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Choice of Grain Sorghum for Infesting, Laying Eggs and Damage Caused by the Sorghum Midge

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Abstract: Sorghum *Sorghum bicolor* has become a key food crop, animal forage, and a commercial raw material. Sorghum is a versatile crop, drought tolerant and modified to grow under rough environmental situations. Worldwide, the sorghum midge *Stenodiplosis sorghicola,* is a major pest of grain sorghum. Host plant resistance is the most important pest control measure in sorghum production. There is little information on the impact of sorghum midge pest on sorghum. This study assessed the sorghum midge preference for the host plant and its choice where to oviposit its eggs, and the damage caused to grain sorghum, under choice and no choice situations in the experimental field and in cages. A randomized complete block experimental design was used. Significantly ($P \leq 0.05$) fewer (1.67 – 3.27) adult female midge flies infested sorghum germplasm; AS21, AF28, GA08/103, IS8884, IESV94023SH, SEREDO, and SEKEDO compared to the midge susceptible GA010/010 and WAD checks. The same germplasm had less yield loss 14.91-58.79% and considered resistant to midge pest attack and damage. Germplasm GA010/010 was significantly ($P \leq 0.05$) most infested and damaged giving high yield loss of 60 – 99%, and more midge larvae presence of 46 – 66%, considered susceptible to midge. Sorghum midge mostly infested susceptible sorghum germplasm on which it laid eggs compared to resistant ones. High midge pest pressure caused more damage to grain sorghum, irrespective of host resistance status. Sorghum flower structural parts were found to effect resistance or susceptibility to sorghum midge flies. Midge resistant sorghum germplasm; AF28, AS21, GA07/84, SEREDO, and GA08/103 had significantly ($P \leq 0.05$) shorter flower style lengths of 0.39 – 0.64mm, compared to the susceptible germplasm GA010/010 with 0.94mm. Midge resistant germplasm AF28, AS21, SEREDO, and IESV94023SH had significantly ($P \leq 0.05$) smaller exposed portion of the lower glume width ranging between 0.072 – 0.192mm, compared to that of GA010/010 (0.216mm) a midge susceptible germplasm. Unique sorghum floral morphological traits identified in promising sorghum genetic materials against sorghum midge are important in breeding for resistance against sorghum midge.

Keywords: *Stenodiplosis Sorghicolar, Host-Resistance, Antixenosis, Antibiosis.*

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I. INTRODUCTION

Sorghum *Sorghum bicolor* (L.) Moench., is among the millets cereal crop grown for food, forage, beer brewing and bioenergy (Kimber *et al*. (2013). Sorghum is a resilient, tolerant to drought, versatile to harsh conditions in the semi-arid agro-ecological zones, and the South Western highlands of Uganda. In Uganda, sorghum is commonly grown, in the Northern, Eastern, Western and Central regions. Although, the acreage of sorghum crop has not changed over the years, its growth dropped from 457,000Mts in 2007 to 299,000Mts in 2013 (UBOS, 2010; Tenywa *et al*. 2018). Sorghum is a staple cereal food crop and animal feed (fodder) mainly grown by subsistence farmers in Uganda. Recently, sorghum was commercialised as a raw material for brewing beer lager. Its drop in production is however, attributed to several production constraints including diseases and pests ranking high among the key sorghum growth limitations that cause loss to yield (Sharma, 2006). In sorghum production, insect pests are estimated to cause annual losses of more than $ 1,000 in the semi-arid tropical regions.

Worldwide, the key pest of grain sorghum is the sorghum midge *Stenodiplosis sorghicola* Coquillett., (Harris, 1976). Sorghum midge pest damage to grain sorghum is documented to be more than 50%, and a possibility of causing up to 100% total loss of the grain depending on the pest pressure (Knutson and Cronholm 2007; Natarajan and

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Chelliah, 1985), including other biotic and abiotic environmental stresses. Several pest management techniques are employed in sorghum production to limit its damage and loss of yield. These involve cultural, biological, chemical, botanical, host resistance, and a combination of more than one pest control method - integrated pest management (IPM). Host-plant resistance mechanism is very important and affordable in keeping sorghum midge pest populations to lower economic levels (Sharma 1993). Non-preference (antixenosis) by infesting female midge flies on flowering sorghum heads is a major host-plant resistance mechanism. In this resistance mechanism, the sorghum flower morphological interceptions affect female midge flies laying eggs. Difficulty in ovipositing eggs or 'oviposition non-preference' is a key mechanism of host plant resistance known to control female midge flies (Franzmann, 1993). Sorghum midge resistant genetic materials have been reported elsewhere, and they include genotypes; AF28, DJ6514, TAM2566, ICSV745, ICSV89058, IS10712, ICSV197 and ICSV745X90562. Known sorghum midge susceptible germplasm include; IS8193, IESV94023SH and SWARNA (Olabimpe *et al.*, 2021). Wild sorghum relatives make a good source of resistance genes to *Sorghum bicolor* (Nwanze *et al.*, 1995). Antibiosis is another type of host plant resistance in which fewer sorghum midge larvae, or adult midge flies emerge from the sorghum spikelets.

Sharma *et al.*, 2002, observed that planting of the same germplasm in an extensive area in successive growing seasons leads to breakdown of host resistance to pests. Thus, continuous identification and introgression of sorghum midge resistant genes into promising sorghum genotypes increases its pest resistance gene base and duration of usefulness in pest control (Sharma and Franzmann, 2001). Some sorghum genotypes have potential to resist sorghum midge infestation and damage, and can be used in breeding programmes as a source of resistance genes in sorghum midge pest management. Kuhlman *et al.*, 2010, reported that hybridization of *S. bicolor* with a wild sorghum species *S. macrospermum* was shown to be partially compatible, although Nwanze *et al.*, (1995), succeeded in transferring host resistance traits against the sorghum shoot fly *Atherigona soccata* R. pest.

Commercial sorghum hybrids with a big range of resistance levels to sorghum midge have been developed in Australia. They not only simplify management and cost reduction, but provide significantly greater sorghum midge control (Henzel and Franzmann, 1994). Having information about host-plant resistance mechanisms and related factors affecting host-plant resistance to insect pests is quite useful in choosing genetic improvement methods, and suitable selection criteria of sorghum to resist insect pests (Sharma, 1993). This study selected sorghum genotypes as hosts and assessed them for midge fly preference and subsequent laying of eggs by the adult female sorghum midge flies. This helped identify promising resistant and susceptible sorghum genetic materials to use in the breeding pipelines.

II. MATERIALS AND METHODS

A number of separate experiments were conducted to establish sorghum midge preference for oviposition and damage of grain sorghum under multi-choice field conditions, multi choice cage conditions, no choice cage conditions, and morphological measurements of sorghum flower spikelets to ascertain antixenosis and antibiosis sorghum plant resistance mechanisms against sorghum midge pest.

➢ *Choice of Grain Sorghum for Infestation, Laying Eggs and Damage Caused by the Sorghum Midge Under Multi-Choice Field Conditions*

Evaluation of 30 sorghum germplasm for preference, laying eggs and damage by the sorghum midge pest was layed out in an alpha lattice experimental design under multi-choice field conditions. Sorghum germplasm; AF28, SEREDO, IS8884, DJ6514 were used as checks for sorghum midge resistance, while IS8193, IESV94023SH and SWARNA were checks for midge susceptible germplasm (Sharma *et al.*,2003) in addition to the rest of the other sorghum germplasm evaluated. The sorghum experiment was setup at the National Semi Arid Resources Research Institute (NaSARRI), on-station at Serere. Each sorghum germplasm was planted in a 5 row plot, 4m long spaced 60 cm and thinned to 20cm apart from plant to plant in a row. To control interference from shoot fly and stem borer pests' damage, an insecticide Carbofuran 3G was applied (Sharma *et al.*, 2003) at seedling stage 3 weeks after germination. Five sorghum heads per germplasm in a plot at 100% flowering (with pollen) were randomly sampled for midge fly presence and infestation data recorded (Table 1). Some flowering sorghum panicles were dressed with transparent polythene bags and shaken to dislodge adult midge flies that had infested the sorghum heads and counted. At physiological maturity growth stage, sorghum midge damage records were collected from 3 randomly sampled sorghum heads per germplasm using a damage rating visual score scale of 1-9: for which 1 = <10%, 2 = 11-20%, 3 = 21-30%, 4 = 31-40%, 5 = 41-50%, 6 = 51-60%, 7 = 61-70%, 8 = 71-80%, 9 = >80%.

To establish the damage caused to the flower spikelets by the midge larvae, six primary branches were collected from the top, middle, and bottom part of each sorghum panicle, and bulked. Secondary branches (racemes) were further removed from the primary branches, and thoroughly mixed for each germplasm, and all spikelets detached. A total of 250 spikelets were randomly counted from each lot, and chaffy spikelets counted and expressed as % midge damaged spikelets (Sharma *et al*. 2003).

At physiological maturity, sorghum yield data for both midge infested (panicles not protected in nets) and non-infested (panicles protected in blue net bags at flag leaf to physiological maturity) sorghum panicles were collected. Ten mature sorghum panicles of each of the test germplasm (infested and non-infested) were sampled from an inner row/plot, and grain weight taken. From midge infested panicles we determined loss in grain yield by subtracting the

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yield from the non-midge damaged yield and expressed as % of grain yields in non-infested panicles.

- *Choice of Grain Sorghum by the Sorghum Midge Under Multi-Choice Cage Conditions*

The multi-choice field conditions are usually influenced by the daily fluctuations of midge fly population densities, and the effects of staggered flowering of the sorghum fields, over time in a given area (Sharma *et al*. 1994). To avoid this effect, eight selected sorghum germplasm (*Sorghum bicolor* M.) heads were evaluated for choice of grain sorghum and laying of eggs by adult female sorghum midge flies *Stenodiplosis sorghicola* Coq., under confinement in a blue net cage. Eight selected flowering sorghum germplasm panicles, 25cm long having pollen on them with a peduncle were randomly sampled and cut from an established sorghum field at 10.00hrs. Each of the 8 sorghum germplasm heads were fixed to stand upright on moisturised flower preservative sponge spaced 10 X 11cm, were placed in a wooden cage of size 30x30x90cm on a table in a laboratory. They sorghum heads were arranged in a completely randomized experimental design, and each germplasm replicated three times. The cage was covered in a blue net, and, a black opaque polyethene sheet covered on top of the cage to limit laboratory light from the ceiling bulbs interfering with the midge fly movements. Using transparent vials, 40 sorghum female midge flies were introduced into the cage (5 flies per each of the 8 sorghum germplasm heads) and record of infestation / head taken after 15, 30 and 60 minutes duration (Sharma and Franzmann, 2001). The same procedure was repeated with a new set of 80 sorghum midge flies introduced into the cage (10 flies per the 8 sorghum germplasm) and records taken. Data was expressed in percentages where the number of female midge flies counted on each sorghum panicle was divided by the total number of midge flies in the cage multiplied by 100. The experiment addressed uniformity in insect pressure and environmental conditions. This experiment was run for ten times while changing the position of each sorghum germplasm head in the cage.

- *Laying of Eggs on Grain Sorghum Germplasm by the Sorghum Midge Under the No-Choice Cage Situation*

A no-choice cage situation technique was used to evaluate laying of eggs by the sorghum midge flies on individual sorghum germplasm potted in a screen house and heads caged at flowering. Sixteen sorghum germplasm; AF28, AS21, IESV94023SH, AS25, GA07/84, IESV92043DL, WAD, AS15, SEREDO, SESO3, IMUMWA AJELE, MACIA, AS30, IESV92037SH, GA08/103, and GA010/010 were planted in pots with sandy loam soils in the screen house replicated 3 timesin a randomised complete block experimental design (RCBD). Different experiments were setup to cater for each of the 3 midge fly population densities of 5, 15, 25. Flowering sorghum panicles having pollen were trimmed to 25 spikelets and caged with a wire frame 15 X 30cm covered in a blue net. Female sorghum midge flies were released into the cages at 5, 15 and 25 population densities to infest the 25 spikelets left on each sorghum panicle. Five spikelets were randomly picked from each of the caged panicles a day after, and kept in a fridge ready to collect data on midge fly eggs laid. A binocular microscope (50X) was used to observe and count eggs laid in the spikelets preserved in the fridge. Sorghum spikelets were dissected and data on number eggs laid per germplasm, percentage spikelets having eggs, and, midge larvae (after 7 days) per sorghum germplasm for every midge population density recorded. Data was taken at an average temperature 29.65^0C and relative humidity 70.1% in the screen house. This experiment ensured uniformity in insect pest pressure and environmental conditions. Data were analysed using analysis of variance after ASIN(SQRT(E2/100)) transformation, means separated with (LSD) at $P \leq 0.05$. GenStat 17^{th} Version (64 bit) software was used for statistical analysis.

- *Morphological Measurements on Grain Sorghum Spikelets to Ascertain Antixenosis and Antibiosis in Sorghum Host Plant Resistance Mechanisms Against Sorghum Midge*

Morphological studies were made on sorghum flower spikelet parts through linear measurements of the two glumes (upper or inner and lower or outer), the floral style length (SL), and the exposed area of the lower glume (EGB2) at flowering bearing pollen. Spikelets of 15 selected sorghum were planted in the field plots of size 4mX3m, sorghum spaced at 60cmX20cm in four rows per plot. Sorghum spikelets were picked from flowering sorghum heads in a field setup in a randomised complete block experimental design having 3 replicates. Five spikelets were randomly picked from each of the flowering sorghum germplasm head and the linear measurements; length of upper glume (GL1), breadth length in the middle (GB1), and length of lower glume (GL2) and breadth length (GB2), and the floral style length (SL) were all taken using a binocular microscope (X50), and an ocular micrometre (2.5 ocular units =1mm). Lower glume exposed part (GL2) not covered by the upper glume (EGB2) calculated as GL1/GL2, and GB1/GB2. The area for laying eggs by the midge in the glume was got as GL1*GB1. The flower style length (SL) was also measured. Data were subjected to analysis of variance, and means compared using LSD at $P \leq 0.05$.

III. RESULTS

- *Choice of Grain Sorghum for Infestation, Laying Eggs and Damage Caused by the Sorghum Midge Under Multi-Choice Field Conditions*

Under multi-choice field condition technique, adult sorghum midge flies infested sorghum germplasm grown under open field conditions. Sorghum midge fly infestations ranged from 2.4 – 3.1 flies per panicle on sorghum germplasm; AS21, AF28, SEREDO, GA08/103, EPURIPUR, IS8884, SEKEDO, and DJ6514 with significantly ($P \leq 0.05$) less midge fly infestations compared to GA010/010 and IS8193 (the midge fly susceptible checks) sorghum germplasm with more midge fly infestations of 5.0 - 7.6 flies/panicle (Table 1). Sorghum germplasm; AS21, SESO3, AS15, GAO7/84, GA08/103, IESV92037SH, LDRM/9/2/2, SEREDO, and SESO2 were less damaged with a visual damage rating score range 1 – 3 (less damaged scores) on a 1-9 damage score scale where 1=<10%, 2=11-20%, 3=21-

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30%, 4=31-40%, 5=41-50%, 6=51-60%, 7=61-70%, 8=71-80%, 9=>80%. . These were compared to SWARNA, IS2205, and GA010/010 (midge susceptible) with 4 – 7 damage rate scores (Table 1). Sorghum damage was also assessed by counting chaffy (midge damaged) spikelets. Similarly, sorghum genotypes AS21, SESO3, AS15, GAO7/84, GA08/103, IESV92037SH, LDRM/9/2/2, SEREDO, and SESO2) had less chaffy spikelets ranging between 6 – 29.7%. Germplasm AS21 had the lowest number of midge damaged spikelets at 6%, compared to IS1044 and SWARNA that had more than 70% chaffy spikelets (Table 1).

Thus, following the damage rating score scale of (1-9), sorghum germplasm AS21 and SESO3 were rated as highly resistant to midge damage, while AS15, GAO7/84, GA08/103, IESV92037SH, LDRM/9/2/2, SEREDO, and SESO2 were rated as resistant to sorghum midge damage. Furthermore, sorghum germplasm; SEKEDO, AF28, IS8884, AS21, IESV94023SH, SEREDO, and GA08/103 demonstrated less yield loss of 22 – 59% to sorghum midge damage and therefore, categorised as resistant (Table 2).

➢ *Choice of Grain Sorghum for Infestation by the Sorghum Midge Under Multi-Choice Cage Conditions*

Female sorghum midge flies were observed significantly ($P \leq 0.05$) less attracted to settle on sorghum heads varieties; AS21, IESV94023SH, SEREDO and SESO3 flowering sorghum panicles at 5 female flies population density for a duration of 30 minutes infestation (Table 3 and Figure 1). Similarly, at a population density of 10 female midge flies in a duration of 15 minutes, the flies were observed less attracted to sorghum varieties; AS15, AS21, IESV94023SH, SEREDO and SESO3 (Table 3 and Figure 2).

On the contrary, more female sorghum midge flies were attracted to sorghum genotypes GA010/010, AS30 and MACIA, during the first 15 minutes of 10 female midge flies infestation/panicle (Table 3 and Figure 2). A similar trend of sorghum midge fly responses was observed in both population densities of (5 and 10) after all the time durations of 15, 30 and 60 minutes.

➢ *Laying of Eggs and Damage to Grain Sorghum Germplasm by the Sorghum Midge Under the No-Choice Cage Situation*

Sorghum midge oviposition and damage on grain sorghum under no-choice cage conditions was assessed under three different midge fly population densities of; 5, 15 and 25 female midge flies. Sorghum germplasm infested with 5 sorghum midge flies/head; AF28, AS15, AS30, GA07/84, MACIA, and SEREDO, had significantly ($P \leq 0.001$) less % spikelets with midge fly eggs at 5.33 – 17.8% compared to GA010/010, GA08/103, and IESV92037SH with more % spikelets having midge eggs at 50.67 – 59.11% (Table 4 and Figure 3). At 5 midge flies, sorghum germplasm; AF28, GA07/84, IMUMWA AJELE, MACIA, SEREDO, SESO 3, and AS25 had significantly ($P \leq 0.001$) less midge egg number compared to GA08/103 and WAD. Germplasm; AF28, AS15, SEREDO, MACIA, and AS21 had less % spikelets infested with larvae 3.7 – 18.60 % compared to GA010/010, GA08/103 and IESV92037SH that had most % spikelets infested with midge larvae 52.00 – 60.10%, thus, exhibiting the antibiosis type of host resistance mechanism against the midge larvae. Meanwhile, sorghum Germplasm; AF28, AS21, and IESV94023SH had significantly ($P \leq 0.001$) less % spikelet damage 14.33 – 19.67% compared to genotypes GA10/010, GA08/103, IESV92037SH that had higher % spikelets damaged 53.57 – 63.40%. These variations in egg and larvae numbers in midge resistant and susceptible sorghum germplasm could be attributed to a possible sorghum grain chemical composition, and the probable effect of the prevailing environmental conditions on the development of the midge flies (Table 4 and Figure 3).

At a population density of 15 sorghum midge flies per head, sorghum germplasm; AF28, AS21, IESV94023SH, MACIA, SEREDO and SESO3 had significantly ($P \leq 0.011$) less % spikelets with midge eggs 13.30 – 29.30%, compared to GA010/010, MACIA, IMUMWA AJELE, IESV92037SH, GA08/103, and AS25 that had more % spikelets with eggs (56.0 – 95.9%). Sorghum germplasm that had significantly ($P \leq 0.05$) less midge eggs (5 – 18.3 eggs / 25 spikelets) number included; AS21, GA07/84, IESV9204DL, Macia and WAD compared to GA08/103 and IESV92037SH with 33 – 43 eggs/25 spikelets. Sorghum germplasm that had significantly ($P \leq 0.001$) less % spikelets infested with midge larvae 6.30 – 29.30% included; AF28, AS15, AS21, GA07/84, SEREDO, AS25, SESO3, IESV92043DL, IMUMWA AJELE, IESV94023SH, AS30 and AS25, compared to GA010/010, GA08/103, and IESV92037SH that had more % spikelets infested with midge larvae 55.30 – 62.70%. Germplasm AF28, AS21, GA07/84, IESV94023SH, WAD, and IESV94043DL had significantly ($P \leq 0.001$) less % damaged spikelets 17.55 – 30.0%, compared to germplasm GA010/010, IESV92037, GA08/103, AS 30, and MACIA that had higher % spikelets damaged 50.16 – 64.81% (Table 4 and Figure 4)).

At population density of 25 midge flies per sorghum panicle, only sorghum germplasm AF28 had significantly ($P \leq 0.009$) less % spikelets with sorghum midge eggs 16%, compared to IESV92037SH and GA08/103, that had significantly ($P \leq 0.05$) more % spikelets with midge eggs 73.3 – 98 eggs/25 spikelets (Table 4 and Figure 5). Meanwhile, sorghum germplasm; AF28, AS15, SEREDO, AS25, AS21, GA07/84, AS30, MACIA, SESO3, and IESV94023SH had significantly ($P \leq 0.009$) less % spikelets infested with midge larvae 8.00 – 27.9%, compared to GA010/010 and GA08/103 that had relatively more % spikelets infested with midge larvae 66.10 – 66.70%. Sorghum germplasm; AF28, AS21, AS25 and IESV94023SH had significantly ($P \geq 0.001$) less % damaged spikelets 19.52 – 26.29%, compared to IESV92037SH, GA010/010, GA08/103, AS30, MACIA, and IMUMWA AJELE that had more % damaged spikelets 39.7 - 66.70%. (Table 4 and Figure 5).

In summary, under the sorghum midge population densities of 15 and 20 flies per head, the trend was similar to the population density of 5 midge flies/head. The common

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sorghum germplasm; AF28, AS21, SEREDO, GA07/84 and IESV94023SH exhibited a significantly ($P \leq 0.05$) less % spikelets with midge eggs, less midge egg number, less % spikelets with larvae, and less % damage to spikelets. The susceptible sorghum germplasm; GA010/010, GA08/103 and IESV92037SH had significantly ($P \leq 0.05$) higher spikelets with midge eggs, higher midge egg numbers, higher % spikelets with larvae, and more damage inflicted on to the spikelets. In general, the higher the midge fly population, the more % sorghum spikelets with midge eggs, more midge egg number is laid, more spiklets have midge larvae, and more spikelets are damaged by the midge larvae (Table 4). These results demonstrate major sorghum host resistance mechanisms of antibiosis where fewer larvae were found in the sorghum panicle spikelets, as well as antixenosis (midge fly non-preference for oviposition).

- *Morphological Measurements on Grain Sorghum Spikelets to Ascertain Antixenosis and Antibiosis in Sorghum Host Plant Resistance Mechanisms Against Sorghum Midge*

Spikelet measurements from glume length GL1 (upper glume) ranged from 1.53 – 2.1mm. Known resistant sorghum genotypes; AF28, AS21 and IESV94023SH had a significantly ($P \leq 0.05$) longer upper glume length GL1, than that of GA010/010 a midge susceptible one (Table 5). Glume length GL2 ranged from 1.65mm (AS15) to 2.1mm (IESV94023SH). Known midge resistant accessions AF28 (2.056mm), IESV94023SH (2.104mm) and AS21 (1.848mm), had a significantly ($P \leq 0.05$) longer glume length GL2 than that of GA010/010 (1.692mm) known to be susceptible to sorghum midge. The outer glume breadth GB1 ranged from 1.056mm (AS15) to 1.68mm (AS21). Known resistant sorghum germplasm; AF28 (1.228mm), AS21 (1.68mm), and IESV94023SH (1.328mm) had a significantly ($P \leq 0.05$) wider glume breadth than that of GA010/010 (1.124mm) a midge susceptible germplasm. The floral style length SL ranged from 0.392mm (AF28) to 0.904mm (GA010/010). Known midge resistant sorghum germpalsm; AF28 (0.392mm), AS21 (0.532mm), IESV94023SH (0.608mm), GA07/84 (0.592mm), GA08/103 (0.628mm), SEREDO (0.64mm) and SESO3 (0.648mm), had significantly ($P \leq 0.05$) shorter floral style length than that of GA010/010 (0.904mm) a known midge susceptible germplasm.

Similarly, the exposed part of the lower glume EGB2 ranged from mm (AF28) to 0.54mm (GA010/010). Known midge resistant accessions AF28 (0.072mm), AS21 (0.088mm), IESV94023SH (0.10), GA07/84 (0.16mm), GA08/103 (0.132mm), SEREDO (0.192mm), and SESO 3 (0.136mm) had significantly ($P \leq 0.05$) smaller exposed parts of the lower glume available for midge oviposition compared to GA010/010 (0.216mm), and WAD (0.244mm) known susceptible sorghum germplasm to midge. The space available for midge oviposition (GL1*GB1) on sorghum flower glumes ranged from 1.61mm^2 (AS15) to 4.20mm^2 (GA010/010). Known midge resistant germplasm AF28 (2.53mm^2), AS21 (3.21mm^2), IESV94023SH (2.8mm^2), GA07/84 (1.68mm^2), GA08/103 (1.89mm^2, SEREDO (1.67mm^2), SESO 3 (1.92mm^2) had significantly ($P \leq 0.05$) smaller space for midge oviposition, compared to GA010/010 (4.20mm^2) and WAD (3.12mm^2) that are susceptible to midge damage. This information clearly shows that the morphological structure and size of the sorghum flower parts directly influences the prevalence of the sorghum midge pest in the field (Table 5).

IV. DISCUSSION

Evaluation of 30 sorghum germplasm was conducted to characterize host defense mechanisms against the sorghum midge pest. Results on sorghum midge preference for oviposition and subsequent damage under multi-choice field conditions showed that some sorghum varieties were preferred by sorghum midge flies for infestation and oviposition of eggs. Thus, more eggs were laid on preferred sorghum germplasm and subsequently damaged most, compared to others that were less preferred / infested. Much progress has been achieved in identifying sources of host-plant resistance to crop pests on a diversity of crops (Sharma, 2007). A number of factors were responsible for midge preference of some sorghum germplasm, and infesting their spikelets, and the subsequent oviposition of eggs in them.

Non-preference for laying eggs (antixenosis) by visiting female midge flies (Franzmann, 1993), and less survival and growth of midge larvae (antibiosis), form the principle components of host-plant resistance to midge (Sharma *et al.* 2002). For some reason, fewer adult midge flies 2.4 – 3.1 visited and infested sorghum germplasm; AS21, AF28 (check), IS8884 (check) and SEKEDO. This demonstrated that their inflorescence were not preferred by the female midge flies for oviposition and thus, exhibiting the antixenosis (non-preference) mechanism of host plant resistance (Sharma *et al.* 1990a,b; Franzmann, 1993). These were therefore, categorized as resistant to the sorghum midge. The visual damage scores and percentage damage of spikelets due to midge larvae, and sorghum yield loss were correspondingly low to sorghum germplasm AS21 and SEREDO, and they were categorized as resistant to the midge (Table 2). Majority of sorghum germplasm were categorized as moderately resistant including the known midge resistant checks ; AF28, IS8884 (Sharma *et al.*1999) and SEKEDO, while DJ6514 was rated susceptible, despite its being a check for resistance to midge flies (Sharma *et al.* 1992) Table 2. Breakdown of host-plant resistance to midge is common with open pollinated midge resistant sorghum compared to the midge resistant *sorghum bicolor* hybrids (QDAF, 2012). Sharma, (2001) made this observation where a midge resistant sorghum genotype DJ6514 became susceptible to the midge fly damage. He indicated either a possible occurrence of a new sorghum midge biotype, or the breakdown of host resistance mechanisms that are environmentally induced, in situations where an open pollinated midge resistant sorghum variety is repeatedly grown for long over seasons in same communities (Sharma *et al.*, 1998).

Sharma *et al.*, (1997) noted the controversial responses of some of the sorghum germplasm to midge attack under multi-choice field conditions, could have been influenced by

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the daily fluctuations in midge fly population densities, and the effects of non-uniform flowering of the sorghum plants over a duration of time. Thus, causing difficulties in identifying sources of genetic materials with stable resistance. Sorghum germplasm that were significantly ($P \leq 0.001$) high on the visual damage scale, with more spikelets damaged, and with higher yield loss included; DJ6514, IESV23008DL, GA010/010, EPURPUR, IESV9111DL, MACIA, WAD, and SWARNA. Checks considered for midge susceptibility included SWARNA, IS8193, and GA010/010 (Table 1).

Another technique to study host preference by sorghum midge on existing sorghum accessions was conducted under multi-choice cage conditions while observing uniform environment. More female sorghum midge flies were seen attracted to some sorghum germplasm; GA010/010, AS30 and MACIA in the first 15 minutes under uniform population density of 10 flies per panicle. Meanwhile, at uniform population densities of 5 and 10 midge flies/panicle for a duration of 30 and 15 minutes respectively, the number of female flies observed were significantly ($P \leq 0.05$) less attracted to settling on flowering sorghum panicles of germplasm; AS21, IESV94023SH, SEREDO, and SESO3(Figures 1 and 2). Sharma *et al.* (1999) reported that a optical stimulus influences the positioning behaviour of the sorghum midge flies. Midge flies tend to be attracted to red, white, and yellow colours, but less attracted to blue and black colours. Similarly, sorghum midge flies are attracted to sorghum flower odours (Sharma and Franzmann, 2001). Sorghum flower morphological structure is also reported to play a big role in attracting or deterring midge flies not to infest sorghum flowers (Sharma *et al.*, 2002). Thus, antixenosis (non-preference) by infesting sorghum midge female flies where sorghum spikelet structural interceptions to midge oviposition, form major plant resistance mechanisms to sorghum midge, is Lessin agreement with Franzmann, (1993), and Sharma *et al*. (1990a,b) previous reports.

A no-choice cage condition technique was also used to evaluate sorghum midge oviposition on 16 individual sorghum genotype heads, under three female midge fly population densities of 5, 15 and 25. At each of these population densities, sorghum genotypes were assessed for % spikelets with midge eggs, % spikelets with midge larvae, and % damage caused by the larvae. Sorghum germplasm AF28 was a midge resistant check (Sharma *et al*. 1992; Sharma *et al.* 2003). Germplasm AS21, IESV94023SH and GA07/84 were assessed as resistant germplasm against sorghum midge oviposition and damage by midge larvae. Germplasm GA010/010, WAD, MACIA, and IESV92037SH were consistent as susceptible genotypes to the midge flies (Figures 3, 4, 5).

Relatively less sorghum midge larvae survive on sorghum (antibiosis) and is a principle mechanisms of host plant resistance against the sorghum midge (Sharma *et al.* 1993). Sorghum genotypes that exhibited a consistent proportionate trend of reaction against the three sorghum midge population pressures included; AF28, AS21, GA07/84, AS15, IESV94023SH, AS25, SEREDO, and SESO3,and were categorised as resistant sorghum germplasm against the sorghum midge. Meanwhile, germplasm GA010/010, and IESV92037SH were categorised as susceptible to sorghum midge damage (Figures 3-5). Singh, (1987) reported that high midge larval mortality and prolonged developmental period on sorghum germplasm exhibited antibiosis plant resistance mechanism against the sorghum midge pest. Thus, Sorghum germplam; AF21, AS21, SEREDO, AS15, and GA07/84, were infested with less midge larvae and less spikelet damage exhibited the antibiosis mechanism of host resistance against the midge flies (Figures 3, 4, 5).

Known midge resistant sorghum germplasm, IESV94023SH, AF28, AS21, AS15, and GA07/84 had significantly ($P \leq 0.05$) long glume length GL1, varying from 1.528 - 2.208mm, compared to GA010/010 and MACIA the susceptible ones (Table 5). Furthermore, germplasm AF28, AS21, AF15 and WAD had glume length GL2 ranging from 1.65 - 2.104mm, which were significantly ($P \leq 0.05$) longer compared to the susceptible germplasm GA010/010 and MACIA. Similarly, the outer glume breadth GB1 for genotypes IESV94023SH, SEREDO, AS21, and GA08/103 varying from 1.052 mm - 1.68 mm which had significantly ($P \geq 0.05$) wider glume breadth than that of GA010/010 or MACIA. Contrary to the findings of Sharma and Vidyasagar (1994), in which shorter, narrower, and tight glumes were reported to be features for sorghum resistance against the midge, our findings found resistant sorghum genotypes to have longer glumes and wider breadths compared to the susceptible germplasm. The resistant germplasm also had smaller parts of the glume exposed making it hard for midge oviposition. According to Sharma, (1999) eggs laid by midge were positively correlated with the sorghum flower parameters of; style, anther, glume length, lema, and palea, while short flower parts were associated with midge resistance and, attributed to the limited space available for egg laying and midge larvae growth. This could have been our case where there was limited exposed space available for laying eggs in all our germplasm that were found resistant to the sorghum midge!

Sharma *et al.,* (2002) reported that the anther length was positively correlated with percentage spikelets that had midge eggs and larvae. The anther length appears to be a flower part on which the midge oviposits eggs, if not laid on the glumes or stamen, and later the larvae use it to move to the ovary for feeding. If it is relatively long, the midge will probably find it easy to lay more eggs and thus, more larvae moving to damage the flower ovaries (kernels). This study however, measured the floral style length and not the stamen. The style length ranged from 0.98mm (AF28) to 2.26mm (GA010/010), and germplasm GA07/84, SEREDO, AF28, SESO3, and AS21 GA08/103, had significantly ($P \leq 0.05$) shorter floral styles than those of GA010/010 (Table 5). This is a notable floral feature enabling sorghum resistance against midge pest. Similarly, the exposed part of the lower glume ranged from 0.18mm (AF28) to 0.61mm (WAD), and germplasm; GA07/84, GA08/103, AF28, AS21 SEREDO, and SESO3 had significantly ($P \leq 0.05$) smaller exposed parts of the lower glume available for laying eggs, a feature

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which is also important in determining the sorghum resistance status against the sorghum midge. The study found some known midge resistant germplasm; AS21 (19.40mm^2), AF28 (15.79mm^2), and GA08/103 (12.37mm^2) having a significantly (P $\leq$ 0.05) wider space for midge to lay eggs compared to GA010/010 (11.87mm^2). These findings are however contrary to the findings of Sharma *et al.* 2002, in where he noted resistance to sorghum midge was determined by sorghum flower parts having small or no area available for midge to lay eggs.

V. CONCLUSION

This study shows that the sorghum midge flies respond differently to different sorghum germplasm, which is a clear sign of host resistance or susceptibility to midge infestation. Sharma and Franzmann (2002), observed that the wild relatives of sorghum had few or no eggs laid in them, and the species-specific midge occurence on sorghum indicated a close to further evolution of midge *Stenodiplosis / Contarinia* species and sorghum species. Wild sorghum relatives however, are a source of genes for host plant resistance against insect pests (Nwanze *et al.*, 1995).

Thus, the sorghum genetic materials available with special flower morphological traits can be used in further sorghum breeding to develop genotypes that are resistant to the sorghum midge pest damage. Elsewhere, utilisation of host resistance against midge flies has been achieved (Sharma *et al.* 1993; Singh, 1987; Agrawal *et al.* 1987, Teetes 1985,). Morphological structures of the sorghum midge have been reported to influence midge oviposition. Sharma *et al.* 2002, reported that the exposed area of the lower glume and the area obtained which is available for sorghum midge oviposition should be small with tight glumes on the ovary. This is however, contrary to my findings where the exposed area of the glumes together with the calculated area obtained available for midge oviposition as significantly (P $\leq$ 0.05) bigger in resistant sorghum genotypes compared to the susceptible one. Franzmann, (1993), observed that difficulty in laying eggs or ‘oviposition non-preference’ was a principle mechanism of host plat resistance against the sorghum midge flies.

The study indicates that there is a diversity of attributes or traits in sorghum for midge resistance in different sorghum genotypes. Use of these traits in combination can develop sustainable midge resistant sorghum materials. Franzmann, (1996) and Singh (1987) reported the existence of a range of sorghum materials with different resistance levels against the sorghum midge pest. The sorghum resistance characteristics such as the ‘short glume’ spikelets (availing a small area for midge oviposition) can be used in breeding as useful genetic markers. Thus, the search for new traits for plant resistance to pests is essential in diversifying pest control measures including both the morphological and biochemical attributes. So far, the known ones and reported include; long glumes that do not open at flowering, fast ovary growth, short floral parts (glumes, style, stamen, ovary girth), lower sugar, lower amino acids in the ovary, high tannin levels, high phenol in ovary (Sharma *et al.*, (2004; Jotwani, 1978; Rosetto *et al.*, 1975).

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Table 1 Sorghum Midge Infestation and Damage Caused to Grain Sorghum Under Multi-Choice Field Conditions

Sorghum Accession	Mean adult midge flies/ panicle	Visual damage scores (1-9 scale)	Mean % damage (Chaffy spikelets)	Germplasm Status	Mean grain yield (Infested) (gms/panicle)	Mean grain yield (Un-infested) (gms/panicle)	Yield Loss (gms / panicle)	% Yield loss
AS21	2.40	1	6.00	HR	10.83	22.57	21.75	52.16
SESO3	3.80	2	8.00	HR	13.50	37.22	23.72	63.74
AS15	1.38	3	29.70	R	11.94	33.60	21.67	64.35
GA07/84	5.50	2	15.30	R	8.31	55.21	46.90	84.63
GA08/103	1.77	2	16.30	R	16.06	36.91	20.85	56.53
IESV92037SH	3.77	2	18.20	R	12.45	35.90	40.88	65.31
LDRM/9/2/2	2.77	3	27.00	R	10.45	34.93	24.48	69.73
SEREDO **(Check)**	3.27	2	16.30	R	17.37	42.25	24.88	58.79
SESO 2	2.77	3	23.80	R	4.23	30.97	26.74	86.33
AS16	4.90	4	33.00	MR	6.42	36.22	29.80	82.27
AS25	3.77	5	49.30	MR	7.89	44.81	36.92	82.38
AS30	1.00	4	40.70	MR	6.39	33.20	26.82	80.72
EPURIPUR	1.00	5	41.00	MR	0.68	25.68	25.00	97.32
GA010/010 **(Check)**	7.60	4	39.50	MR	0.25	29.03	28.78	99.13
GA08/86	1.90	5	35.70	MR	1.55	14.60	13.06	88.81
ICSV700	3.50	4	43.20	MR	8.10	23.34	15.24	65.43
IESV23008DL	3.10	4	39.20	MR	0.34	36.67	36.33	99.08

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IESV9111DL	3.10	4	39.80	MR	0.70	23.95	23.25	97.10
IESV94023SH	1.67	5	48.30	MR	12.87	27.42	14.55	53.09
IS8193	5.00	5	42.80	MR	12.14	44.97	32.83	72.87
IS8884 **(check)**	3.10	5	45.00	MR	6.59	10.89	4.29	38.30
MACIA	2.17	4	43.80	MR	1.32	27.13	25.81	95.14
SEKEDO	2.77	5	44.70	MR	19.32	22.88	3.56	14.91
SESO 1	3.18	5	48.50	MR	3.68	23.98	20.30	84.66
WAD	4.50	5	46.00	MR	1.71	35.53	33.82	95.19
AF28 **(check)**	2.88	2	44.00	MR	27.33	25.55	16.07	37.24
DJ6514	4.60	6	41.70	S	0.28	30.49	30.21	99.09
IS2205	2.67	6	61.70	S	1.03	27.47	26.45	93.30
SWARNA **(check)**	3.57	7	70.30	S	1.40	35.76	34.36	96.01
IS1044	4.00	7	72.50	HS	3.05	25.27	22.22	87.96
Fpr	**0.03**	**<0.001**	**<0.001**		**<0.001**	**<0.001**	**<0.001**	**<0.001**
CV	**56.80**	**45.40**	**45.60**		**19.00**	**9.30**	**12.30**	**6.90**
LSD	**3.01**	**3.03**	**27.85**		**2.36**	**4.82**	**4.84**	**8.49**
Mean	**3.25**	**4.08**	**37.40**		**7.61**	**31.74**	**24.14**	**75.49**

HR= Highly Resistant, R= Resistant, MR= Moderately Resistant, S= Susceptible, HS= Highly susceptible. Visual damage rating where 1=<10%, 2=11-20%, 3=21-30%, 4=31-40%, 5=41-50%, 6=51-60%, 7=61-70%, 8=71-80%, 9=>80%

Table 2 Damage and Yield Loss Rating at Crop Maturity for Reaction of 30 Sorghum Germplasm to Sorghum Midge

<table>
<tr><th>% Damage Range</th><th>Damage rating (1-9) scale</th><th>Germplasm status</th><th>Germplasm</th><th colspan="2">Categorization Basing on Yield Loss Assessment (%)</th></tr>
<tr><td><10</td><td>1</td><td>Highly Resistant</td><td>SESO3, AS21,</td><td>IS8884, AS21, SEKEDO, SESO3, AF28</td><td>14 – 40%</td></tr>
<tr><td>11-20</td><td>2</td><td rowspan="2">Resistant</td><td rowspan="2">AS15, GA07/84, GA08/103, IESV92037SH, SESO2, SEREDO, LDRM/9/2/2, AF28</td><td>GA08/103, SEREDO, IESV94023SH</td><td rowspan="2">41 – 60%</td></tr>
<tr><td>21-30</td><td>3</td><td rowspan="7">SESO 3, AS15, GA07/84, IESV92037SH, LDRM/9/2/2, SESO 2, AS16, AS25, AS30, EPURIPUR, GA010/010, GA08/86, ICSV700, IESV23008DL, IESV9111DL, IS8193, MACIA, SESO 1, WAD, IS1044, DJ6514, IS2205, SWARNA</td></tr>
<tr><td>31-40</td><td>4</td><td rowspan="2">Moderately Resistant</td><td rowspan="2">EPURIPUR, GA010/010, AS16, AS25, AS30, WAD, GA08/86, ICSV700, IESV23008DL, IESV9111DL, IESV94023SH, IS8193, IS8884, MACIA, SEKEDO, SESO1</td><td rowspan="6">61 – 100%</td></tr>
<tr><td>41-50</td><td>5</td></tr>
<tr><td>51-60</td><td>6</td><td rowspan="2">Susceptible</td><td rowspan="2">IS2205, DJ6514, IS1044</td></tr>
<tr><td>61-70</td><td>7</td></tr>
<tr><td>71-80</td><td>8</td><td rowspan="2">Highly susceptible</td><td rowspan="2">SWARNA</td></tr>
<tr><td>>80%</td><td>9</td></tr>
</table>

Table 3 Host Preference Assessment at 5 and 10 Sorghum Midge Fly Population Densities after 15, 30 and 60 Minutes Duration of Infesting Grain Sorghum Flowers

	% Response for 5 flies/sorghum head infested in cage			**% Response for 10 flies/sorghum head infested in cage**		
Sorghum Germplasm	**15 Minutes**	**30 Minutes**	**60 Minutes**	**15 Minutes**	**30 Minutes**	**60 Minutes**
AS15	20.00(0.38)	53.00(0.82)	40.00(0.68)	13.30(0.37)	25.00(0.52)	11.70(0.35)
AS21	6.70(0.16)	13.30(0.31)	13.30(0.31)	21.70(0.48)	16.70(0.42)	21.70(0.47)
AS30	20.00(0.46)	40.00(0.69)	53.30(0.82)	35.00(0.63)	30.00(0.58)	25.00(0.52)
GA010/010	6.17(0.16)	13.30(0.31)	13.30(0.31)	33.30(0.61)	55.00(0.84)	50.00(0.79)
IESV94023SH	0.00(0.00)	00.00(0.00)	13.30(0.31)	21.70(0.46)	31.70(0.59)	26.70(0.54)
MACIA	0.00(1.000.00)	26.70(0.46)	13.30(0.31)	31.70(0.59)	33.30(0.61)	33.30(0.61)
SEREDO	6.70(0.16)	20.00(0.38)	13.30(0.31)	18.30(0.44)	21.70(0.48)	18.30(0.44)
SESO3	6.70(0.16)	20.00(0.46)	13.30(0.31)	23.30(0.49)	21.70(0.48)	20.00(0.43)
Grand Mean	**0.18**	**0.43**	**0.42**	**0.51**	**0.56**	**0.52**
SE+	**0.22**	**0.23**	**0.23**	**0.08**	**0.14**	**0.16**

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LSD	**0.39**	**0.41**	**0.41**	**0.14**	**0.25**	**0.28**
Fpr	**0.19ns**	**0.023**	**0.08ns**	**0.012**	**0.07ns**	**0.11ns**
CV %	**120.20**	**54.00**	**55.80**	**15.50**	**25.20**	**31.10**

- *Figures in Parentheses are ASIN(SQRT(E2/100)) Transformed Values*

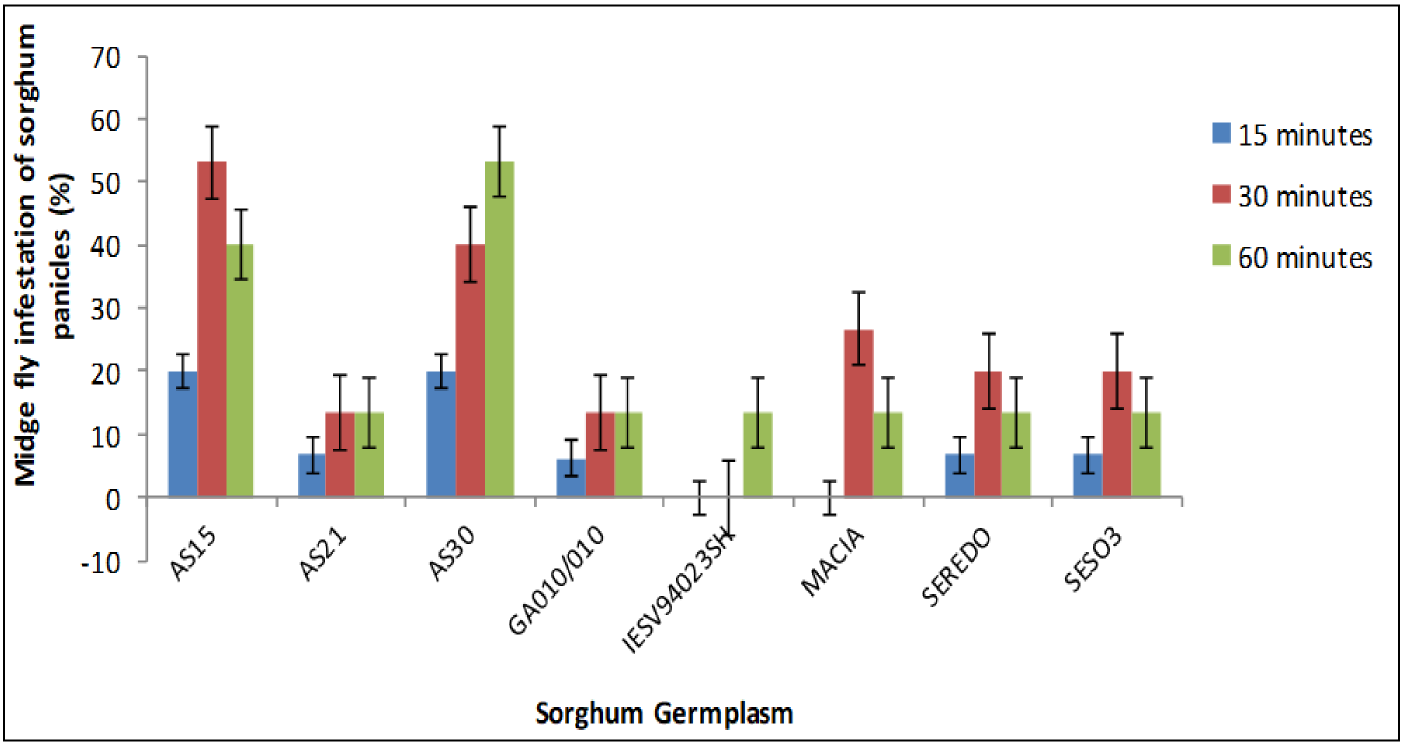

Fig 1 Sorghum Midge Host Preference at 5 Midge Flies/Panicle Infestation after Durations of 15, 30, and 60 Minutes.

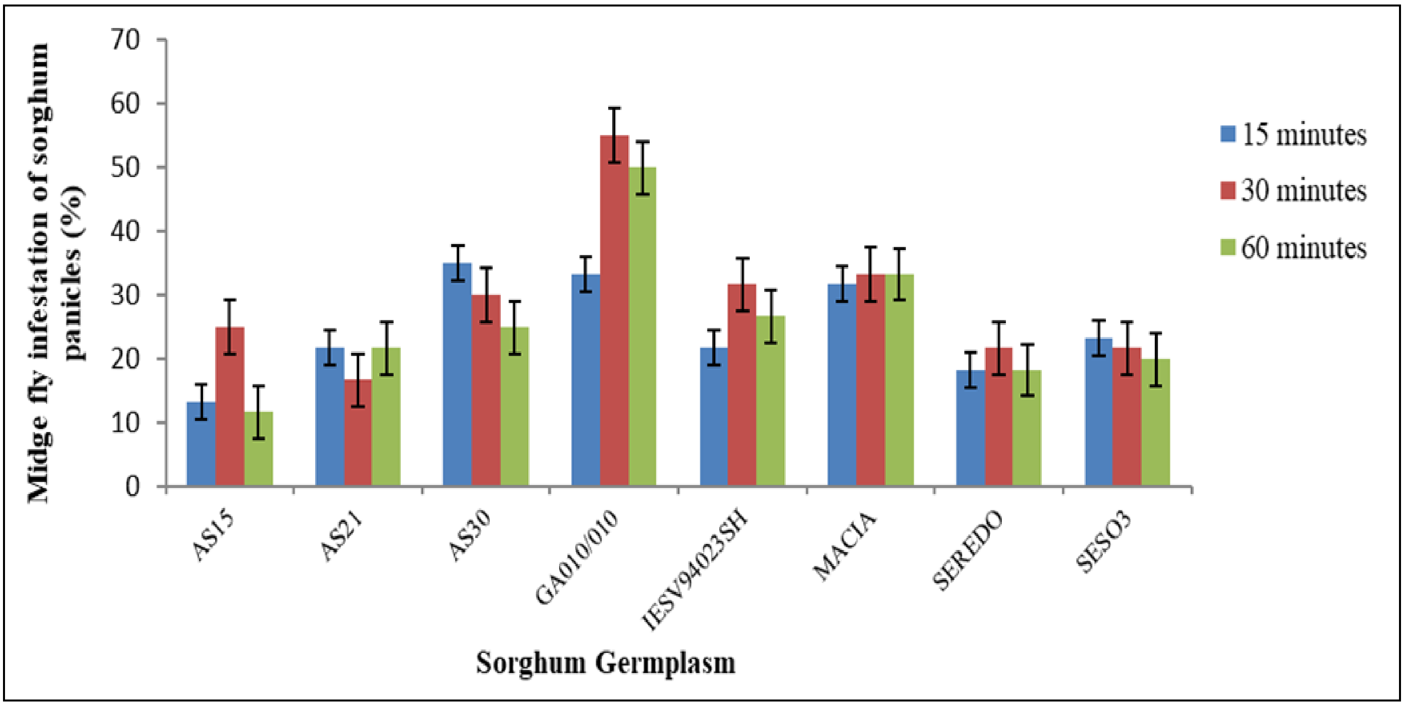

Fig 2 Sorghum Midge Host Preference and Infestations at 10 Midge Flies/Panicle after 15, 30, and 60 Minutes.

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Table 4 Sorghum Midge Assessment for Oviposition and Damage on Sorghum Germplasm Under 5, 15, 25 Midge Population Densities in No Choice Cage Conditions

		5 Sorghum female midge flies / panicle				**15 Sorghum female midge flies / panicle**				**25 Sorghum female midge flies / panicle**			
	Sorghum Germplasm	**% Spikelets with Midge Eggs**	**Midge egg No. / 25 Spikelets**	**% Spikelet with Larvae**	**% Damage Red Ooze Spikelets**	**% Spikelets with Midge Eggs**	**Smidge egg No. / 25 Spikelets**	**% Spikelet with Midge Larvae**	**% Damage Red Ooze Spikelets**	**% Spikelets with Midge eggs**	**Smidge egg No. / 25 Spikelets**	**% spikelet with Midge Larvae**	**% Damage Red Ooze Spikelets**
1	AF28	5.33(0.14)	1.33	3.67(0.19)	14.33(0.39)	13.33(0.37)	26.33	6.33(0.25)	17.55(0.25)	16.00(0.34)	0.00	8.00(0.29)	19.25(0.45)
2	AS21	28.00(0.56)	29.67	18.57(0.44)	15.67(0.41)	24.00(0.51)	5.00	22.63(0.50)	17.78(0.44)	40.00(0.68)	103.70	23.90(0.51)	19.41(0.46)
3	IESV94023SH	29.78(0.58)	8.89	25.22(0.54)	19.67(0.46)	29.33(0.57)	25.67	25.33(0.53)	21.33(0.48)	36.00(0.64)	60.00	27.90(0.56)	21.75(0.49)
4	AS25	21.33(0.48)	11.00	26.07(0.53)	24.00(0.51)	56.00(0.77)	29.33	29.33(0.57)	23.62(0.51)	92.00(1.29)	90.30	21.700.41)	26.29(0.54)
5	GA07/84	9.56(0.31)	4.89	20.00(0.45)	25.53(0.53)	32.00(0.60)	13.00	16.70(0.42)	28.07(0.56)	41.30(0.70)	6.70	25.00(0.52)	61.59 (0.90)
6	IESV92043DL	20.00(0.46)	7.40	41.33(0.70)	27.17(0.55)	32.00(0.60)	18.33	28.99(0.48)	30.000.58)	80.00(1.11)	59.20	46.50(0.75)	30.05(0.59)
7	WAD	35.11(0.63)	30.33	35.54(0.64)	28.13(0.56)	35.11(0.63)	22.00	42.32(0.71)	29.62(0.58)	64.00(0.93)	64.00	46.60(0.75)	34.15(0.62)
8	AS15	12.22(0.36)	12.17	12.33(0.36)	33.00(0.61)	34.67(0.54)	59.00	9.67(0.26)	34.19(0.62)	77.30(1.08)	103.70	12.50(0.30)	35.14(0.63)
9	SEREDO	17.33(0.43)	3.33	11.67(0.29)	33.33(0.61)	25.33(0.53)	42.00	19.52(0.46)	32.60(0.61)	74.70(0.05)	26.30	13.80(0.32)	34.650.63)
10	SESO 3	25.47(0.53)	2.00	25.25(0.53)	34.33(0.63)	28.00(0.56)	32.33	27.88(0.56)	36.41(0.65)	68.00(0.97)	40.30	27.60(0.55)	37.49(0.66)
11	IMUMWA AJELE	29.33(0.57)	3.00	21.67(0.40)	41.83(0.70)	58.67(0.87)	45.00	24190(0.43)	47.62(0.43)	65.30(0.95)	4.70	40.00(0.69)	50.21(0.79)
12	MACIA	15.56(0.41)	5.00	16.13(0.41)	43.43(0.72)	90.67(1.27)	26.67	21.23(0.48)	50.16(0.79)	60.00(0.83)	3.70	25.80(0.53)	52.47(0.80)
13	AS30	17.78(0.36)	16.82	27.59(0.55)	46.33(0.75)	37.33(0.56)	37.00	23.00(0.42)	50.32(0.79)	46.70(0.66)	10.30	25.20(0.44)	57.92(0.87)
14	IESV92037SH	50.67(0.79)	28.33	52.04(0.81)	53.57(0.82)	74.67(1.05)	43.00	55.33(0.84)	62.16(0.91)	84.00(1.16)	84.001.16	39.70(0.59)	69.07(0.98)
15	GA08/103	58.67(0.87)	61.04	58.87(0.88)	56.83(0.85)	58.67(0.87)	33.00	61.33(0.90)	55.56(0.84)	73.30(1.03)	165.30	66.70(0.96)	61.59(0.90)
16	GA010/010	59.11(0.88)	14.24	60.07(0.89)	63.40(0.92)	95.87(0.37)	17.00	62.67(0.91)	64.81(0.94)	98.00(1.46)	127.30	66.10(0.95)	67.25(0.96)
	Grand Mean	**27.20(0.52)**	**14.97**	**28.50(0.54)**	**35.04(0.63)**	**45.35(0.73)**	**29.67**	**29.78(0.54)**	**37.61(0.65)**	**63.5(0.93)**	**48.10**	**32.30(0.57)**	**40.67(0.69)**
	SE±	**6.38 (0.11)**	**2.59**	**7.43(0.13)**	**3.46(0.04)**	**18.05(0.26)**	**8.78**	**10.42 (0.18)**	**3.19 (0.03)**	**17.70 (0.25)**	**20.41**	**12.58 (0.21)**	**2.09 (0.02)**
	LSD at 5%	**10.64(0.19)**	**4.33**	**12.39(0.21)**	**5.78(0.06)**	**30.11(0.43)**	**14.65**	**17.37 (0.31)**	**5.32 (0.06)**	**29.51(0.42)**	**34.03**	**20.97 (0.35)**	**3.49(0.04)**
	Fpr	**<0.001 (<0.001)**	**<0.001**	**<0.001 (<0.001)**	**<0.001 (<0.001)**	**<0.001 (0.001)**	**<0.001**	**<0.001 (0.001)**	**<0.001 (<0.001)**	**<0.001 (<0.001)**	**<0.001**	**<0.001 (0.007)**	**<0.001 (<0.001)**
	CV %	**23.50**	**17.30**		**9.90 (0.06)**	**39.80 (35.00)**	**29.60**	**35.00 (33.70)**	**8.50 (5.10)**	**27.90 (26.80)**	**42.40**	**8.50 (5.10)**	**5.20 (3.20)**

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➢ *Figures in Parentheses are Transformed; ASIN(SQRT(E2/100))*

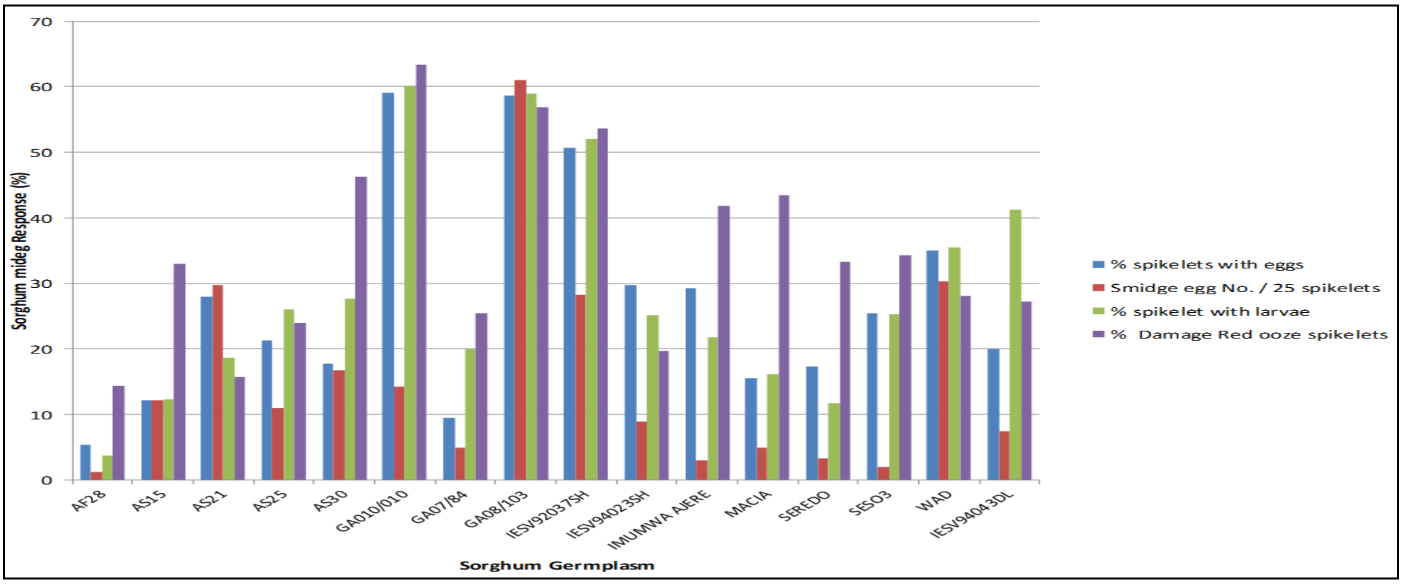

Fig 3 Oviposition by 5 Female Sorghum Midge Flies Infesting 25 Spikelets on Each of the 16 Sorghum Germplasm Under No-Choice Conditions in a Head Cage.

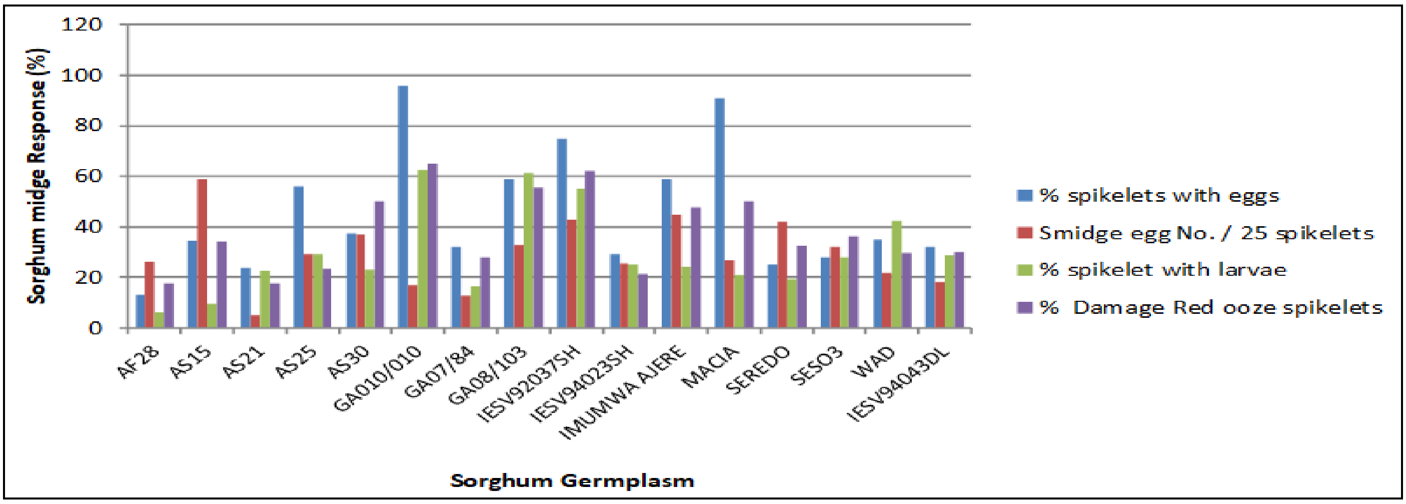

Fig 4 Oviposition by 15 Female Sorghum Midge Flies Infesting 25 Spikelets on Each of the 16 Sorghum Germplasm Under No-Choice Conditions in a Head Cage.

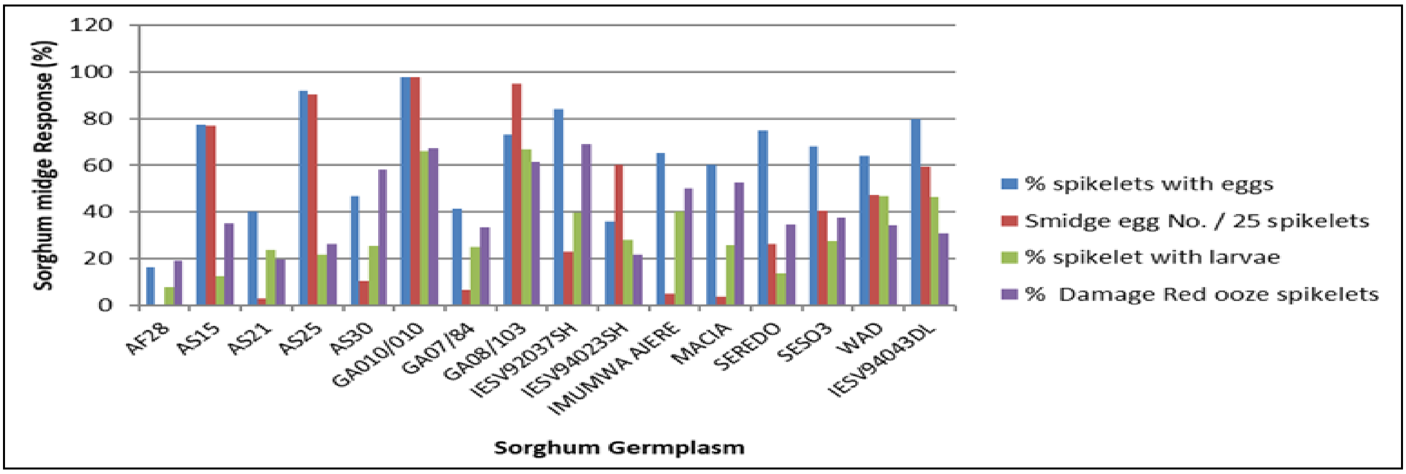

Fig 5 Oviposition by 25 Female Sorghum Midge Flies Infesting 25 Spikelets on Each of the 16 Sorghum Germplasm Under No-Choice Conditions in a Head Cage.

Table 5 Sorghum Spikelet Floral Measurements for Different Sorghum Germplasm

	Glume Linear Measurements								
Germplasm	**Mean upper glume length – GL1 (mm)**	**Mean lower glume length – GL2 (mm)**	**Mean outer glume Breadth – GB1 (mm)**	**Mean inner glume Breadth – GB2 (mm)**	**Exposed portion of lower glume width - EGB2 (mm)**	**Mean style length - SL (mm)**	**GL1/GL2**	**GB2/EGB2**	**GL1*GB1**
AF28	2.064	2.056	1.228	1.19	0.072	0.392	1.00	6.59	2.53
AS15	1.528	1.656	1.056	1.02	0.14	0.68	0.92	2.92	1.61
AS21	1.908	1.848	1.68	1.61	0.088	0.532	1.03	7.30	3.21
AS25	1.712	1.748	1.048	1.01	0.144	0.6	0.98	2.82	1.79
AS30	1.696	1.752	1.112	1.03	0.14	0.76	0.97	2.93	1.89
GA010/010	1.784	1.692	1.124	1.06	0.216	0.904	1.05	1.97	4.20
GA07/84	1.728	1.732	0.972	0.94	0.16	0.592	1.00	2.35	1.68
GA08/103	1.664	1.744	1.136	1.11	0.132	0.628	0.95	3.36	1.89
IESV92037SH	1.892	1.744	1.112	1.05	0.2	0.812	1.08	2.11	2.10
IESV94023SH	2.108	2.104	1.328	1.27	0.1	0.608	1.00	5.07	2.80
IMUMWA AJELE	1.692	1.728	1.112	1.08	0.132	0.756	0.98	3.26	1.88
MACIA	1.64	1.812	1.104	1.08	0.208	0.732	0.91	2.08	1.81
SEREDO	1.588	1.708	1.052	0.98	0.192	0.64	0.93	2.04	1.67
SES0 3	1.716	1.660	1.116	1.08	0.136	0.648	1.03	3.19	1.92
WAD	2.088	1.812	1.492	1.39	0.244	0.756	1.15	2.28	3.12
Fpr	0.001	0.001	0.001	<0.001	0.001	0.001	0.001	0.001	0.001
CV%	3.4	3.6	13.70	12.50	5.10	3.0	4.8	13.30	15.50

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