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RESEARCH PAPER

Impact of midge damage on new sorghum lines performance in eastern part of Burkina Faso

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Abstract

Sorghum is the most grown cereal crop in Burkina Faso, however, its production is low due to biotic constraints. This investigation was conducted in a midge hot-spot site (Kouaré) and a not hot-spot site (Kamboinsé). The study objective was to determine impact of this insect [(*Stenodiplosis*= *Contarinia*) *sorghicola* (Coquillet, 1898)] on the performance of newly developed guinea sorghum lines in Burkina Faso. Field trials were conducted over two years and twenty sorghum lines including checks (Kapelga, ICSV 1049) were evaluated in a randomized complete bloc design. Agro-morphological parameters and midge damage were evaluated in all sites with emphasis on grain yield and midge damage in order of importance to determine lines' performance and level of tolerance to midge. According to heading characteristics, seven lines (Kouria, PR3009B, ICSB 176003, Fambe B, Lata//Grin-9-14-1-1, ICSB 176008, 12B) were well adapted to the sudano-sahelian zone and majority of tested lines were susceptible to midge with a yield loss ranged from 50% to 80% compared to yield in not hot spot site. Only, five lines (ICSB 176002, Kapelga, Kouria, Lata//DouaG-4-27-1-1 and Lata//Grin-9-14-1-1) performed well in a midge hot-spot site. These lines exhibited a high level of tolerance to midge damage and could be promoted for large cultivation in the eastern part of the country to mitigate midge impact.

Key words: Adaptation, Sorghum lines, midge damage, tolerance, Burkina Faso

Introduction

Sorghum is the first cereal grown in Burkina Faso and constitutes a staple food crop for rural population (Bal, 2005). Its production has been estimated to 1871792 tons on about 1907650 ha, which represents 37.89% of total cereals production (MAAH, 2019). However, the production remains weak with a low yield below 1 t/ha on farmer's fields condition. CNRST (2002) reported a yield of 887 kg/ha and MAAH (2019) reported 982 kg/ha. This low yielding is due to biotic and abiotic constraints that reduced considerably its production. Biotics constraints are essentially diseases, weeds (striga) and insects' pests and among them, sorghum midge [(*Stenodiplosis* = *Contarinia) sorghicola* (Coquillet, 1898)], known as the most damaging pest on sorghum in the world (Young and Teetes, 1997). It constitutes the main constraint of sorghum production in the southern, centre-western and eastern part of Burkina (Bonzi, 1979; Dakouo, 1996) inducing grain yield loss up to 33% (Dakouo, 1996). According to the genetic potential of this crop, its yield could be improved once constraints effects are lessened. Therefore, to enhance sorghum productivity in theses areas (southern, centre-western and eastern part of country), midge tolerance trait should be taken into account in breeding activities in order to release varieties that could cope with the insect effect. In fact, in this study, newly developed guinea sorghum varieties and well adapted to either sudanian or sudano-sahelian zones (Ouédraogo et al., 2021) of the country were exposed to midge under midge infestation hot-spot in order to determine their status to midge damage. So, after the agronomic performance and adaptability study of these lines (Ouédraogo et al., 2021), it was necessary to determine their level of tolerance or susceptibility to midge in infested hot-spot in order to guide farmers about varieties that could cope with the insect. Therefore, a particular investigation was done by assessing theses lines in midge infestation hotspot to determine their reaction to the insect.

Materials and Methods

Study locations

The field studies were conducted in two stations (Kamboinsé and Kouaré) of the Institute of Environment and Agricultural research (INERA) during 2020 (867 mm at Fada and 908.6 mm at Kamboinsé) and 2021(767.7 mm at Fada and 749.9 mm at Kamboinsé) rainy seasons from June to October. The locations were chosen based on midge infestations hotspot. Kamboinse is a not hotspot midge infestation site located at Ouagadougou in the centre of the transition zone (sudano-sahelian) whereas Kouaré, a midge infestation hotspot site is located at Fada in Eastern part of the transition zone. During the first year (2020), lines were planting 07 July at Kamboinsé and 10 July at Fada. During the second year, lines were planting 12 July at Kamboinsé and 15 July at Fada.

Methodology

Experimental design was a randomized complete bloc with genotypes as studied factors, four replications with the twenty lines. At each location, plot area was 12.8 m^2, including four rows of 4 m length. Distance between rows was 0.8 m and 0.4 m between hills on each row with a total of 10 hills per row. Between 4 and 8 seeds were sown by hand in each hill, in 3-cm deep holes in all four locations. Seeds were sown only after receiving at least 20 mm rainfall. Two weeks after sowing, plants were thinned to two plants per hill.

Material

Twenty sorghum lines including checks (Kapelga, ICSV 1049) were evaluated in the two different locations. Majority (16) of lines where from guinea race except ICSV 1049, PR3009B (Caudatum) AND 014-SB-EPDU-1004 and 12B (Caudatum-Guinea). Table 1 summarise the lines status.

Table 1: List of guinea lines involved in the evaluation

No	GENOTYPES	Line race	Line statut
1	014-SB-EPDU-1004	Caudatum-Guinea	Tested line
2	12B	Caudatum-Guinea	Tested line
3	ICSB 176002	Guinea	Tested line
4	ICSB 176003	Guinea	Tested line
5	ICSB 176016	Guinea	Tested line
6	ICSB 176019	Guinea	Tested line
7	ICSB 176029	Guinea	Tested line
8	ICSB 176017	Guinea	Tested line
9	ICSB 176005	Guinea	Tested line
10	ICSB 176006	Guinea	Tested line
11	ICSB 176008	Guinea	Tested line
12	Fambe B	Guinea	Tested line
13	Lata//DouaG-4-27-1-1	Guinea	Tested line
14	Lata//Grin-9-14-1-1	Guinea	Tested line
15	Lata//Ridb-3-9-1-1	Guinea	Tested line
16	ICSV 166001	Guinea	Tested line
17	PR3009B	Caudatum	Tested line
18	Kapelga	Guinea	Check
19	Kouria	Guinea	Tested line
20	ICSV1049	Caudatum	Check

Data collection and analysis

Data collected included days to 50% heading (HD), empty panicle number (EPN), panicles weight (PW), grain weight (GW), midge damage (MD) and grain yield (GY). Grain yield was measured in tons per hectare adjusted to grain moisture content at 12%.

Days to 50% heading was recorded by counting the number of days from planting to when 50% of the plants in a plot headed. Panicle weight (kg) and grain weight (kg) were recorded determined by weighing. Empty panicles number was recorded by counting the number of empty panicles after harvest. Midge damage was a visual assessment (scoring from 1-9) as loss of grain yield in five panicles expressed as a percentage (1: 1-10% of yield loss; 2:11-20% of yield loss; 3: 21-30% of yield loss; 4: 31-40% of yield loss; 5: 41-50% of yield loss; 6: 51-60% of yield loss; 7: 61- 70% of yield loss; 8: 71-80% of yield loss; 9: > 80% of yield loss).

Analysis of the effect of location, genotypes, and their interactions on response variables was computed with SAS 9.1 software. Means were calculated from collected data and yield losses percentage were deduced for each variety.

Results

Analysis of variance

The analysis of variance across sites (environments), genotypes and interactions genotypes by sites were highly significant ($p < 0.001$) for all traits. Across years, it was only significantly different ($p < 0.001$) for heading parameter and the remaining trait (empty panicle number, panicles weight, grain weight, grain yield and midge damage) were not significantly different. Except, the heading dates, the coefficient of variation was large for the remaining studied traits (Table 2).

Table 2: Mean square of genotype, site, year and genotype by site interaction analysis for all traits

Source	df	HD	EPN	PW	GW	GY	MD
Year	1	851.51***	7.5ns	0.007ns	0.72ns	171345.5ns	0.00ns
Site	1	1881.80***	7191.52***	412.01***	219.74***	11253611.9***	864.61***
Rep	3	49.93ns	195.34ns	0.34ns	0.26ns	251562.1ns	3.21ns
Genotype	19	348.52***	149.97***	11.82***	3.52***	3262778.5***	5.82***
Genotype*Site	19	168.46***	374.34***	6.09***	2.92***	2510789.1***	5.5***
Error		32.03	193.75	1.41	0.65	580170.2	1.94
R-squ		0.59	0.32	0.66	0.66	0.58	0.67
CV (%)		7.30	124.66	36.64	49.18	47.72	51.55
F value		10.88	2.84	8.40	5.40	5.62	2.99
Pr>F		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

*** = highly significant; ns = not significant; HD = Heading date; EPN= Empty Panicle Number; PW= Panicle Weight; GW= Grain Weight; GY= Grain Yield; MD= Midge Damage

Significant different were found for all parameters studied and heading date which is an indicator of agro-climatic adaptation revealed that the earliest line headed around 67 days after planting (dap) (Kouria) while latest one headed around 84 dap (ICSB 176029). The majority of lines headed around 77 dap and among them. nine lines (12B. Fambe B, ICSV1049, ICSB 176003, ICSB 176016, ICSB 176008, Kapelga, Kouria and PR3009B) headed before 77 dap while the remaining (eleven lines) headed after 77 dap. Two lines (Kouria: 67 dap and PR3009B:71.2) headed earlier than the checks (Kapelga: 72.7 dap and ICSV 1049: 73.3 dap (Table 3).

Panicle and grain weight as yield parameters accounted importantly to grain yield while empty panicles number appeared to be a yield reduction factor. The overall mean of empty panicles number was 11.2 (Year 1= 11.7 and year 2= 11.0) and it ranged from 4.6 (ICSB 176005) to 27.3 (ICSB 176029). Twelve lines (ICSB 176005, ICSB 176002, ICSB 176008, ICSV1049, Kapelga, 12B, Fambe B, Lata//DouaG-4-27-1-1, ICSB 176003, PR3009B, ICSB 176006 and ICSB 176016) including the checks had empty panicle number less than 10 while the eight lines remaining (014-SB-EPDU-1004, Kouria, Lata//Grin-9-14-1-1, Lata//Ridb-3-9-1-1, ND07 e21(17x30)F2-6-v, ICSB 176019, ICSB 176017 and ICSB 176029) exhibited a huge number of empty panicles ranging from 10.5 up to 27.3. The study showed that greater the panicle and grain weighted, greater is the grain yield. In contrast to panicle and grain weight, the higher midge damage score resulted in lower grain yield (Table 3 and 4). The average midge damage was 2.7 but the damage score varied from 1 to 6.6 (table 4). At Kamboinsé, yield losses due to midge damage was not significant and all genotypes had less than 10% yield loss while at Kouaré, yield loss due to midge reached up to 60% (Table 4). Average yield was 1596.0 kg/ha and the lowest yield was 110.4 kg/ha (ICSB 176029) at Kouaré research station under severe midge pressure. The highest yield overall was obtained with Lata//Ridb-3-9-1-1 (4965.23 kg/ha) at Kamboinsé research station. Overall, yields were lower at Kouaré than Kamboinsé where highest yields were obtained (Table 4).

Table 3: Great mean of trait during evaluation across sites

Traits / Genotypes	HD	EPN	PW	GW	GY	MD
014-SB-EPDU-1004	81.2±7.7	10.5±13.6	3.9±2.5	2.0±1.6	1937.7±1426.7	1.9±1.7
12B	74.4±6.0	8.3±10.5	3.3±1.7	1.7±1.2	1629.1±995.3	3.5±2.7
Fambe B	75.5±5.2	8.9±9.0	3.5±1.7	1.7±1.2	1636.0±859.1	2.8±2.2
ICSV1049	73.3±2.8	7.4±7.8	3.3±1.4	1.9±1.1	1892.7±919.9	2.4±1.7
ICSB 176002	77.1±10.1	5.1±9.6	3.0±1.2	1.8±0.8	1793.2±690.5	2.7±2.1
ICSB 176003	73.4±4.7	9.3±9.0	2.5±0.9	1.2±0.6	1198.3±585.7	1.9±1.1
ICSB 176016	76.9±4.0	9.8±16.6	3.2±1.8	1.5±1.1	1460.3±999.8	3.6±2.9
ICSB 176019	83.8±8.4	17.1±15.1	2.0±1.0	0.9±0.8	848.2±689.3	3.4±3.0
ICSB 176029	84.1±9.0	27.3±31.8	2.3±1.2	1.0±0.9	885.4±779.8	3.4±2.4
ICSB 176017	83.3±9.8	22.7±26.4	2.1±1.3	0.9±1.0	840.5±782.1	3.3±2.8
ICSB 176005	79.7±8.4	4.6±7.1	2.4±1.3	1.2±0.8	1156.7±689.1	1.8±1.3
ICSB 176006	81.9±4.9	9.6±12.7	2.9±1.2	1.4±0.8	1453.7±783.2	2.4±1.4
ICSB 176008	75.7±7.3	5.1±5.9	3.5±1.9	1.9±1.3	1908.0±1256.9	3.5±2.7
Kapelga	72.7±8.2	7.9±15.4	2.7±1.5	1.6±1.2	1632.2±1004.7	2.5±2.3
Kouria	67.0±6.1	10.5±18.4	3.3±1.6	2.0±1.3	1906.8±876.1	2.8±2.9
Lata//DouaG-4-27-1-1	79.6±5.8	8.9±11.0	4.5±2.2	2.1±1.4	2053.5±1132.5	2.9±2.3
Lata//Grin-9-14-1-1	77.0±6.3	10.8±9.8	5.0±1.7	2.0±0.9	2081.8±703.6	2.1±1.4
Lata//Ridb-3-9-1-1	80.5±9.2	15.6±16.1	5.0±3.1	2.8±2.5	2511.9±1890.5	2.3±1.5
ND07 e21(17x30)F2-6-v	82.0±7.3	16.3±17.9	3.7±2.7	1.8±1.8	1791.0±1748.0	3.1±3.0
PR3009B	71.2±4.0	9.3±10.6	2.7±1.3	1.4±0.9	1302.8±665.8	2.1±1.7
Mean Year 1	79.1±7.4	11.7±10.3	3.2±1.2	1.6±1.2	1619.1±877.4	2.7±2.3
Mean Yaer 2	75.8±5.9	11.0±12.7	3.2±1.3	1.6±1.2	1572.8±657.9	2.7±2.3
Great Mean	77.5±4.9	11.2±9.8	3.2±1.2	1.6±1.2	1596.0±869.5	2.7±2.3

HD = Heading date; EPN= Empty Panicle Number; PW= Panicle Weight; GW= Grain Weight; GY= Grain Yield; MD= Midge Damage

The visualisation of box plot confirms data trend in the result tables. As revealed by the figure, for empty panicles number and midge damage, the medians are a higher in Fada than Kamboinsé (KBS). Empty panicle number at Fada had a median of 12 which is much closer to the 25th percentile of entry 9 than to the 75th percentile of entry 21 and there are outliers of about 40. For midge damage, the 25th percentile, the median and the 75th percentile overlap at Kamboinsé. There is only an important variation at Fada where the median of 4.5 is closer to the 25th percentile of 3.4 than to the 75th percentile of 5.4. There is a correlation between the empty panicle number and midge damage in all two sites. The strength among the two parameter is 0.523. For panicles weight and grain yield, the box plot shows a slight increase from Kouaré to Kamboinsé. At Kouaré, panicle weight ranged from 1.63 kg (25th percentile) to 3.04 kg (75th percentile) and grain yield ranged from 523.26 kg (25th percentile) to 1597.29 kg (75th percentile) while at Kamboinsé, panicle weight ranged from 2.80 kg (25th percentile) to 7.11 kg (75th percentile) and grain yield ranged from 1304.51 kg (25th percentile) to 3823.84 (75th percentile). There was a good correlation (0.913) between the panicle weight and grain yield in the two sites of study (Figure 1).

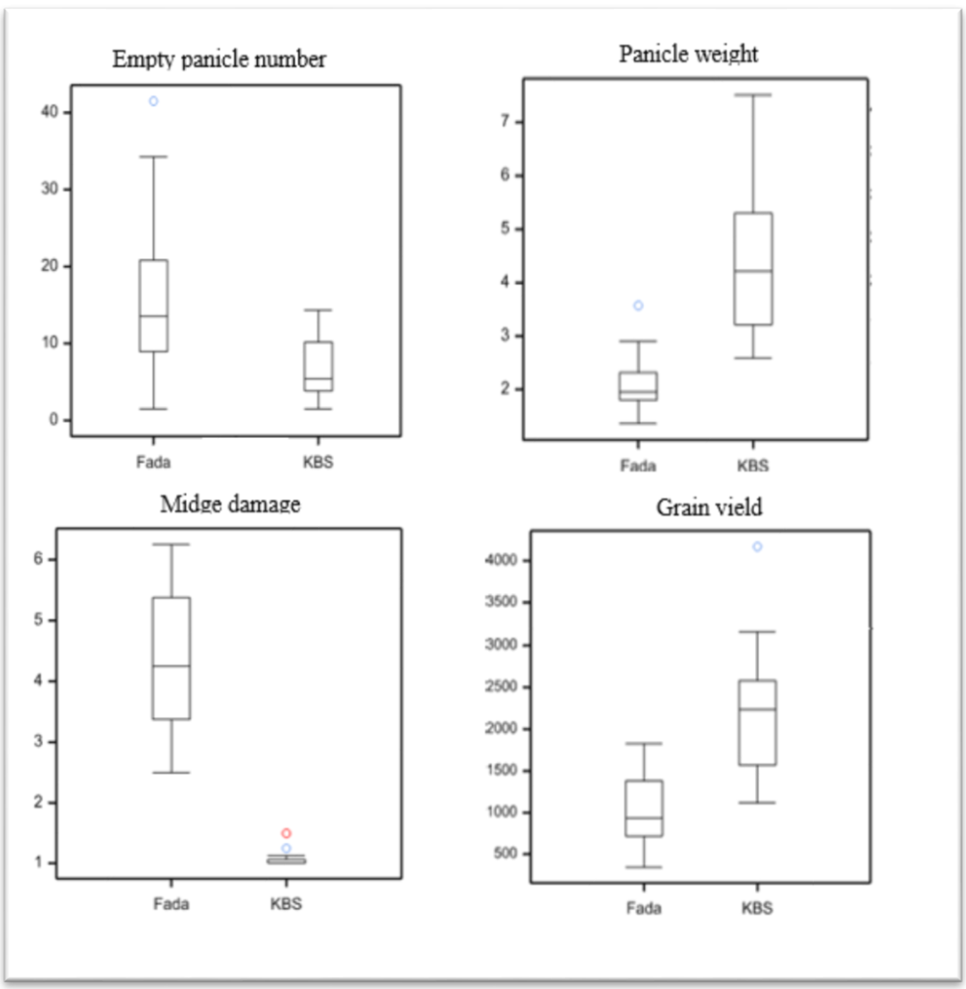
The analyses over years and sites demonstrated that line performances were similar to data illustrated by box plot. The lines performed poorer at Kouaré than Kamboinsé. At Kouaré, in the midge infestation hotspot, all lines had lower performance compared to not-hotspot sites (Kamboinsé). ICSB176029 (110.4 kg/ha: year 2) had lowest yield across years followed by ICSB176019 (308.8 kg/ha: year 1) at Kouaré. At Kamboinsé, low yielding lines were ICSB176017 (872 kg/ha recorded during year 1) and ICSB176003 (1104.5 kg/ha recorded during year 2). Two lines [ND07e21(17x30) F2-6-v (3703.4 kg/ha during year 1 and Lata//Ridb-3-9-1-1 (4865.2 kg/ha during year 2)] had better yield at Kamboinsé than in other sites while at Fada, high yielding lines were Lata//Grin-9-14-1-1 (1926 kg/ha during year 1) and Kapelga (1906.3 kg/ha 2 during year 2). The high yielding lines at Kouaré performed less that high yielding in the two other sites (Table 4).

The overall average damage was 2.17 across years and sites but the scores vary from 1 to 6.6 according to studied sites (Table 4) as showed in the box plot. The average midge score at Kamboinsé was 1.02 and it ranged from 0.9

to 1.5 during year 1 and year 2. The highest midge score was recorded at Kouaré where it reached up 6.6 during year 1 evaluation and ranged from 2 to 6.6. During year 2 evaluation, the means was 3.3 and the score ranged from 2.5 to 6.3. The data confirms that midge score was higher in the midge hotspot than in not hot spot site (Table 4).

Data on midge reaction revealed different levels of tolerance in evaluated lines. Overall, ICSB 176016 had higher midge damage score across sites (6.6 and 6.3 respectively during year 1 and year 2) and its yield was reduced up to 66.86% at Kouaré compared to not hot spot site (Kamboinsé). However, ND07 e21(17x30) F2-6-v was a line with great yield loss (81.51%) despite midge damage score (5.6 and 5.3 during year 1 and 2 respectively) below the high score (6.6) exhibited by ICSB 176016. In addition, nine other lines (ICSB 176029, PR3009B, Fambe B, ICSB 176008, ICSB 176017, ICSB 176019, 014-SB-EPDU-1004, 12B and Lata//Ridb-3-9-1-1) had more than 50% yield losses at Kouaré compared to Kamboinsé. Nine lines (Kapelga, Lata//Grin-9-14-1-1, ICSB 176005, ICSB 176002, ICSB 176003, ICSV1049, Lata//DouaG-4-27-1-1, ICSB 176006 and Kouria) including the checks had yield losses less than 50% in midge hot spot sites compared to yield in not hot spot site (Table 5). The yield gaps between lines were larger under heavy midge pressure site (Kouaré) than less midge pressure site (Kamboinsé).

At Kouaré, nine lines (014-SB-EPDU-1004, 12B, ICSB 176002, ICSB 176003, ICSB 176019, ICSB 176006, ICSB 176008, Kapelga, ND07 e21(17x30) F2-6-v) yielded less during year 1 evaluation than year 2 and in opposite, the remaining (eleven) lines yielded more during the first-year evaluation than the second year. Among those lines, five (12B, ICSB 176003, ICSB 176008, Kapelga and ND07 e21(17x30) F2-6-v) were recorded with a yield reduction beyond 50%. During year 1 evaluation, two lines (ICSB 176029 and ICSB 176017) among the eleventh remaining, performed well with a grain yield above 50% compared to yield performance during year 2 evaluation (Table 5).



KBS=Kamboinsé

Figure 1: Box plots comparing empty panicles number, panicles weight, grain yield and midge damage in different sites (Kamboinse and Fada)

Table 4: Grain yield mean and midge damage scores in the two sites of evaluation

Traits	**Grain Yield (GY)**				**Midge damage (MD)**			
Sites	**Kamboinsé**		**Fada**		**Kamboinsé**		**Fada**	
Genotypes / **Year**	2020	2021	2020	2021	2020	2021	2020	2021
014-SB-EPDU-1004	3657.7±847.2	2647.6±257.7	667.4±573.6	804.7±547.6	1±0	1±0	2.8±2.3	2.8±2.1
12B	2640.3±570.7	2374.0±406.2	657.9±145.1	1023.4±476.1	0.9±0	1±0	6±1,4	6±1.9
Fambe B	2148.8±527.7	2541.9±570.2	1047.8±698.4	921.9±130.7	1.2±0.5	1.3±0.5	4.7±2.5	4.3±2.5
ICSV1049	2589.6±253.9	2038.1±518.9	1457.4±1707.6	1429.7±174.2	1±0	0.9±0	3.7±1.5	3.8±1.5
ICSB 176002	2145.8±82.9	1821.3±234.0	1351.6±1114.0	1523.4±685.2	0.9±0	1.2±0.5	3.9±2.1	4.3±2.2
ICSB 176003	1771.6±834.9	1104.5±355.7	746.5±550.3	1253.9±268.5	0.9±0	0.9±0	3±0.9	2.8±0.9
ICSB 176016	2440.7±1228.2	1919.9±421.7	781±476.4	664.1±161.6	1±0	1±0	6.6±1.7	6.3±1.7
ICSB 176019	1380.7±799.7	1395.5±462.1	308.8±164.8	418±298.4	0.9±0	1±0	6.1±2.6	5.8±2.6
ICSB 176029	1100.2±365.0	1546.9±733.4	1146.4±891.7	110.4±51.0	1.5±1	1.5±1	5.4±2.1	5.3±2.1
ICSB 176017	872±771.3	1683.9±835.9	515.2±337.6	234.4±132.5	1±0	1±0	6±2.3	5.5±2.9
ICSB 176005	925.2±1097.0	1583.0±512.8	995.8±405.6	835.9±566.7	1±0	1±0	2±1.7	2.5±1.4
ICSB 176006	2060.2±879.0	1494.1±264.3	852.5±473.0	1132.8±894.2	1±0	1±0.5	3.8±0.5	3.8±1.3
ICSB 176008	3609.8±879.0	2031.3±131.1	391±172.3	1820.3±862.3	1±0	1±0	5.5±1.4	6±1.4
Kapelga	1346.1±1796.8	2246.1±391.3	1196.5±602.3	1906.3±395.4	0.9±0	0.9±0	3.6±2.7	4±2.7
Kouria	1813±248.7	3088.9±482.1	1615.6±712.3	1093.8±293.7	0.9±0	1±0	4.5±3.5	4.5±2.7
Lata//DouaG-4-27-1-1	2646.6±1647.1	2505.9±929.5	1544.9±798.7	1460.9±498.7	1.5±0.5	1±0	4.3±2.3	4.5±1.7
Lata//Grin-9-14-1-1	2907.3±321.2	1932.6±994.1	1926±566.5	1726.6±500.8	0.9±0	0.9±0	3.1±1.2	3.3±1.3
Lata//Ridb-3-9-1-1	3367.9±863.2	4965.2±858.2	1155.7±525.4	683.6±242.5	1±0	1±0	3.4±1.2	3.5±0.9
ND07 e21(17x30)F2-6-v	3703.4±2245.1	1923.8±381.1	380.4±413.5	660.2±287.4	1±0	0.9±0	5.6±3.3	5.3±3.3
PR3009B	1789.1±623.3	1900.4±243.9	1111±628.2	566.4±230.8	0.9±0	0.9±0	3±1,9	3.3±1.9
Mean SED	658.6	392.6	460.7	279.8	0.2	0.2	1.4	1.5
Mean LSD	1318.9	785.2	922.4	559.7	0.4	0.4	2.8	3

Table 5: Lines yield potential and status to midge damage

Genotypes	Grain yield over 2 years		Yield loss percentage (%)	Yield loss percentage (%) at Fada	Genotypes Status to midge
	Kamboinsé	Kouaré			
014-SB-EPDU-1004	3152.65	736.05	76.65	-20.5	Susceptible
12B	2507.15	840.65	66.47	-55.5	Susceptible
Fambe B	2345.35	984.85	58.01	12.0	Susceptible
ICSV1049	2313.85	1443.55	37.61	1.9	Tolerant
ICSB 176002	1983.55	1437.5	27.53	-12.7	Tolerant
ICSB 176003	1438.05	1000.2	30.45	-67.9	Tolerant
ICSB 176016	2180.3	722.55	66.86	14.96	Susceptible
ICSB 176019	1388.1	363.4	73.82	-35.36	Susceptible
ICSB 176029	1323.55	627.9	52.56	90.36	Susceptible
ICSB 176017	1277.95	374.8	70.67	54.50	Susceptible
ICSB 176005	1254.1	915.85	26.97	16.05	Tolerant
ICSB 176006	1777.15	992.65	44.14	-32.87	Tolerant
ICSB 176008	2820.55	1105.65	60.80	-365.5	Susceptible
Kapelga	1796.1	1551.4	13.62	-59.32	Tolerant
Kouria	2450.95	1354.7	44.73	32;29	Tolerant
Lata//DouaG-4-27-1-1	2576.25	1502.9	41.66	5.43	Tolerant
Lata//Grin-9-14-1-1	2419.95	1826.3	24.53	10	Tolerant
Lata//Ridb-3-9-1-1	4116.55	919.65	77.66	40	Susceptible
ND07 e21(17x30) F2-6-v	2813.6	520.3	81.51	-73.55	Susceptible
PR3009B	1844.75	838.7	54.57	49.01	Susceptible

Discussion

The significant mean squares for years, environments and genotypes for grain yield and midge damage indicated that climatic condition across years were variable, the environments were diverse and genotypes reacted differently from each other. The highly significant mean squares of environments for different traits revealed that the environments were diverse, which is in agreement with investigation conducted by Guinko (1984) indicating there are clearly different agro climatic zones in Burkina Faso. The two studied sites (Kamboinsé and Kouaré) are located in the same agro climatic zone, however, according to Dakouo et al., (2005) Kouaré is a midge hot spot site while Kamboinsé is a not hot spot site. Interaction factors such as genotypes by environment (sites) showed significant ($p< 0.001$) differences for all traits, indicating that genotypes interacted differently across environments. In fact, the presence of a biotic constraint (midge insect) with high pressure at Fada, explain why lines did not express their genetic potential such as at Kamboinsé.

Adaptation of lines to different growing areas was revealed through heading response and by comparison with the checks (Kapelga and ICSV 1049). Kapelga is one the most grown and well adapted varieties in all agro climatic zones whereas ICSV1049 is the most grown varieties in the northern part of the country. Kapelga and ICSV 1049 headed respectively around 72.7 and 73.3 dap. Only four others lines [Kouria (67 dap), PR3009B (71.2 dap), ICSB 176003 (73.4 dap) and 12B (74.4 dap)] headed before 75 dap and have almost the same heading date as the checks except Kouria. This indicated that those lines could reach physiological maturity around 105 to 110 dap which correspond to the end of rainy season (early October) in sudano-sahelian zone. However, the remaining lines (14) headed between 75 to 85 dap. This suggests that those lines could be cultivated in sudanian agro climatic zone due to lasting moisture up to end of October. Zongo (1991) and Barro (2010) indicated that sorghum landraces or local varieties with plant cycle of 120 days could be cultivated in sudanian climatic zone of Burkina Faso.

Box plot is a simple graphic method used to rapidly summarize and interpret tabular data. The box plot tool may also be used to visually and identify patterns that may otherwise be hidden in a data set (Tukey, 1977; Hoeglin et al., 1983). In this study, agronomic performance of evaluated lines was linked to midge damage across sites and the box plot analysis revealed a correlation between panicle weight and grain yield and between empty panicle number and midge damage. This indicates that more the panicles weighted, higher is the grain yield. In opposite, it also indicates that more the empty panicles number, higher is the midge damage score and lower is the grain yield. Yields were lower in the midge infestation hotspot (Kouaré) than in not hot spot site (Kamboinsé) due to high pressure of the insect. ICSB176029 (110.4 kg/ha) had the lowest yield with about 52.56% yield loss at Fada compared to yield at Kamboinsé. In this study, yield losses reached up to 81.51%

at Kouaré compared to Kamboinsé for the same variety. In fact, ICSB 176029 had a lower yield and was the line outlying concerning empty panicle number (41.55). This confirms the correlation between empty panicle number and midge damage. In this investigation, midge damage was greater than that reported by Dakouo et al. (2005) who showed that midge damage could reach 33% in the south, central west and the eastern zones of the country. It was also beyond the result (yield reduction of about 55.8% to 67.3%) reported by Kadi Kadi et al. (2005) in Niger. These lines are very susceptible to midge and could not be cultivated in midge infestation hotspot, however their yield potential may be highly appreciated in not-hot spot site.

Six (06) lines (ICSB 176002, Kapelga, ICSV 1049, Kouria, Lata//DouaG-4-27-1-1, Lata//Grin-9-14-1-1) including checks performed well in all sites with low midge damage. Kapelga had a reduction of about 13.62% at Kouaré compared to grain yield at Kamboinsé. The line (ICSB 176002) had less than 30% yield loss and the three lines (Kouria, Lata//DouaG-4-27-1-1, Lata//Grin-9-14-1-1) had yield reduction less than 50% compared to yield obtained in not hot spot sites. Lata//Grin-9-14-1-1 did not perform well during second years' evaluation at Fada due to a slight increase of midge damage on its panicle (year 1=3.1±1,2 and year 2= 3.3±1,3). Hamidou et al. (2020) found F1 sorghum hybrid with less than 30% midge damage. Dakouo et al. (2005) showed lines tolerant to midge damage with a yield reduction under 30%.

The analysis of variance revealed that midge damage was not significant across year, however, by taking into account the standard deviation, it appears some slight difference within years for the same line. In fact, during the first year of the trial, midge score was slightly high for those lines [014-SB-EPDU-1004 (year1=2.8±2.3 to 2.8±2.1 during year 2), ICSB 176003 (year 1= 3±0.9 to year 2= 2.8±0.9), ICSB 176019(year 1=6.1±2.6 to year 2=5.8±2.6), ND07 e21(17x30) F2-6-v (year 1= 5.6±3.3 to year 2=5.3±3.3)] than midge damage during the second year. This slight variation of midge pressure had an important impact on the performance of tested lines. The effect of these variation had caused significant yield reduction of those lines up to 50 %.

Conclusion

Nine (9) of the tested lines (including checks), well adapted to the sudano-sahelian zone were also tolerant to midge damage. The remaining lines with long plant cycle were not suitable for sudano-sahelian zone but could be adapted to agro climatic areas with long rainy season such as the sudanian zone of the country. Most of the remaining lines that headed after 75 dap were also susceptible to midge damage. Yield reduction due to midge damage was variable among lines and more susceptible lines loss within 50 to 80% of their yield potential compared to yield obtained in not-hotspot site. Among tolerant and adapted lines to sudano-sahelian zone, five lines (ICSB 176002, Kapelga, Kouria, Lata//DouaG-4-27-1-1, Lata//Grin-9-14-1-1) including a check performed well in all studied sites, particularly with low impact of midge damage. These lines exhibited a high level of tolerance to midge damage and could be promoted for large cultivation in the eastern part of the country to mitigate midge impact.

Conflict of Interest

The authors state that they have no conflict of interest

Author Contributions

The experiment conducted, Nofou Ouedraogo; Formal analysis, Nofou Ouedraogo; Investigation, Nofou Ouedraogo, Gilles Ibié Thio and Inoussa drabo; Resources, Vernon Gracen and Baloua Nebie; Supervision & Validation, Issouf Kouraogo, Armel Prisca Sawadogo; Writing – original draft, Nofou Ouedraogo; Writing – review & editing, Baloua Nebie.

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