Fall Armyworm (Spodoptera Frugiperda) Infestation on Advanced Sorghum Genotypes Under Field Conditions in Arid And Semi-Arid Areas in Kenya

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Abstract

Fall armyworm (FAW) (*Spodoptera frugiperda)*) continues to cause enormous losses in Sorghum and other cereals in the world. Excessive use of synthetic insecticides to manage the pest poses environmental hazards. The objective of this study was to screen several sorghum genotypes against FAW. A total of 49 sorghum breeding lines from Genetic Resources Research Institute (GeRRI), and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) were screened for FAW resistance. The study was carried out in Koibatek Agricultural Training Centre (ATC) during the 2018/2019 long/short rain seasons. The experiments were laid out in *Alpha lattice* design, 49 x 7, and replicated three times. Sorghum was planted, at a spacing of 75 cm x 20 cm with 3 rows in 2.5 m by 1.5 m plots. Data was collected on larval counts (LC) and grain yield (tons ha^{-1}). Data was subjected to analysis of variance using Statistical software (SAS) version 9.2. Statistical differences among the treatment means for all the variables were compared using LSD test at $p \leq 0.05$. Results indicated that grain yield was 0.88tons ha^{-1} during the first season and 2.44 tons ha^{-1} during the second season. Higher larval count was observed during the whorl stage compared to seedling stage. Mean larval count ranged between 2.90 and 4.49 $plant^{-1}$ during season one and two in Koibatek, ATC. Genotypes GBK - 001103, GBK - 000121 and GBK 000392 had low larval count as well as high yields. Results of this study shows there are promising sorghum genotypes that are tolerant to fall Army worm which can be used in sorghum breeding programs.

Key words*: Fall armyworm, sorghum bicolor, Host plant resistance, Host plant damage, screening for resistance, Biocontrol*

1.0 INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench is a drought tolerant crop that can provide food security in Arid and semi arid areas (ASALs) (USDA, 2017). This potential has however been threatened by biotic and abiotic factors. Biotic factors limiting sorghum production include pests amongst them, Fall army worm (FAW) (*Spodoptera frugiperda* J.E. Smith) (*Lepidoptera Noctuidae*). Fall army worm a native to South America is a new pest first reported in Africa in 2016 in Nigeria, Sao Tome and Togo (Georgen *et al*., 2016). The pest has now spread to Africa, Asia, Europe and Australia (Shylesha *et al*., 2018; Maino *et al*., 2021; Wang *et al*., 2023). Grain yield losses ranging between 22 and 67% have been reported in African countries (Day *et al*., 2017; Kumela *et al*., 2018; De Groote and Bruce, 2020; Kassie, 2020). Factors that cause the successful dispersal and invasion of the FAW is its ability to produce large number of eggs, fly long distances as well as ability to feed on large number of plant crops species though cereals such as maize and sorghum are the major hosts.

Since FAW invasion in 2016, African governments have invested heavily on registered Synthetic insecticides to manage the pest. However, farmers apply high doses (Otim *et al.,* 2020) posing environmental hazards and increased cost of production. Ability of the young larvae to feed at night and hide in the funnel during the day time reduces the effectiveness of the chemicals especially the contact insecticides. There is also high risk of developing resistance to some insecticides molecules (Zhang *et al*., 2021 and Liu *et al.*, 2019). Recent studies in Africa have reported numerous association of FAW with egg, larval and pupal parasitoids such as *Telenomous spp*, *Trichogramma spp*, *Cortesia spp*, *Chelonus* spp (Sisay *et al*., 2018; Laminou *et al.,* 2020; Agboyi *et al*., 2020; Otim *et al*., 2021; Ahissou *et al.,* 2021) but more studies on their effectiveness needs to be carried out. Predators such as Ants (Pheidole spp), beetles (*Cheilomenes* spp), Earwigs (*Doru* spp) (Koffi *et al.,* 2020; Malo and Hore, 2020 and Ahissou *et al.,* 2021) have also been reported in Africa but more studies on their abundance and level of predation needs to be carried out. Entomopathogenic or disease causing organisms such as Fungi, Viruses, and Nematodes are available in the soils and could manage FAW. Studies on Entomopathogens such as *Bacillus thuringiensis*, *Beauveria Bassiana*, *Metarhizium anisopliae*, *Nomuraea rileyi* and *Spodoptera frugiperda multiple* Nucleopolyhedrosis virus (SfMNPV) have been carried out (Akutse 2020; Rajula *et al*., 2021; Russo *et al*., 2021; Fallet *et al*., 2022) but more efficacy studies in the field need to be carried out. Effectiveness of the Entomopathogens is also highly influenced by the environment. Nucleopolyhedrosis viruses (NPV) are highly denatured by ultraviolet light. Plant derived pesticides possess compounds which act as toxicants, antifeedant, repellents or growth inhibitors on insect pests. Neem based *Azadirachta*, *Tephrosia Vogelii* among others have been reported to manage several insect pests (Ogendo *et al.*, 2008; Tavares *et al*., 2010 and Mukui 2013) but only limited field efficacy trials have been carried out on FAW.

Use of resistant sorghum genotypes provides a sustainable management option to manage FAW in sorghum production. Fall armyworm resistant maize lines and Hybrids have already been developed (Prasanna *et al*., 2022) in the background of Maize stem borers resistant traits but only limited research work has been done on sorghum. Use of FAW resistant sorghum genotypes in combination with other FAW management strategies would constitute a tailor made IPM package suitable within an individual farming system and capability of the farmer for sustainability. This study aimed at identifying and validating levels of host plant resistance in currently available Kenyan adapted sorghum germplasm. Forty-nine (49) advanced sorghum lines from Genetic Resources Research Institute (GeRRI), and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) were evaluated against FAW infestation and associated grain yield losses for two seasons in 2018/2019 in Koibatek ATC (Agricultural Training Centre) in Baringo county. The identified FAW tolerant and high grain yield sorghum lines will be used by breeders to improve sorghum production.

2.0 MATERIALS AND METHODS

2.1 Experimental site

This study was conducted in Koibatek Agricultural Training Centre (ATC), in Baringo County, Kenya. Koibatek is a medium altitude zone with an altitude of 1890 m A.S.L in Agro-ecological zone UM4, with low agricultural potential. The station lies within longitude 36^{o} 66' E and latitude 10^{o} 35' S. Average annual rainfall is 767 mm; mean annual minimum and maximum temperature are 10.9^{o}C and 28.8^{o}C respectively. Soils are Vitric Andosols with moderate to high soil fertility and well drained deep to sandy loam soils (Jaetzold and Schmidt, 2011).

2.2 Study Germplasm and Experimental design

This study involved evaluation of 49 sorghum advanced genotypes from Genetic Resources Research Institute (GeRRI), The experiment was carried out for two seasons during May – October 2018 and 2019 in Koibatek. The test entries were planted in three replicates using 49 x 7 *Alpha lattice* experimental design. Each plot consisted of three rows, measuring two meters in length, spaced 75cm between rows and 20cm intra row.

2.3 Data Collection

Fall army worm larval Count during seedling (V3) and whorl stages (V6): The number of larvae plant $^{-1}$ (Larval count) was assessed during the vegetative stage, 30 days after seedling emergence when there was infestation and at the whorl stages by pulling the whorl leaf from 5 infested plants selected randomly and unfolding the leaves to expose and count the FAW larvae (Anderson and Cherry, 1983). This was repeated after 10 days and was carried out three times during the whorl stage.
Grain yield (tons Ha^{-1}): Grain yield was obtained by harvesting the middle row per plot.

2.4 Data Analyses

Data on Fall army worm larval count was transformed using square root transformation before being subjected to ANOVA using Statistical software (SAS) version 9.2. Treatment means for transformed data were separated using LSD ($p \leq 0.05$).

3.0 Results

3.1.3 Fall Army worm Larval count

Results from this study showed significant ($P \leq 0.05$) genotypic variation for both larval count (grain yield in Koibatek, ATC during seasons one (2018) and two (2019) (Table1.0). Higher grain yield was observed in season one, 2.44±0.07tons ha^{-1} compared to season two, 0.88±0.03 tons ha^{-1}. Genotypes GBK-001103 and GBK-000121 had the highest grain yields (2.29, 2.14 tons ha^{-1} during seasons one and two respectively), compared to susceptible check, KARI Mtama 1 (0.05 tons ha^{-1}, 1.62 tons ha^{-1} during seasons one and two respectively). GBK-000392 had higher grain yields of 4.19 tons ha^{-1} during season one compared to season two, 2.86 tons ha$^{-1.}$ Higher larval count was observed during the whorl stage (V6), (4.49±0.14, 2.94±0.13 larvae plant^{-1} during seasons one and two respectively) compared to seedlings stage V3, (3.09±0.11, 2.90±0.08 larvae plant^{-1} during seasons one and two respectively), Table 1.0. Higher larval count was observed during season one in (3.09±0.11, 4.49±0.14 larvae plant^{-1} during seedlings stage (V3) and whorl stage (V6) respectively compared to season two (2.90±0.08, 2.94±0.13 larvae plant^{-1} during seedlings stage (V3) and whorl stage (V6) respectively). Genotype GBK- 001103 had low larval count (2.33, 3.33 larvae plant $^{-1}$ during seedling stage (V3) and whorl stage (V6) respectively) compared to susceptible check, KARI Mtama 1 susceptible check (3.33, 6.67 larvae plant^{-1}). Similar low larval count (2.33, 1,33 larvae plant $^{-1}$) was observed during season two for this genotype. (Table 1.0).

Table 1.0: Fall army worm, larval count, and grain yield of selected sorghum breeding lines in Koibatek, Kenya (2018/2019)

	Season one May /October 2018			**Season two (2019) May/October 2019**		
Genotype	**Larval count (larvae plant^{-1})**		**Yield (tons ha^{-1})**	**larval count (larvae plant^{-1}**		**Yield (tons ha^{-1})**
	Seedling stage(V3)	**Whorl stage(V6)**		**Seedling stage(V3)**	**Whorl stage(V6)**	
GBK-001103	2.33^{defg}	3.33^{efgh}	2.29^{a}	2.33^{defg}	1.33^{f}	2.33^{fghi}
GBK -000121	1.67^{fg}	5.67^{abcd}	2.14^{ab}	1.67^{fg}	2.33^{cdef}	2.37^{fghi}
GBK-037565	1.33^{g}	4.33^{bcde}	1.67^{cdef}	1.33^{g}	2.0^{def}	2.48^{fghi}
GBK-044672	1.67^{fg}	5.00^{abcd}	1.53^{defg}	1.67^{fg}	2.0^{def}	3.2^{bcde}
IS 21055	2.67^{cdef}	3.33^{efgh}	1.30^{fghi}	2.67^{cdef}	1.67^{ef}	3.92^{abc}
GBK-000392	3.00^{bcde}	4.33^{bcde}	2.86^{klmn}	3.00^{bcde}	2.67^{bcde}	4.19^{ab}
KARI Mtama 1(SC)	3.33^{abcd}	6.67^{a}	0.05^{v}	3.33^{abcd}	4.00^{abc}	1.62^{nopq}
LSD ($p \leq 0.05$)	**1.64**	**2.05**	**0.47**	**1.89**	**1.97**	**1.08**
CV (%)	**24.55**	**21.19**	**24.02**	**30.3**	**30.97**	**20.6**
Mean ±SE	**3.09± 0.11**	**4.49±0.14**	**0.88±0.03**	**2.90± 0.08**	**2.94± 0.13**	**2.44± 0.07**
Source of variation						
Block (Group)	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
Genotype (GE)	**0.002**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**

KEY: Scoring scale, 1 to 9 scale, where score 1, <10% leaf area damaged, 9>80% leaf area damage, where 1-2 highly resistant, 3-4 resistant, 4-5 moderately resistant, 5-6 intermediate, 6-7 moderately susceptible, 7-8 susceptible, and 9-highly susceptible. SC=susceptible check; Yield=Grain yield tons ha^{-1}; SE = Standard error; GE=Genotype; means in the same column followed by the same letter are not significantly different ($P \leq .05$); **NB:** Genotypes presented represent best performing and FAW resistant lines amongst 49 genotypes evaluated.

Discussion

There was a significant ($P \leq 0.05$) genotypic variation for both larval count and grain yield in Koibatek, ATC during seasons one (2018) and two (2019). This showed that FAW infestation and grain yield were largely influenced by the different genotypes. Higher grain yield during season two compared to season one could have been caused by low FAW larval infestation and larval count observed during that season. Very high larval count during season one was observed and could have resulted in low yields. A similar seasonal variation on FAW infestation was observed by Sisay *et al*. (2019) in Ethiopia, Kenya and Tanzania. Overall, higher larval count was observed during the whorl leaf stage (V6) compared to seedling stage (V3) in Koibatek during seasons one and two. As the season starts and progresses, there is a progressive build-up of pest population along the growth stages of the crop which also influence the level of infestation and damage. Fall Armyworm damage normally progresses during the growing season with small and tiny holes made by few young larval instars and this damage progresses further with larger lagged holes produced by many grown instar larvae (Venkateswarlu *et al*., 2018). Niassy *et al*. (2021) also reported a similar trend of high FAW adult and larval population during the vegetative and reproductive stage compared to maturity stage. Seasonal variation across seasons was also observed with high larval count during the first season in Koibatek compared to Second season in Koibatek. Lower larval count observed during the second season (May 2019/October 2019) in Koibatek compared to first season (May 2018/October 2018) could have been caused by heavy rainfall (Appendix 2) that could have washed and drowned the larvae in the funnels in Koibatek. Low temperatures observed during the second season could have reduced the larval count since their optimum temperature ranges between 26^{o}C and 30^{o}C (Du Plessis *et al*., 2020). Genotypes GBK-001103 and GBK- 000121 had low larval count and high yields during season one compared susceptible check, KARI Mtama one. Similarly GBK-000392 had high grain yield during season two. GBK - 037565 had low larval counts during seasons two.

Conclusions and Recommendation

Data from this study shows that Genotypes GBK-001103, GBK- 000121 and GBK - 037565 had low FAW infestation and high grain yields and could be tolerant to FAW infestation. GBK-000392 had high yields in season two compared to season one showing that it could be more stable in season two in Koibatek, ATC. Further field evaluations and validation of FAW resistance in High yielding and FAW resistant genotypes such as GBK-001103, GBK- 000121 and GBK - 037565 GBK-000392, should be carried out for further sorghum breeding improvements initiatives. More germplasm could also be evaluated to increase resistant genotypes and improve others resistance and agronomic traits.

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APPENDICES

Appendix I: List of Evaluated Germplasm

	Genotype	Source		Genotype	Source
1	GBK -000121	GeRRI	26	GBK-001106	GeRRI
2	GBK -000975	GeRRI	27	GBK-013089	GeRRI
3	GBK-000010	GeRRI	28	GBK-013122	GeRRI
4	GBK-000120	GeRRI	29	GBK-013132	GeRRI
5	GBK-000123	GeRRI	30	GBK-037565	GeRRI
6	GBK-000124	GeRRI	31	GBK-044625	GeRRI
7	GBK-000387	GeRRI	32	GBK-044647	GeRRI
8	GBK-000389	GeRRI	33	GBK-044653	GeRRI
9	GBK-000391	GeRRI	34	GBK-044672	GeRRI
10	GBK-000392	GeRRI	35	GBK-044693	GeRRI
11	GBK-000412	GeRRI	36	IESV 92036 SH	ICRISAT
12	GBK-000424	GeRRI	37	IESV 92042 SH	ICRISAT
13	GBK-000425	GeRRI	38	IESV 24029	ICRISAT
14	GBK-000426	GeRRI	39	IESV 92022/1 SH	ICRISAT
15	GBK-000444	GeRRI	40	IESV 92030 SH	ICRISAT
16	GBK-000445	GeRRI	41	IESV 92041 SH	ICRISAT
17	GBK-000446	GeRRI	42	IS 21055	ICRISAT
18	GBK-000447	GeRRI	43	IS 8193	ICRISAT
19	GBK-000936	GeRRI	44	IS2108	ICRISAT
20	GBK-000943	GeRRI	45	KARI Mtama 1	KALRO (COMMERCIAL)
21	GBK-000946	GeRRI	46	SIAYA-6-1	LOCAL
22	GBK-000973	GeRRI	47	WAGITA	LOCAL
23	GBK-000979	GeRRI	48	BUSIA 21	LOCAL
24	GBK-000983	GeRRI	49	BUSIA 30-3	LOCAL
25	GBK-001103	GeRRI			

Appendix 2: Weather data, ATC, Koibatek Weather station during the 2018/2019 growing season

Year	Month	Rain.mm	Max.Temp (0c)	Min Temp(0c)	Rel. Hum
2018	May	349.5	21.81	9.00	48.70
2018	June	45.8	28.20	10.50	43.20
2018	July	0	21.10	10.00	56.30
2018	August	324.2	19.20	10.00	58.80
2018	September	21.5	16.20	10.20	63.20
2018	October	125.8	15.20	9.00	65.40
2019	May	87.65	12.30	9.00	73.20
2019	June	402.5	10.20	8.00	61.00
2019	July	131.8	16.70	9.00	75.30
2019	**August**	**189**	22.10	10.00	60.40
2019	**September**	**167.9**	18.10	11.00	51.10
2019	**October**	**211.8**	22.30	12.00	60.80