]	277.22[j]	0.592[b]
QL33 x L21	0.32[b]	216.67[h]	65.333[j]	26.94[o]	97.46[t]	0.70[b]
TX640 x L22	0.42[b]	236.67[e]	66.333[h]	24.26[r]	138.53[q]	0.534[b]
QL33 x L22	0.26[e]	203.33[l]	63.667[m]	21.15[ab]	109.79[s]	0.641[b]
TX640 x L23	0.48[a]	188.33[o]	67.333[e]	26.91[o]	212.85[l]	0.501[b]
QL33 x L23	0.32[b]	238.33[d]	64.333[k]	25.50[o]	136.09[q]	0.615[a]
TX640 x L24	0.48[a]	250[a]	62[q]	29.72[j]	392.42[b]	0.301[b]
QL33 x L24	0.42[b]	166.67[s]	61.667[r]	19.15[af]	175.13[n]	0.619[b]
TX640 x L25	0.36[b]	201.67[m]	64[l]	23.57[v]	383.12[c]	0.518[b]
QL33 x L25	0.48[a]	230[e]	68.333[b]	23.71[u]	178.32[n]	0.592[b]
GRAND MEAN	0.42	214.30	65.42	25.90	201.64	0.55
LSD	0.20	36.62	4.19	9.09	172.97	0.44

Crosses with the same letter are not different.

DISCUSSION

Combining ability provides criteria to select parents for hybridization as suggested by Harer & Bapat (1982). In this study, negative GCA for plant height, days to 50% flowering and midge damage were desirable while positive GCA for grains yield and 1000 seeds weight were desirable. In the first planting, L3, L10, L13, L14, L19, L20, L22 and L25 displayed desirable negative GCA effects for midge damage. Based on this, these lines were classified as good general combiners for sorghum midge resistance. However, L10, L14, L19, and L22 did not exhibit high resistance to midge damage, despite having high GCA values. L3, L13, L20 and L25 recorded lowest mean values (less than 0.30) for midge damage and are the best lines to use to improve sorghum for midge resistance for early planting. In the second planting date, L3, L4, L6, L11, L13 and L18 demonstrated desirable, significant GCA effects for midge damage. Among these lines, L13, L4 and L11 actually had the lowest midge damage rating (less than 0.40) and were classified as the best lines for sorghum midge resistance. Resistance to sorghum midge over different environments was documented (Sharma et al., 1993, Sharma et al., 2004). In addition to the good general combining ability for midge damage, some lines demonstrated good general combining ability for some of the other traits. Thus, in the first planting date, L13 was a good general combiner for dwarf structure, high yield and earliness; L22 was a good general combiner for yield and shortness; L14 for earliness and shortness and L19 showed good general combinability for yield. In the second planting date, all the lines which were good general combiners for resistance to sorghum midge were also good general combiners for yield increase except L3 and L11. The line L3 was good general combiner for earliness and dwarf structure; L11 was a general good general combiner for dwarf structure. Since these lines are good general combiners for some yield related traits, they may be of great importance in a sorghum breeding program where the objectives are to incorporate midge resistance and yield related traits. Good general combining ability for yield and yield related traits has been documented by Tadesse et al., (2008), and Prasuna Rani (2012). Prakash et al., (2010); and Kanawade et al., (2001) identified sorghum parental lines as good general combiners for earliness based on negative GCA effects for days to 50% and for tall plants. Badiru (2012) identified good general combiners for earliness and shortness based on negative GCA effects of these characters.

Marilia et al., (2001) stated that specific combining ability (SCA) effects of hybrids alone has limited value for choosing parents in a breeding program, and must be used in combination with other parameters such GCA of the respective parents and actual performance of the hybrids. However, SCA is important to identify parents of opposite heterotic types which should be improved within and not across heterotic groups. The hybrid combinations with significant mean performance, significant and desirable heterosis and significant desirable SCA estimates and which involve at least one of the parents with high GCA would likely enhance the concentration of favorable alleles and this is what a breeder desires to improve a trait (Kenga et al., 2004). However, enhancing favorable alleles should be done separately on opposite sides of heterotic groups. In this investigation, good specific combiners were identified based on crosses mean value and GCA effects of the parents involved in the cross. Negative significant SCA effects for plant height, days to 50% flowering and midge damage rating are desirable while positive significant SCA for 1000 seeds weight and grain yields per plant is desirable. The results for the specific combining ability of the hybrids showed that L13xTX640 and L14xQL33 in the first planting date; L4xQL33, L6xTX640, L18xQL33 in the second planting date are good specific combiners for midge resistance. These hybrids are very promising and are worthy to be used in further sorghum breeding programs for resistance to sorghum midge. This is in agreement with several findings for midge resistance in sorghum (Sharma et al., 2004), Ratnadass et al., (2002), Sharma et al., (1993). Some crosses had good specific combining ability for yield and yield related traits in this study. The crosses L12xTX640 and L2xQL33 in the first planting date and L24xTX640 in the second were good specific combiners for grain yield. Crosses L3xTX640 in the first planting date, L21xTX640 and L25xTX640 in the second planting date were found good specific combiners for earliness. The crosses L7xQL33, L9xTX640, L21xQL33, L25xTX640 were good specific combiners for plant height in the second planting date. Many authors reported similar results in sorghum (Kanawade et al., 2001), Gaikawad et al., (2002) and Ghorade et al., (2014). Makanda et al., (2010) identified good specific combiners for grain yield of sorghum by investigating combining ability in Mozambique, South Africa and Zimbabwe. The variance due to general combining ability (σ^2gca) was less than that of specific combining ability (σ^2sca) for all the traits under study in both planting dates as well as across planting dates showing the predominance of non-additive gene action. This was confirmed by the ratio σ^2gca/ σ^2sca being less than one. Therefore, because non-additive effects like epistasis and over dominance as well as dominance are predominant, it would be useful to use recurrent selection to increase GCA of inbred lines in separate heterotic groups as long as testers are used to select hybrids with good SCA to advance. Lines L7, L 12, L 17, L 18, and L 24 are opposite heterotic types from TX640 and L2, L4 and L7 are opposite to QL 33. Heterosis breeding will be a better choice for improving these traits. Non-additive gene action for these traits based on the GCA and SCA variance has been previously reported in sorghum (Premalatha *et al*. 2006). Similar results were obtained by Tariq *et al*., (2014) who concluded that selection of superior plants for these traits in the later generation would be advantageous. Comparable results were also reported for aluminum tolerance in sorghum (Menezes *et al*., 2014).

Significant and desirable GCA effects were observed for plant height, days to 50% flowering, grain yield per panicle and midge damage. This indicates the presence of additive gene effects in expression of these traits. Kanga *et al.,* (2004) reported the presence of both additive and non-additive gene effects for yield and yield related traits. Additive and non-additive gene action controlling stem brix and associated traits in sorghum were also reported (Makanda *et al.,* 2009). However, additive gene action has been documented for fresh and dry yield in forage sorghum, while non-additive gene effects were predominant for most of the quality traits (Tariq *et al*., 2014). Based on General and Specific Combining Ability, an investigation on the inheritance of resistance to sorghum midge in a set of diallel crosses revealed the presence of both additive and non-additive gene action for resistance to sorghum midge (Agrawal *et al*., 1988). Additive gene action for midge resistance was documented in sorghum (Ratnadass *et al.,* 2002). However, predominance of only additive gene action in the expression of resistance to sorghum midge has also been reported (Sharma *et al*., 1996, Sharma *et al.,* 2000).

CONCLUSSION

In Niger, there is potential for breeding sorghum for midge resistance using land race derived inbred lines. Based on GCA and SCA effects, some land race derived lines and crosses have been identified with resistance to sorghum midge as well as other desirable yield related characters. These lines could be used as parental materials and play an important role in breeding sorghum for midge resistance in Niger. Moreover, general and specific combining ability were found to be significant for midge resistance and other yield related characters. Variances due to SCA were higher in magnitude than GCA for midge resistance and yield related traits. Thus both additive and non-additive gene actions were found to play an important role in controlling these traits with non-additive being more important. On the other hand, based on mean performance and SCA, the crosses L13xTX640 and L14xQL33 in the first planting date; L4xQL33, L6xTX640, L18xQL33 were found to be the best midge resistant hybrids. The crosses L12xTX640 and L2xQL33 in the first planting date and L24xTX640 in the second were found to be the best hybrids for grain yield.

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