Insect Incidence and Damage on Pearl Millet (Pennisetum glaucum) Under Various Nitrogen Regimes in Alabama

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Insect incidence and damage on pearl millet *(Pennisetum glaucum*) under various nitrogen regimes in Alabama

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Abstract

Although pearl millet [*Pennisetum glaucum* (L.) R. Br.; Poales: Poaceae] is grown extensively on 5 continents and is attacked by various insects at all stages of growth and development, little is specifically known of how yields of this important crop are affected by insect herbivory. This study was conducted in north central Alabama to determine insect occurrence on pearl millet and to determine the levels of damage caused by insects feeding on pearl millet genotypes at different nitrogen rates. The field experiment was laid out following a randomized complete block design with 4 replications in which 4 genotypes and 4 fertilizer levels were arranged in factorial combinations. The pearl millet genotypes consisted of 2 open pollinated lines, '2304' and 'LHBO8', and 2 hybrids, '606A1*2304' and '707A1*4280' and fertilization rates used were 0, 40, 80 and 120 kg ha^{-1} N. Insect samplings were carried out weekly from 61 to 109 days after planting (DAP). Insects in 6 orders and 11 families were found on pearl millet genotypes. Eastern leaf-footed stinkbug (*Leptoglossus phyllopus* (L.); Hemiptera: Coreidae) was the most prevalent and dominant insect species found followed by the American bird grasshopper (*Schistocerca americana* Drury; Orthoptera: Acrididae) and the differential grasshopper (*Melanoplus differentialis* (Thomas: Orthoptera: Acrididae). Population of *L. phyllopus* was at its peak during the latter part of the growing season from 81 to 109 DAP. Populations of *S. americana* and *M. differentialis* declined as crop matured (61 DAP > 66 DAP >75 DAP). Results also showed that leaf and head damage did not differ among genotypes and nitrogen rates tested.

Key Words: Pearl millet; insects; genotype; nitrogen

Resumen

Aunque el mijo perla [*Pennisetum glaucum* (L.) R. Br.; Poales: Poaceae] es cultivado ampliamente en los 5 continentes y es afectada por varios insectos en todas las etapas de crecimiento y desarrollo, poco se sabe en concreto de cómo los rendimientos de este importante cultivo son influidos por insectos herbívoros. Sin embargo, aproximadamente el 15 por ciento del daño de la panícula en el mijo perla puede resultar en pérdidas económicas. En consecuencia, en el sureste de los EE.UU., existe la necesidad de determinar cuales son las plagas que están presentes durante la epoca de crecimiento y determinar su impacto en el rendimiento del mijo perla, un cultivo que en las últimas décadas ha llegado a jugar un papel importante en la agricultura de Estados Unidos como una fuente de alimentos para animales, forraje, pastos y otros alimentos. Se realizó este estudio en el nor-centro de Alabama para determinar la ocurrencia de insectos en el mijo perla y determinar los niveles de daños causados por los insectos que se alimentan de los cultivares de mijo perla en diferentes dosis de nitrógeno. El experimento de campo fue establecido siguiendo un diseño de bloques completos al azar con 4 repeticiones en la que 4 genotipos y 4 niveles de fertilización fueron dispuestos en combinaciones factoriales. Los genotipos de mijo perla consistieron en 2 líneas de polinización abierta, ‹2304› y ‹LHBO8›, y 2 híbridos,›606A1*2304› y ‹707A1*4280 ‹ y las tasas de fertilización utilizadas fueron 0, 40, 80 y 120 kg ha-1 N. Se realizó el muestreo de los insectos semanalmente 61-109 días después de la siembra (DDS). Se encontraran insectos en 6 órdenes y 11 familias en las variedades de mijo perla. El chinche con patas en forma de hojas (*Leptoglossus phyllopus* (L.); Hemiptera: Coreidae) fue la especie más prevalente y dominante de insectos que se encuentran seguido por el saltamonte pájaro americano (*Schistocerca americana* Drury; Orthoptera: Acrididae) y el saltamonte diferencial (*Melanoplus differentialis* Thomas (Orthoptera:. Acrididae). La población del *L. phyllopus* fue la maxima durante la última parte de la temporada de crecimiento 81-109 DDS. La población de *S. americana* y *M. differentialis* disminuyó mientras que el cultivo maduró (61 DDS > 66 DDS > 75 DDS). Los resultados también mostraron que el daño a la hoja y a la cabeza no fue diferente entre los genotipos y las dosis de nitrógeno probadas.

Palabras Clave: mijo perla; insectos; genotipo; nitrógeno

Pearl millet (*Pennisetum glaucum* (L.)R. Br.; Poales: Poaceae) is grown on 5 continents including Asia, Africa, North America, South America and Australia, while its use varies from one continent to another. It is estimated that 26 million hectares of pearl millet are grown in Africa and India as food grain (Gulia et al. 2007). In the United States, about 607,000 hectares of pearl millet are cultivated annually mostly

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in North Dakota, Nebraska, South Dakota and in some southeastern states including Georgia and Florida where it is used as hay and a summer grazing crop (Dewey et al. 2009). Pearl millet is also grown for other purposes such as pasture, silage, food, building material, seed crop and fuel (Baker 1993). The commercial use of pearl millet in the United States began in early 1990s, although the crop was introduced in South Dakota during the early 1980s (Sedivec & Schatz 1991). The crop has nutritional benefits and is a good source of protein, crude fiber, calcium and phosphorous for animal feed. The protein content of pearl millet is higher than that of maize (*Zea mays* L.; Poales: Poaceae); it ranges from 27% to 32% and also has a higher energy content (Ejeta et al. 1987; Davis et al. 2003) compared to wheat (*Triticum aestivum* L.; Poales: Poaceae), maize and sorghum (*Sorghum bicolor* (L.) Moench; Poales: Poaceae) (Hill & Hanna 1990). In the southeast, early-maturing hybrids can be planted from late April to early August (Wilson et al. 2006). The plant attains physiological maturity at 75 to 85 days after seed germination (Dewey et al. 2009).

Pearl millet has been reported to give appreciable yield with low nutrient availability and higher yield with increased fertilizer application (Gascho et al. 1995). A boost in grain yield was reported by Maman et al. (1999) and Limon-Ortega et al. (1998) when nitrogen was applied at 78 kg ha^{-1}. According to Menezes et al. (1999), a nitrogen rate of 112 kg ha^{-1} was found to be optimal for high grain yield. However, yield can be reduced irrespective of N-fertilizer application under late planting (Rurinda et al. 2014) and drought conditions (Bashir et al., 2014).

Pearl millet and sorghum, being C4 species, have high photosynthetic efficiencies, high dry matter production ability (Rai et al. 1999) and closely related developmental stages (Maman et al. 2004). It is estimated that 30% of yield loss in sorghum is due to insect pest and pathogen attack (Reddy & Zehr 2004). Nwanze & Harris (1992) reported that less than 12 insect species are of economic importance on pearl millet in West Africa, although millet can attract up to 150 insect species. Agriculture in the southeastern U.S. has been threatened by stink bugs such as *Euschistus servus* (Say) (Hemiptera: Pentatomidae), *Leptoglossus phyllopus* (L.) (Hemiptera: Coreidae) and southern green stink bug (*Nezara viridula* (L.); Hemiptera: Pentatomidae). They are considered primary pests on grains, fruits, seeds and vegetable crops (Schaefer & Panizzi 2000). Chinch bug and European corn borer are known for causing significant damage to pearl millet (Andrews et al. 1996), but according to Kennedy (2002) and Hudson (1995), chinch bug causes the most damage in pearl millet fields, especially when grown closer to maize or sorghum fields, since the insect can quickly move to the later-planted pearl millet.

Insect damage in pearl millet can occur on foliage, flowers as well as seeds, and has been recorded across all plant growth stages, i.e., 3rd leaf stage, 5th leaf stage, head initiation, flag leaf stage, boot stage, 50% stigma emergence, milk stage and dough stage (Maiti & Bidinger 1981). Before any insect control strategy is implemented, an assessment of insect occurrence and impact needs to be conducted to establish the economic threshold of the insect damage (Youm & Owusu 1998). Therefore, with increased interest in growing pearl millet because of its broad uses, the objectives of this study were to determine occurrence of insect pests from emergence to physiological maturity, and to identify and assess potential damage of major species on various pearl millet genotypes under different levels of nitrogen fertilization.

Materials and Methods

This study was conducted at Alabama A & M University's Winfred Thomas Agricultural Research Station (WTARS) located in Hazel Green, Alabama (N 34° 54' 57.600" W 86° 38' 49.600"; 248.1 m). The experiment was arranged in a randomized complete block design with 4 replications in which genotypes and N fertilizer levels were allocated plots in factorial combinations. Each plot measured 3.05 × 1.14 m and seeds were sown at the rate of 5 kg ha^{-1} at a spacing of 12.7 cm within row and 70 cm between rows. The genotypes consisted of two open-pollinated lines, '2304' and 'LHB08' and 2 hybrids, '606A1*2304' and '707A1*4280'. The plots were planted on 7 June, 2010 and nitrogen treatments of 0, 40, 80, and 120 kg ha^{-1} were applied upon crop establishment.

The plants were monitored for insect incidence from the time of emergence to harvest (14 Oct 2010). The insect sampling on weekly interval was carried out starting booting stage (pre-emergence of head) when insect density on plant became noticeable and carried through plant maturity. Insect sampling was carried out between 8:00 a.m. and 11:00 a.m. on 5 randomly selected plants along a diagonal transect positioned across each plot. The insects were collected using sweep net and by shaking the heads/panicles into transparent plastic bags. The insect samples were placed in a standard freezer for storage, subsequent insect count and identification.

Damage to foliage was determined and rated on a 0 to 5 scale where 0 = no damage, 1 = less than 25% of leaves damaged, 2 = more than 25% of leaves damaged but less than 50%, 3 = more than 50% of leaves damaged but less than 75% and 4 = more than 75% of leaves damaged but less than 100% and 5 = 100% of leaves damaged. Percentage leaf damage was the relative percentage of leaf damaged on the entire plot in relation to the canopy. At maturity, a similar scale was used to assess the head damage. Head damage is the cumulative ratio of damaged panicle to the total number of panicles within each plot.

At harvest, 5 randomly selected plants were cut at ground level, panicles removed and remainder dried to a constant weight individually for vegetative dry weight $plant^{-1}$ estimation. The whole plots were harvested for estimation of grain yield. Insect count was transformed using log_{10} before analysis. Data were analyzed using General Linear Model (GLM) procedure in Statistical Analysis System (SAS) package ver. 9.3. Treatment means were separated using Duncan's Multiple Range Test at < 0.05.

Results

PEST AND BENEFICIAL INSECT SPECIES ON PEARL MILLET

Pest and beneficial insects belonging in 6 orders and 12 families were found to occur on pearl millet. Pest species collected were eastern leaf-footed stinkbug (*L. phyllopus*), Brown stink bug (*E. servus*), American bird grasshopper (*S. americana*), differential grasshopper (*M. differentialis*), Corn earworm (*H. zea*), and margined blister beetle (*E. pestifera)*. The beneficial insects identified include Sweat bee *(Halictus spp.),* Honey bee (*Apis mellifera)*, Pink spotted lady bird beetle (*Coleomegilla maculata)*. While some of the beneficial insects are associated with pollination others are natural feeders of insect pests. The list of insect species and the crop stages of occurrence are shown in Table 1.

NITROGEN

The rate of nitrogen applied did not significantly affect leaf damage across the genotypes (Table 2). However, incidence of different insects varied with nitrogen and genotypes. The pattern observed for *L. phyllopus* indicated high frequency for all 4 nitrogen rates, on all 4 genotypes and nitrogen rates. The number of *L. phyllopus* increased with increasing N levels (0 kg ha^{-1} < 40 kg ha^{-1} < 80 kg ha^{-1}< 120 kg ha^{-1}) as shown in Fig. 1. *Schistocerca americana* was the second most domi-

Table 1. Insect species, and their time and stage of occurrence on pearl millet grown in Northern Alabama.

Insect	Order: Family	Insect Importance	Crop developmental stage at Occurrence (DAP)	Peak occurrence of insects (DAP)
American bird grasshopper (*Schistocerca americana*)	Orthoptera:Acrididae	Pest	61-109 (Milk stage – physiological maturity)	61-66 (Milk stage)
Brown stink bug (*Euschistus servus*)	Hemiptera:Pentatomidae	Pest	61-109 (Milk stage – physiological maturity)	61-66 (Milk stage)
Colorado potato beetle (*Leptinotarsa decemlineata*)	Coleoptera: Chrysomelidae	Pest	61-81 (Milk stage-physiological maturity)	61 (Milk stage)
Foreign grain beetle (*Ahasverus advena*)	Coleoptera:Silvanidae	Pest	66 (Dough stage)	66 (Dough stage)
Multicolored Asian lady beetle (*Harmonia axyridis*)	Coleoptera: Coccinellidae	Beneficial	66 (Dough stage)	66 (Dough stage)
Sweat bee (*Halictus spp.*)	Hymenoptera: Halictidae	Beneficial	66-75 (Dough stage – physiological maturity)	66 (Dough stage)
Monarch butterfly (*Danaus plexippus*)	Lepidoptera: Nymphalidae	Beneficial	66-81 (Dough stage)	66 (Dough stage)
Handsome grasshopper (*Syrbula admirabilis*)	Orthoptera: Acrididae	Pest	61-75 (Milk stage –physiological maturity)	66 (Dough stage)
Syrphid fly (*Toxomerus geminatus*)	Diptera: Syrphidae	Pest	66-81 (Dough stage – physiological maturity)	66 (Dough stage)
Marginal blister beetle (*Epicauta pestifera*)	Coleoptera: Meloidae	Pest	66 & 95 (Dough stage and Physiological maturity)	66 (Dough stage)
Honey bee (*Apis mellifera*)	Hymenoptera: Apidae	Beneficial	61-95 (Milk stage – physiological maturity)	81 (Physiological maturity)
Differential grasshopper (*Melanoplus differentialis*)	Orthoptera:Acrididae	Pest	66-109 (Dough stage – physiological maturity)	66 (Dough stage)
Pink spotted lady bird beetle (*Coleomegilla maculata*)	Coleoptera:Coccinellidae	Beneficial	66-109 (Dough stage-physiological maturity)	81 (Physiological maturity)
Eastern leaf-footed stinkbug (*Leptoglossus phyllopus*)	Hemiptera:Coreidae	Pest	61-109 (Milk stage – physiological maturity)	95-109 (Physiological maturity)
Corn earworm (*Helicoverpa zea*)	Lepidoptera: Noctuidae	Pest	66-109 (Dough stage – physiological maturity)	95 (Physiological maturity)

nant insect across all treatments. It was more prevalent in the pearl millet genotypes treated with 0, 80 and 120 kg ha^{-1} nitrogen (Fig. 1), while *A. mellifera* was the third most prevalent insect species but the population decreased with increase in N rate. Responses of beneficial insects to N treatment varied. Some beneficial species increased with increasing nitrogen rate e.g. *Halictus* spp. and *D. plexippus*, while low numbers of *H. axyridis*, *T. geminatus* and *Halictus* spp. were recorded across genotypes irrespective of nitrogen treatment. The relative abundance of beneficial insect on 4 genotypes showed the following trend: LHB08 > 606A1*2304 > 707A1*4280 > 2304. Although general insect damage was observed across test plots, leaf damage on plants that received different levels of nitrogen did not differ statistically. A trend, however, indicated an increase of damage from low to high nitrogen rates (Table 2).

PLANT STAGES (DAYS AFTER PLANTING)

Insect abundance varied significantly with plant stage and sampling dates. Insect numbers peaked during the reproductive stage of the crop between 66–81 days after planting (DAP) at flowering through seed filling stages of the crop (Table 2). Overall, *L. phyllopus* and *S. americana* were the most prevalent and destructive insect species feeding on pearl millet across treatments at the different DAPs. The abundance of *L. phyllopus* was low at 66 DAP, but increased later in the growing season (81 DAP - 109 DAP). *Coleomegilla maculata* and *H. zea* were present in small numbers at 61 DAP and 66 DAP, but followed an increasing trend with plant growth. On the other hand, population levels of *E. servus, D. plexippus, S. americana, M. differentialis, E. pestifera and Halictus* spp. were high when the plants reached milking stage (61 DAP), but their numbers dropped with physiological maturity at 109 DAP. *Harmonia axyridis* occurred at low numbers throughout the season. Among insects visiting or foraging across plant genotypes, significant statistical differences were not observed in their population at 61, 95 and 105 DAP, but at 66 DAP, the numbers of *Halictus* spp. were significantly different among the 4 genotypes while at 75 DAP *A. mellifera* and *T. geminatus* were the only insects whose populations were significantly lower ($P = 0.05$). At 81 DAP (Table 3), significant difference for *A. mellifera* was observed among the 4 genotypes. The occurrence of *S. americana* declined toward the end of the season.

PEARL MILLET GENOTYPES

None of the 4 genotypes escaped insect damage during the growing season. However, there were variations in the number of insects that were observed on various stages of plant growth. Overall, genotype '707A1*4280' had the highest distribution of insect pest infestation across all the insect types (sucking and chewing insects) followed by genotypes'LHBO8', '606A1*2304' and '2304'. *Leptoglossus phyllopus* infested all the 4 genotypes at a very high population and its distribution on the 4 genotypes in an increasing order was: '707A1*4280'>' LHBO8'>'606A1*2304'>'2304' (Fig. 2). *Schistocerca americana* was the second most prevalent insect pest across all the 4 genotypes. Its occurrence was most frequent on 'LHBO8', followed by '2304', '606A1*2304' and then '707A1*4280'. *Melanopus differentialis* was the third most prevalent insect pest on the 4 genotypes (Fig. 2).

LEAF AND HEAD DAMAGE, AND YIELD

Leaf damage on pearl millet treated with the 4 nitrogen rates and the 4 genotypes over the growing season did not differ statistically. Foliar feeding damage was caused by *S. americana, M. differentialis, H. zea* and *E. pestifera* (Table 2). Head damage was prominent on some of the plants and could be attributed to pod sucking insects, i.e.

Table 2. Leaf damage, head damage, vegetative dry weight and estimated yield for 4 nitrogen rates and 4 pearl millet genotypes.

Nitrogen rate (kg ha^{-1})	Leaf damage (Mean Score)	Head Damage (Mean Score)	Vegetative Dry Weight (kg $plant^{-1}$)	Yield (kg ha^{-1})
N0	0.1[a]	1.0[ab]	0.060[a]	2492.9[a]
N40	0.2[a]	1.0[ab]	0.065[a]	2688.6[a]
N80	0.4[a]	0.8[b]	0.070[a]	2643.4[a]
N120	0.8[a]	1.5[a]	0.080[a]	3239.0[a]
		By Genotype		
2304	0.3[a]	1.4[a]	0.060[a]	1102.1[c]
LHBO8	0.5[a]	0.8[b]	0.070[a]	6154.7[a]
606A1*2304	0.4[a]	0.6[b]	0.070[a]	821.4[c]
707A1*4280	0.3[a]	1.5[a]	0.075[a]	3214.4[b]

Treatment means followed by the same letter(s) within the same column are not significantly different at $P \leq 0.05$

Leaf and head damage were based on 0-5 scale; 0 = no damage, 1 = less than 25% damaged, 2 = more than 25% damaged but less than 50%, 3 = more than 50% damaged but less than 75%, 4 = more than 75% damaged but less than 100%, and 5 = 100% of leaves damaged.

L. phyllopus and *E. servus*. Head/panicle damage was greatest at 120 kg ha^{-1} N, which was significantly different from that at 80 kg ha^{-1} N. Higher levels of head damage by insects on genotype '707A1x4280' and '2304' were recorded, which were significantly different from damage on 'LHBO8' and '606A1*2304' (Table 2). Although there was not any significant difference in grain yield across nitrogen regimes, grain yield varied among genotypes (Table 2). There was no significant difference in the vegetative dry weight between N treatments and the 4 genotypes (Table 2). Estimated grain yield of genotype LHBO8 (6,154 kg ha^{-1}) was significantly greater than that of all the other genotypes across nitrogen rates.

Discussion

This study showed that *L. phyllopus* can be considered as the most prevalent insect on pearl millet grown in Northern Alabama, followed by *S. americana.* According to Kuhar et al. (2010), the piercing and sucking injury caused by *L. phyllopus* is very similar to that of the chinch bug (*Blissus leucopterus* Say), which has been identified as the most economically important insect of pearl millet (Hudson 1995). There was a general increase in the population of *L. phyllopus* and *S. americana* with increasing nitrogen rate. This indicates a pattern of preference by these insects for plants with higher nitrogen levels. Coley et al. (1985) have explained that such insect population increases could be due to the decrease in plant defenses against herbivores at enhanced nutrient conditions. Nabity et al. (2012) found an increase in efficiency of conversion of feed to body mass in insects at higher soil N fertility levels.

Increases in the populations of *L. phyllopus* and *S. americana* at different times during the season were inverse in occurrence. Reduction in the population of *S. americana* occurred later in the growing season, which may be due to onset of senescence, drying and shedding of foliage and thus, decreased food availability. Sharma et al.

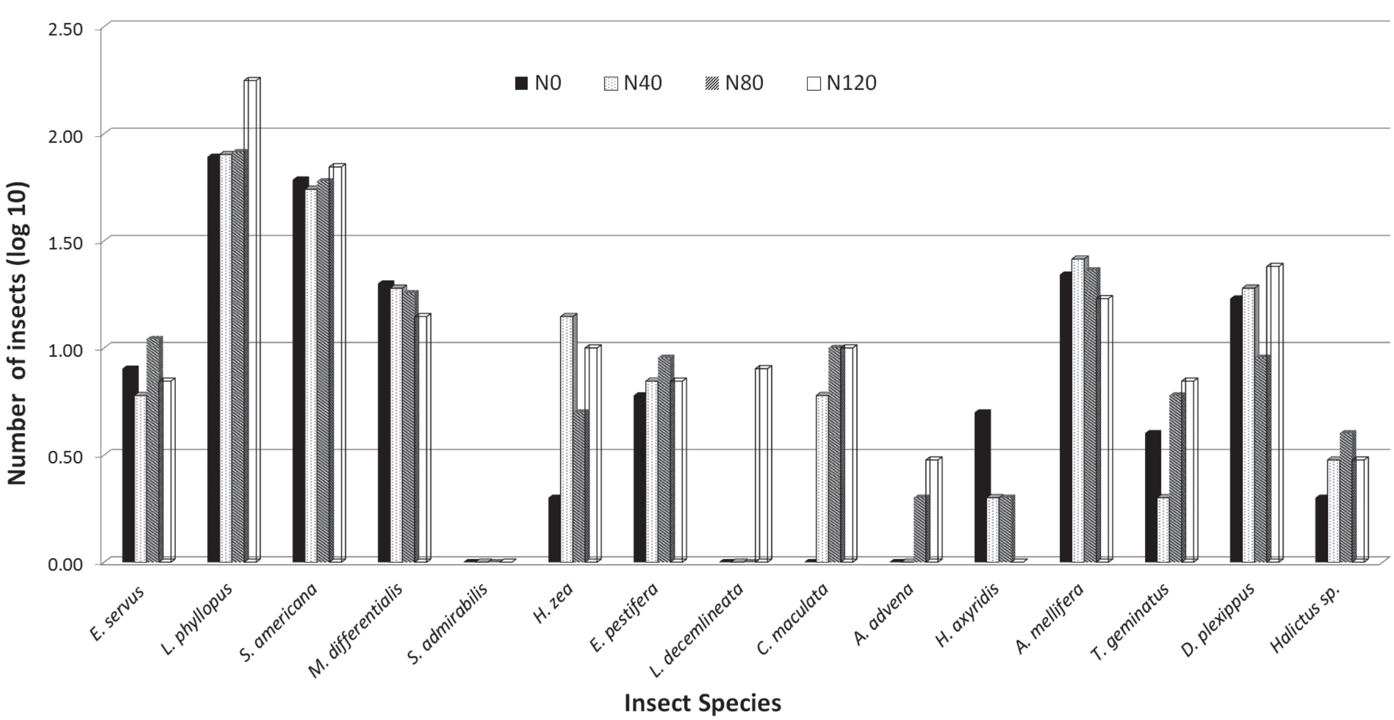

Fig. 1. Number (log_{10}) of insects per plot on pearl millet under 4 nitrogen rates.

Table 3. Densities of various insect species (per plot) on pearl millet from 61 to 109 days after planting.

	Days After Planting (DAP)					
Insect Species	61	66	75	81	95	109
Apis mellifera	0.5929	—	**0.0036***	**0.0032***	0.6786	—
Coleomegilla maculata	0.4518	0.4893	0.9723	0.8502	—	0.6016
Danaus plexippus	—	0.3605	0.3529	0.7881	0.3472	—
Epicauta pestifera	0.2721	0.3854	—	—	0.4505	—
Euschistus servus	0.3908	0.2852	0.0969	0.2890	0.2154	0.0817
Harmonia axyridis	—	0.5397	—	0.3740	—	0.3906
Helicoverpa zea	0.2697	0.3049	0.4022	0.1174	0.6641	0.2797
Halictus spp.	—	**0.0155***	0.5482	0.2659	—	—
Leptoglossus phyllopus	—	0.9609	0.6675	0.2137	0.2578	0.5438
Melanoplus differentialis	—	0.4441	0.9614	0.5400	0.7605	0.7025
Schistocerca americana	0.8851	0.9642	0.2866	0.2995	0.3359	—
Toxomerus geminatus	—	0.3080	**0.0030***	0.2223	0.2639	—

*Indicates significant difference (α = 0.05) among the 4 pearl millet genotypes for the presence of that species during the sampling period. Values represent probability for greater *F* and *n* = 12.

—Indicates no detection during sampling date.

(1997) reported that several species of grasshopper including the desert locust, *S. gregaria*, caused damage to grasses such as sorghum by feeding on leaves, flowers and grain. *Leptoglossus phyllopus* was more prevalent later in the season when grain filling was at its peak. *Leptoglossus phyllopus* is known to be a grain feeder (Abudulai et al. 2001), hence increasing the potential for head damage and yield loss. Cover crop management in neighboring field can be chopped and disked in September before the *L. phyllopus* becomes attracted to crops (Mead, 2010). Although the population of *E. servus* was sparse in general, it had its peak at 66 DAP when pearl millet was at milk stage (Maiti & Bidinger 1981). Mizell et al. (2008) also reported that stink bug prefer to feed primarily on the seeds of grain crop when they are in milk stage.

This study gives credence to the fact that pearl millet growing in this region is a desirable host plant for many species of insect pests that can cause severe crop damage if not controlled. Our results indicate that certain insect species congregate and harm the crop at higher incidence with increase in nitrogen rate. Because of the diverse uses of pearl millet as animal feed, hay, pasture and silage in the U.S., growing pearl millet requires careful selection of high yielding genotypes in combination with proper nitrogen management to reduce pest damage.

Pearl millet has been reported to produce substantial yield on marginal land and with minimal N input (Obeng et al. 2012). This study shows that higher N rates may result in enhanced insect infestation impacting the yield. However, further studies are needed to establish appropriate nitrogen regimes that can support optimum reproductive growth and grain development with minimal insect pest infestation.

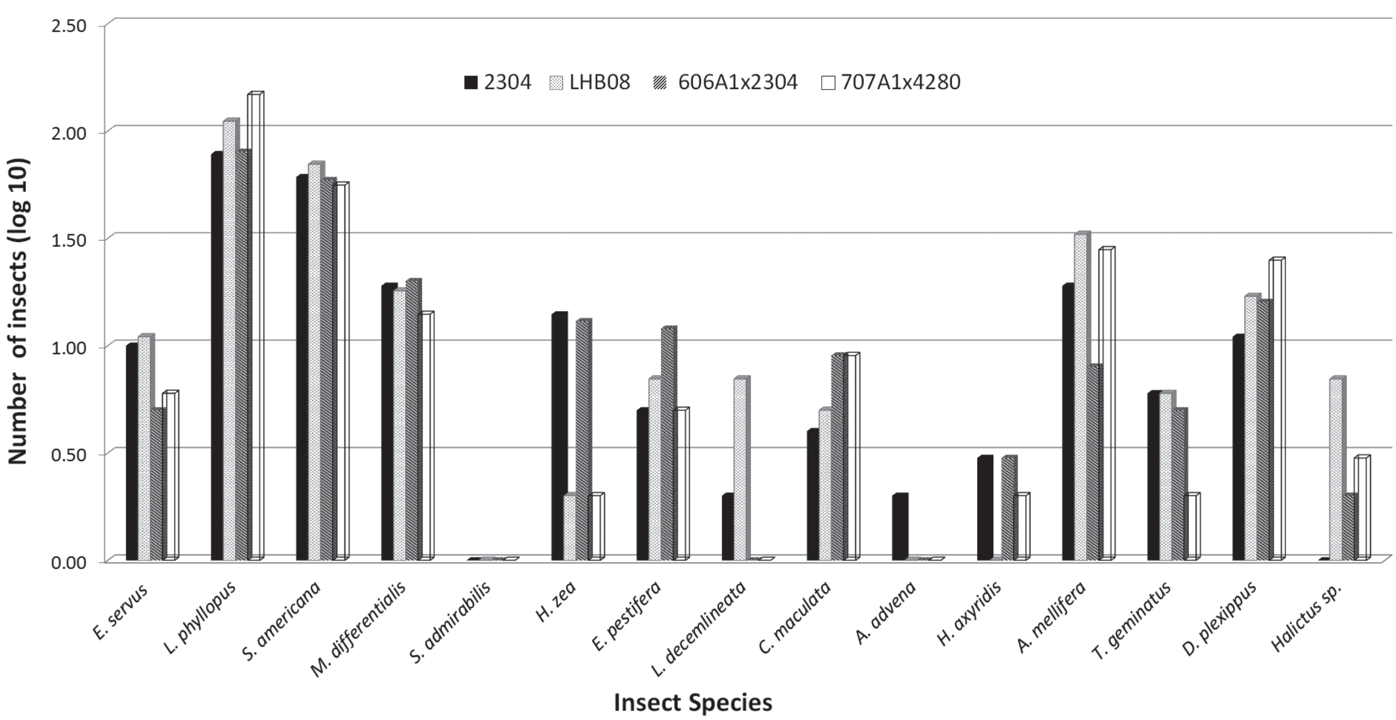

Fig. 2. Number ($\log_{10}$) of different insects per plot on 4 pearl millet genotypes.

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