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Effect of variety and nitrogen fertilization on insect pest incidence in *Sorghum* in the Sudan Savanna of Ghana.

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Abstract
Studies were conducted at Yinduri in the Sudan Savanna zone of Ghana to evaluate the effects of nitrogen (N) fertilization on insect infestation and damage to *Kapaala*,(an improved *Sorghum* variety released by the Council for Scientific and Industrial Research (CSIR)) and *Kundabua*, the popular land race grown by farmers in the study area. Both varieties supported similar levels of shootfly (*Atherigona soccata*) attack (deadhearts) but N application increased *Dead Heart* prevalence in a dose-dependent manner, the increase being more pronounced on *Kapaala*. *Kundabua* supported significantly lower mrid bug (*Eurystylus oldi)* population and thus suffered lower grain quality loss (viability, grain mass) than *Kapaala.* Application of N to the crop increased infestation and damage by headbugs as was the case for shootfly. *Kapaala* produced significantly higher yield. The grain yield also increased with N application from 1.08 t/ha at 0 N to 1.48 t/ha at 100 N for *Kapaala* compared to 0.95 t to 1.16 tons/ha for *Kundabua.* These studies confirm the higher yield potential of the improved variety as well as its greater susceptibility to head bugs, probably the most important panicle pest of *Sorghum* in Ghana today. The importance of N fertilizers to increased *Sorghum* production was also demonstrated with a caution to limit application rate to below 50 kg to minimize adverse effects of insect pests and maintain or improve grain quality.

Keywords: *Sorghum*, fertilizers, insect pests, mirid head bugs, integrated pest management

1. Introduction
Insect pests are a major constraint to increased *Sorghum* production in West Africa, with over 100 species recorded [1, 2]. In Ghana, the plant is attacked by pests at virtually all phenological stages. However, only a few of these are considered to be economically important among which are stem borers, shootfly, *Atherigona soccata*, Rondani (Diptera: Muscidae), spittle bugs, *Boophilus spp, Locris Rubra* (Hemiptera: Aprophoidae), midge, *Stenodiplosissorghicola*, Coquillett (Diptera: Cecidomyiidae) and a complex of pentatomid and mirid head bugs [3, 4, 5, 6]. Changes in varietal susceptibility and farming systems have over the years induced a greater incidence of panicle feeding insects, resulting in low adoption of improved varieties by farmers. These improved varieties however are believed to hold the key to increased and sustainable *Sorghum* production as they combine early maturity with higher yields and possess better potentials for commercial exploitation and industrial utilization.

Developing effective and sustainable IPM packages for key pests of the crop has thus become a priority for research and development workers, especially in Northern Ghana where the bulk of the crop is cultivated. As a largely subsistence crop, such packages must have their foundations in indigenous knowledge and cultural practices employed by farmers over the years. Many cultural practices have been shown to reduce pest incidence and damage to *Sorghum* in Ghana among which are manipulating date of planting to create phonological asynchronies [7, 6, 8], use of crop rotations [9], management of crop residue to reduce dry season carryover [10 8, 6], intercropping with non-hosts and use of optimum agronomic practices such as soil fertility management [5, 6]. Nitrogen deficiency, and generally low soil fertility, are some of the most important constraints in *Sorghum* production and various measures have been recommended for providing good soil conditions for increased production. The advent of the green revolution in Ghana brought in its wake increased use of agrochemicals notably pesticides and fertilizers. It is recommended to apply N to *Sorghum* at rates ranging from 40 – 100 kg/ha [11, 12] and even though this has contributed to increased levels of production in the short term, the long term negative effects have since been questioned.

There is therefore the need to define levels and frequency of use of these inputs that increase yield sustainably and have a less negative impact less on the various agroecosystem services. As noted by [13], despite the potential links between soil fertility and crop protection, the evolution of integrated pest management (IPM) and integrated soil fertility management (ISFM) have proceeded separately globally. There is however the need to integrate these in order to maximize synergism and minimize adverse consequences. This paper reports studies conducted in the Sudan Savanna zone of Ghana on the effects of nitrogen fertilization on pest incidence and yield of improved and local *Sorghum* varieties.

2. Materials and methods

Two *Sorghum* varieties (*Kapaala* and *Kundabua*) were subjected to four levels of nitrogen fertilizer application during the cropping seasons of 2011 and 2012 at Yinduri in the Talensi District of the Upper East Region of Ghana. *Kapaala* is an improved caudatum type *Sorghum* variety developed by the Council for Scientific& Industrial Research (CSIR), Ghana while *Kundabua* is a popular *Sorghum* landrace cultivated widely in the area. The four levels of N applied were 0, 25, 50 and 100 kg N/ha applied as Urea four weeks after planting (WAP). Varieties constituted the main plots with N levels as subplots. Each treatment was replicated four times in plots consisting of 7 rows, each measuring 10 m long. Rows were constructed using a fixed mouldboard ridger to give a spacing of 0.75 m between rows. Within-row spacing was 20 cm between plant stands. The same experimental procedure was followed in 2012 except that the experimental design was changed from split-plot to a factorial randomised complete block design (RCBD) to study more closely, the relationship between variety and sowing date and give both equal emphasis. The whole experimental area was treated with NPK fertilizer during land preparation at the prevailing recommended rate for the crop. All other recommendations for *Sorghum* cultivation in the northern savannah were followed except for pest control.

Data on shootfly infestation (% deadhearts) was collected at 6 weeks after emergence (WAE) by counting the total number of deadhearts in the three inner-most rows of each plot and dividing by the total number of plants in the same area. Weekly from flowering, 5 panicles each from rows 2 and 5 of each plot were randomly harvested in to polythene bags and sent to the laboratory for assessment of head bug population and damage. Midge damage was estimated as a percentage of the total number of chaffy panicles showing white pupal cases. At maturity, all panicles in the three inner rows of each plot were harvested and observations recorded on grain yield, percentage floaters (light grain) and percentage germination. Seed viability and percent light grain were used as indicators of grain damage due to head bug feeding.

Data on insect pest incidence/damage, grain yield and quality were subjected to two way ANOVA using statistix package and means compared at 5% using Least Significant Difference (LSD) technique.

3. Results

In both the cropping seasons, midge and stem borer damage were negligible and have therefore not been included in the results and analysis**.** In 2011, crop damage due to shootfly was similar in both varieties but significantly higher at N levels above 25 kg N/ha (Table 1). Shootfly damage increased with increasing N levels but was significantly higher in treated plots than in control plots only when 100 kg N was applied per hectare. Interaction effects were insignificant

The predominant head bug was *Eurystylusoldi* during both years though *Creatiadespallidus* was also recorded in a few panicles. There were significant differences between varieties and among N rates (Table 1). *Kapaala* panicles supported significantly higher head bug population than *Kundabua* at both the milky and dough stages of grain development. N increased head bug population at greater levels on *Kapaala* especially during the milky stage of grain development

The variation in head bug population resulted in significant difference in the percentage grain between varieties and also among N rates (Table 2). All N levels resulted in significantly higher proportion of light grain than the controls. *Kapaala* showed greater % light grain (27%) than *Kundabua* (20%) and also suffered more damage as the levels of N applied to the crop was increased.

Kapaala produced significantly higher grain yield than *Kundabua* (Table 2). N application significantly increased yield of both varieties in a dose-dependent manner but interaction effects between variety and N levels were insignificant. Grain yield for *Kapaala* increased from 1.08 t/ha at 0 N to 1.48 t/ha at 100 kg N/ha compared to *Kundabua* where yields ranged from 0.95t to 1.16 tons at 0 and 100 kgN/ha respectively. Plants receiving N levels above 25Kh/ha produced grain that had significantly lower viability than the controls. *Kundabua,* the local variety produced significantly higher percentage of viable grain (73%) than *Kapaala* (65%) but interaction effects between variety and N levels were not significant. The results for 2012 followed the same trend with the highest shootfly damage, (32%), recorded in Kapaala plots receiving 100 kgN/ha. This was significantly higher than the 24% damage recorded for the same treatment for *Kundabua*.

Table 1: Insect incidence and damage as affected by variety and N application – 2011

Variety	% Deadhearts					Mirid bugs/panicle (MS)*					Mirid bugs/panicle (DS)*				
	0	25	50	100	Mean	0	25	50	100	Mean	0	25	50	100	Mean
Kapaala	24.5	25,5	28.0	28.0	**26.5**	15.5	13.4	33.0	30.0	**23.0**	14.9	16.3	19.4	21.0	**17.9a**
Kundabua	17.2	19.8	19.0	28.8	**21.0**	16.1	15.2	15.1	18.1	**16.1**	10.9	11.9	13.4	13.0	**12.3b**
Mean	**20.9**	**22.7**	**23.5**	**28.0**		**15.8**	**14.3**	**24.1**	**24.1**		**12.9b**	**14.1ab**	**16.4a**	**17.0a**	
LSD 0.05 V	6.7					4.8					3.6				
N	5.3					3.7					3.2				

*Figures followed by the same letter in a row and also column are not significantly different at p =0.05

Table 2: Grain yield and quality as affected by variety and N application – 2011

Variety	Grain yield kg/ha 0 25 50 100 Mean	% light grain 0 ,25 50 100 Mean	% germination 0 25 50 100 Mean
Kapaala	1.08 1.34 1.65 1.85 **1.48a**	19.3 25.0 30.0 33.0**26.9a**	68 68 60 64**65.0b**
Kundabua	0.95 1.181.201.29 **1.16b**	9.6 19.2 20.0 29.3**19.5b**	78 75 68 70**72.8a**
Mean		**14.5c22.1b 25.0b 31.2a**	**73.0a 71.5ab 64.0c67.0b**
LSD 0.05 V	0.26	9.6	6.7
N	0.22	5.4	5.3

Figures followed by the same letter in a row and also column are not significantly different at p =0.05

Table 3: Insect incidence, damage and grain yield parameters as affected by Variety and N application – 2012

Treatment	% deadhearts	Mirid bugs /panicle (MS)*	Mirid bugs /panicle (DS)*	Grain yield t/ha	% light grain	% viability
Kapaala + 0 N	19.0cd	16cd	20bc	1.10bc	22.0ab	72ab
Kapaala + 25 N	18.0d	21bc	25.5ab	1.12bc	19.8b	75ab
Kapaala + 50 N	23.0bc	20bc	28a	1.30ab	26.5a	69b
Kapaala + 100 N	32.0a	35a	31a	1.35a	30.5a	66b
Kundabua + 0 N	18.0d	11d	17c	0.99c	14.0b	84a
Kundabua + 25N	16.5d	14d	20bc	1.07c	14.5b	82a
Kundabua + 50 N	16.8d	18bc	19c	1.10bc	22.5ab	78ab
Kundabua + 100 N	24.0b	26b	29a	1.18bc	22.8ab	70b
LSD (0.05%)	4.8	6.5	6.0	0.22	9.3	12.4

*****Figures followed by the same letter in a row and also column are not significantly different at p =0.05

Nitrogen application also appeared to increase shootfly damage to *Kapaala* in a dose-dependent manner though the difference was not always significant, but for *Kundabua* only the highest N rate showed that effect. For head bugs also, the highest population at the milky stage was recovered from panicles of *Kapaala* plants treated with 100 kg N/ha (35 bugs/panicle) followed by *Kundabua* at same N level (26 bugs/panicle). Application of N to *Kundabua* increased head bug population significantly only at 50 kg N/ha. *Kapaala p*lants receiving 100 kg N/ha produced the highest yield but also had significantly higher % light grain and lower seed viability than the other treatment combinations (Table 3). On the other hand treatment combinations involving *Kundabua* and 0 and 25 kg N/ha produced the seeds with the highest germinability and grain mass as measured by % light grain.

4. Discussion

Kapaala, the improved variety supported higher population of mirid head bugs and infestation level also increased with increasing N application. The higher head bugs population also resulted in greater decrease in grain quality, especially viability and grain mass. These results confirm earlier findings that land races and local farmer varieties are often more adapted to their local conditions and therefore tend to be more resistant or tolerant to local insect pests [14]. *Kapaala* is a *caudatum* type *Sorghum* with a compact panicle architecture while *Kundabua* is of the guinense type with loose droopy heads. The former are known to provide ideal conditions for habitation and reproduction by headbugs and are thus often more susceptible [15, 16]. In fact, [17] recorded 2-4 times more *E. immaculatus* adults and nymphs on panicles of caudatum type varieties than on local guinense types in Nigeria while in Ghana, [18] recorded higher population of mirid bugs on two caudatum varieties compared with *Kobori*, a local variety with loose droopy panicles.

Soil fertility management can have several effects on plant quality, which in turn, can affect insect abundance and subsequent levels of herbivore damage. This can result from influence of the nutrients on survival, oviposition, growth rates, and reproduction in the insects that use these hosts [13]. [19] reviewed 50 years of research relating to crop nutrition and insect attack and found that of over 180 studies, 135 showed increased infestation and/or damage by insect herbivores in N-fertilized crops compared with fewer than 50 studies in which herbivore damage was reduced by normal fertilization regimens. Also [20] reported that of the 100 studies he reviewed, two thirds showed an increase in insect growth, survival, reproductive rate, population densities or plant damage levels in response to increased N fertilization. The other third of the arthropod studies showed either a decrease in damage with fertilizer N or no significant change.

Results from the current studies agree with the majority of these studies as high N levels increased infestation and damage to *Sorghum* by shootfly and head bugs.

Nitrogen application to *Sorghum* increases seedling growth rate and succulence and this could increase attractiveness to ovipositing shootfly and/or increase susceptibility to infestation. In fact, a significant positive correlation has been shown to exist between seedling plant height and incidence of *A. soccata* [21, 22]. (Chawanpong M *et al* 1984) [23] reported higher shootfly oviposition on *Sorghum* seedlings following application of nitrogen, while [24] observed a positive association between levels of nitrogen in *Sorghum* seedlings and *A. soccata* oviposition, feeding and dead heart formation. The current results also agree with [17] who reported that *Sorghum* receiving high doses of N were more susceptible to headbug attack and suffered heavier losses. Recommended rates of nitrogen fertilizer for *Sorghum* production in Ghana have ranged between 40 – 100 kg N/ha [11]. Results from this study indicate that rates beyond 50 kg/ha increase pest damage and may thus be counterproductive from the technical as well as economic points of view. This would be in line with [12] who found 45 kgN/ha the most economical fertilizer rate for *Sorghum* production in the Sudan savannah of Ghana.

5. Conclusion

The present study clearly shows that the improved variety *Kapaala* is more susceptible especially to mirid head bug *E. oldi* which can cause significant loss in grain yield and quality. It can also be concluded that fertilizer application increases grain yield in both improved and local varieties, the effect being more pronounced in the former. However, the application rate above 50 kg N/ha may cause increase in insect incidence and damage.

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