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Research Article

POD-Sucking Insect Incidence in Soybean (*Glycine max L.*) Under Enhanced Efficiency Fertilization

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Abstract: Pod sucking insects have been a major constraint to sustainable production of soybean (Glycine max L.) in sub-Saharan Africa. The influence of fertilization on the incidence of these pests and their impact on yield of soybean is yet to be ascertained. Field studies were conducted at Nyankpala (on-station) and Nasia (on-farm) during the 2024 cropping season to evaluate the impact of enhanced efficiency fertilization on pod-sucking insect infestations and agronomic performance of soybean. A single-factor experiment laid out in a randomized complete block design with seven fertilization regimes, each replicated three times, was used. Data were collected on the population densities and damage incidence of pod-sucking insects and their effect on grain yield of the soybean crop. The results showed that the primary pod-sucking insect species identified in the study fields were Riptortus dentipes, Nezara viridula and Mirperus jaculus. Soybean yield and pod-sucking bug abundance and pod damage were significantly affected by the fertilizer treatments. The fertilization regimes: NIT+CLB+YLI, YLI+CLB+NIT, 0FERT+CLB+CLB and YLII+CLB+0FERT, generally recorded higher populations of Riptortus dentipes, Nezara viridula and Mirperus jaculus, and lower pod damages compared to TSP+0FERT and the unfertilized plots. Also, these treatments recorded higher grain yields than the control treatments. The findings from this study revealed that the use of these fertilizer products can augment pest infestations and grain yield of soybean and significantly increase net economic returns in soybean. Hence, these fertilizer products should be considered for developing crop nutrition and protection strategies for maximum production of soybean in the savanna zone of Ghana.

Keywords: Pod-sucking bugs, soybean, fertilization, grain yield.

Introduction

Despite the economic importance of soybean (Glycine max L.), its productivity in Africa still remains limited. Average yield stands at 0.5 tons/ha as against the achievable yield of 4.5 tons/ha [2,8]. Previous studies have indicated pressing issues constraining soybean production. According to [17], a major constraint to soybean production in the west African sub-region is poor soil fertility and biotic stresses imposed as a result of damages caused by insect pests. Generally, African savannas are noted for relatively low nitrogen and phosphorus availability. Apart from poor soil fertility, insect pests are important factors limiting soybean yield throughout its production belt in West Africa. In the savanna ecology of Ghana, soybean yield losses, estimated to be between 25.8% to 42.8% have been attributed to infestation and damage by foliage-feeding and pod-sucking insects [2]. reported significant damage has been caused by armyworms, Spodoptera spp and stink bugs Nezara viridula. Pod sucking bugs are highly polyphagous and typically suck sap from pods, seeds and other parts of the soybean plant.

These bugs also cause necrosis which inhibits the agronomic performance of soybean, leading to adverse economic impact on yield. According to [22], pod sucking bugs, defoliators, phloem and stem feeders reduce the ability of soybean crops to fully utilize nutrients from the soils. This as shown by [2], leads to 42.8% soybean yield losses particularly in northern zone of Ghana.

With appropriate crop nutrition programs and insect pest control, soybean yields up to 4.5 t ha-1 can be attained [8]. This has however been a major challenge, even though no association has been established between fertilization and insect pests in the savanna ecology of Ghana. Previous study indicated appreciable yields due to enhanced crop nutrition from Triple Superphosphate and Calcium Ammonium Nitrate applications. However, it is unclear how crop nutrition may affect insect pest incidence in the agro ecosystem. With the right soil nutrition and fertilizer management, insect pests in soybean could be significantly reduced with accompanied increased yields. Several studies have examined the effect of P and K fertilizers on soybean resistance to insects and enhanced yields. However, there is limited research information regarding the effect of fertilizers on insect pest incidence in soybean ecosystems. A researchable gap, being an unclear association between fertilization and resistance of soybean against pod sucking bugs has been identified

Farmers need the right sources of inorganic fertilizer to help boost plant growth and vigour in soybean, to enhance crop ability to withstand biotic stresses (particularly insect pests) for maximum yields of soybean in the savanna ecology of Ghana. YaraLegume™ fertilizers are new fertilizer formulations which have been introduced as an alternative to TSP fertilizers, traditionally used by farmers. These include YaraLegume I (0 N – 18 P – 13 K + 31 CaO (Insoluble) + 4 S + 2 MgO); YaraLegume II (4 N–18 P–13 K + 31 CaO (Insoluble) + 6 CaO (Soluble) + 3 MgO + 3 S + 0.075 B) and Nitrabor (15.4 N + 26 CaO + 0.3 B). The agronomic efficacy of these formulations is yet to be established for soybean production in the savanna ecological zone of Ghana. This study sought to determine the effect of YaraLegumeTM fertilizer formulations on soybean resistance to major pod feeding pests and their impact on yield and of soybean in the savanna ecology of Ghana

Materials and Methods

Study area

The study was conducted at the experimental field of the University for Development Studies, Nyankpala, Ghana, during the 2024 cropping season. The area typically has a tropical continental climate with a single rainy season that lasts from May to October (and peaks around late August or early September), followed by a lengthy dry season [10]. The soils in this area are primarily composed of voltaic shale and sandstone and are characterized as ferric luvisols because of their predominant sandy loam to loamy sand texture [24]. Average annual rainfall is between 950 and 1,200 mm.

Land Preparation, Experimental Design

The field was disc-ploughed and harrowed with a hoe during the first week of July. The single-factor experiment laid out in a Randomized Complete Block Design (RCBD), with six treatments and four replicates for each treatment, was used. Field sizes of 34 m x 16 m with plot size of 4 m x 4 m were used. A 1 m and 2 m alleys were allowed between treatments in each block and between blocks, respectively. The treatments included five different fertilization regimes and the untreated control (Tables 1, 2).

S/N	Treatments		Description	
		At planting	4 WAP	6 WAP
1	YLII+Croplift Bio+0FERT	YaraLegume II @ 250 kg/ha	Croplift Bio @2.5L/ha	No fertilizer
2	0FERT+ Croplift Bio +YLII	No fertilization	CropliftBio @2.5L/ha	YaraLegume II @ 250 kg /ha
3	NIT+ Croplift Bio +YLI	Nitrabor @ 65 kg/ha	CropliftBio @2.5L/ha	YaraLegume I @ 185 Kg/ha
4	YLI+ Croplift Bio +NIT	YaraLegume I @ 185 Kg/ha	CropliftBio @2.5L/ha	Nitrabor @ 65 kg /ha
5	0FERT+ Croplift Bio + Croplift Bio	No fertilization	CropliftBio @2.5L/ha	CropliftBio @2.5L/ha
6	TSP+0FERT	TSP @ 250 Kg/ha	No fertilization	No fertilization
7	CONTROL	No fertilization	No fertilization	No fertilization

Table 1: Fertilizer treatment protocols used for the trial

Fertilizer formulation	Symbol	Nutrient composition (%)											
		N (NO^{-2}+ NH^{+4})	P (P_2O_5)	K (K_2O)	MgO	S	CaO		B	Cu	Mn	Mo	Zn
							Soluble	Insoluble					
Croplift Bio	CLB	8.5	3.4	6	-	-	-	-	0.02	0.1	0.003	1	0.6
New YaraLegume	YLII	4	18	13	3	3	31	6	0.075				
Yara Legume	YLI	0	18	13	2	4	31	-	-				
Nitrabor	NIT	15.4	-	-	-	-	-	26	0.3				
TSP	-	-	48	-	-	-	-	-	-				

Table 2: Nutrient composition of fertilizer formulations used in the study

Planting and Application of Treatments

The field was disc-ploughed and levelled with a hand-weeding hoe during the third week of May. The Jenguma soybean variety obtained from the Ganoma Agro Inputs Shop, Tamale, Ghana, was used for planting. The field was planted in the second week of June 2024, with refilling taking place a week later. Four seeds were put per hill, which were then thinned to three. The plants were spaced 10 cm within rows and 40 cm between rows. The pre-emergence herbicide, Glyphader 480 (360g/l glyphosate a.e.; SL) was applied at a rate of 2.5l/ha at planting to control surviving weeds. The application of the fertilizer treatments was done strictly under the protocol indicated in Table 1 above, using the deep placement method.

Sampling and Identification of POD-Sucking Insect Species

Sampling and identification of pod-sucking insect species involved checking for stink bug infestation and damage using visual examination and the sweep net technique. However, most stink bugs occurred later than leaf worms and scouting began when the soybean plants started to bloom (R1) and continued until pod development and maturity (R8). Also, it was necessary to sample several sites in each plot (5-6 per plot) due to the tremendous variability in stink bug distribution within the field. Three inner rows were selected from each plot for sampling, which involved rapid visual examination of selected rows in each plot for pod-sucking insects. The target species were pod-sucking bugs. All plants in the selected rows were counted and visually examined to record the number of pod-sucking bugs. The observed species were transported to the laboratory and carefully identified using an identification chart and guide. The sweep net was also used in collecting samples. Each sweep net sample consists of 3 separate sweeps done continuously by briskly thrusting the net downward in an arc of about 3 feet and perpendicular to the plant rows.

At the pod formation stage, green pods were sampled from each plot, transported to a laboratory and examined for external feeding symptoms, after which they were dissected at the suture to evaluate for evidence of internal feeding on the interior pod wall and seed coat. Observed symptoms of stink bug feeding on green pods included shrivelling, indentions, discolouration and puncture marks

Estimation of Population Densities of POD-Sucking Bugs

In estimating the abundance and population dynamics of pod-sucking bugs. Observation for the presence of pod-sucking bugs started at the flowering stage (R1) and counting was usually done in the morning when the temperature was usually relatively low.

Identified pod-sucking bugs were counted and recorded in each plot based on their visual presence. For each plot, the visual counting of pod-sucking bugs present was done from the inner three rows. Direct counting was done when the flower set began and usually in the morning when the temperature was relatively low. Observed numbers for each pod-sucking bug species were recorded over different sampling periods (weekly after the flower set).

Assessment of Damage Incidence of POD-Sucking Bugs

Damage scores were recorded for green and dried pods over different sampling periods. The intensity of damaged pods was calculated below as previously done by (14). The intensity of pod damage was calculated as:

$$\text{Damaged Pods} = \frac{\text{Number of punctured pods}}{\text{Number of total pods}} \times 100\%$$

Estimation of Soybean Grain Yield and Quality

An area of 16 m2 per treatment was harvested, threshed and winnowed. The grains were then air-dried for two days and weighed at 12% moisture content. A moisture meter was used to ensure 12% moisture. Seeds were then weighed to obtain the yield for each treatment. A hundred seeds of soybean grains were picked randomly, and the weight was taken, as the weight of grains is representative of the oil content, protein content and crude fat.

Data Analysis

All count values were log-transformed to normalize the data before analysis. Data were subjected to the analysis of variance (ANOVA) using Genstat statistical package (12th edition), and treatment means were compared using Fisher's least significant difference (LSD) test at 5% probability level.

Results

POD-Sucking Bug Species Identified

The green stink bug, Nezara viridula, the small or minor coried bug, Riptortus dentipes, and the giant corried bug, Mirperus jaculus (Thunberg), were the three main pod-sucking insects seen in both study sites during the reproductive growth stage of the soybean (Figure 1).

Nezara viridula

Riptortus dentipes

Mirperus jaculus

Figure 1: Sap sucking insect species infesting soybean under the fertilization regimes

Abundance of POD-Sucking Bugs

The fertilization regimes had a significant effect ($P < 0.001$) on the abundance of pod sucking bugs (Figure 2). The average number of pod sucking bugs ranged from 0.55 in the control treatment to 1.18 in NIT+CLB+YLI. It was observed that the abundance of pod sucking bugs in the control treatment was significantly lower compared to all other treatments. pod sucking bugs abundance followed the order of Control < 0FERT+CLB+CLB < TSP+0FERT < 0FERT+CLB+YLII < YLII+CLB+0FERT < YLI+CLB+NIT < NIT+CLB+YLI. Among the treatments, the abundance of pod sucking bugs in 0FERT+CLB+CLB was statistically similar to that of TSP+0FERT, but significantly higher than that of the control treatment and lower than that of the other treatments. Furthermore, the abundance of pod sucking bugs in TSP+0FERT, although statistically similar to 0FERT+CLB+YLII, was significantly lower than YLII+CLB+0FERT, YLI+CLB+NIT, and NIT+CLB+YLI. The abundance of pod sucking bugs in YLII+CLB+0FERT was statistically similar to that of YLI+CLB+NIT and NIT+CLB+YLI, but significantly higher than all the other treatments. Notably, NIT+CLB+YLI had the highest abundance of pod sucking bugs among all the treatments.

Population Dynamics of POD-Sucking Bugs

The study spanned from 8 weeks after planting to 14 weeks after planting, and observations were made on multiple treatments, including the control treatment, TSP+0FERT, NIT+CLB+YLI, YLI+CLB+NIT, 0FERT+CLB+CLB, 0FERT+CLB+YLII and YLII+CLB+0FERT. Throughout the study period, it was evident that the abundance of pod sucking bugs increased steadily across all treatments from 8 weeks after planting to 14 weeks after planting (Figure 3).

Specifically, in the TSP+0FERT treatment, the abundance of pod sucking bugs exhibited a distinct pattern. It dwindled downwards from 10 to 12 weeks after planting, suggesting a temporary decline in pest population during this period. However, this trend reversed after 12 weeks, and the abundance increased at an increasing rate, reaching higher levels by 14 weeks after planting. Similar to the TSP+0FERT treatment, the Control treatment also experienced a steady increase in pod sucking bugs abundance from 8 to 14 weeks after planting

However, it is worth noting that the abundance recorded in the control treatment was comparatively lower than that of the other treatments. In contrast to the control treatment, all other treatments demonstrated higher infestation levels, as evidenced by the increasing rate of pod sucking bugs abundance from 8 to 14 weeks after planting. Notably, treatments involving NIT+CLB+YLI, YLI+CLB+NIT, 0FERT+CLB+CLB, 0FERT+CLB+YLII, and YLII+CLB+0FERT exhibited very close similarity in abundance, indicating that these fertilization regimes had a comparable impact on promoting pest population growth.

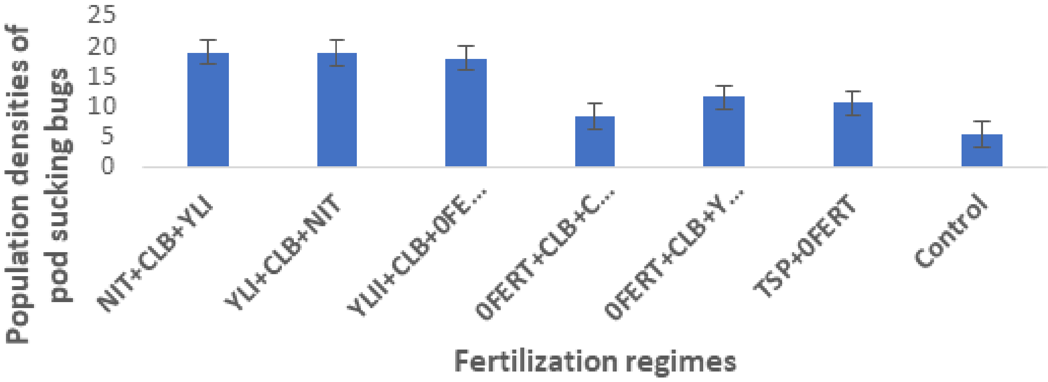

Figure 2: Population densities of sap sucking insects on soybean under the fertilization regimes

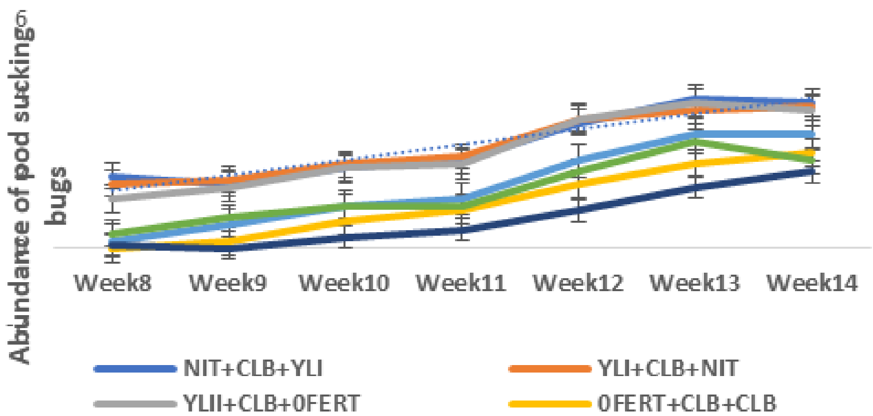

Figure 3: Trend of occurrence of pod sucking insects in soybean field under the fertilization regimes.

Damage Incidence of POD-Sucking Bugs

Damage incidence of pod sucking insects affected by the fertilization regimes is represented in Figure 4. The fertilization regimes had a significant impact ($P < 0.001$) on the damage incidence on the soybean crops. The extent of damage varied from 72.64% in the control treatment to 17.01% in YLI+CLB+NIT, representing significant statistical difference in the control treatment, relative to the other treatments. Among the treatments, the percentage of damage in YLI+CLB+NIT was statistically similar to that of NIT+CLB+YLI, but it was significantly lower than that of all other treatments. The order of damage percentage was YLI+CLB+NIT < NIT+CLB+YLI < YLII+CLB+0FERT < 0FERT+CLB+CLB < 0FERT+CLB+YLII < TSP+0FERT < Control. Furthermore, the damage experienced in YLII+CLB+0FERT was statistically different and higher than those observed in YLI+CLB+NIT and NIT+CLB+YLI treatments. In addition, the percentage of damage in 0FERT+CLB+CLB was statistically similar to that of 0FERT+CLB+YLII, but significantly higher than all other treatments, except for TSP+0FERT and Control. However, the percentage of damage in TSP+0FERT was statistically similar to that of 0FERT+CLB+YLII, but it was higher than all treatments, except for Control, which had the highest percentage of damage and was significantly different from all other treatments.

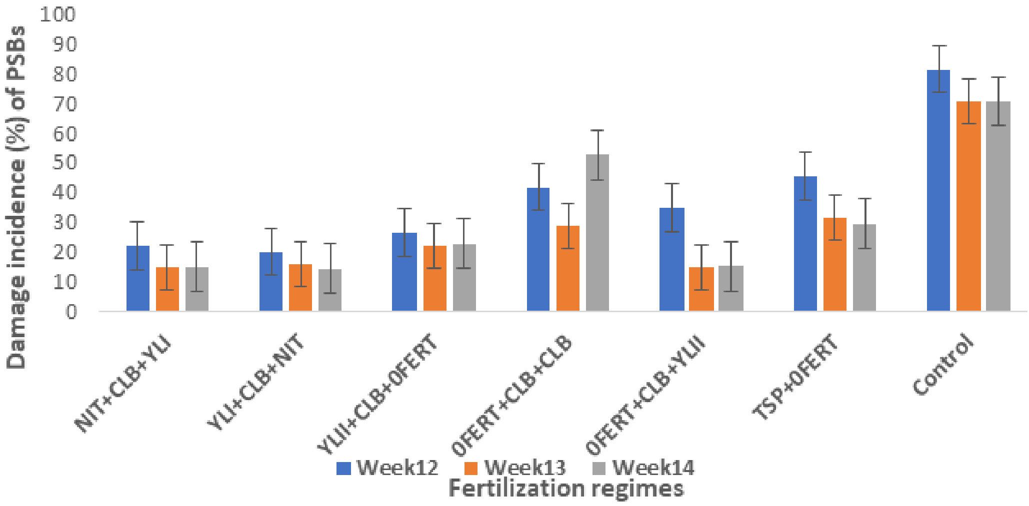

Figure 4: Damage incidence of pod sucking insects on soybean under the fertilization regimes

Trend of Damage of POD-Sucking Bugs on Soybeans

Figure 5 showed the trend in pod sucking bugs damage incidence observed during a study that spanned weeks 12 to 14. Throughout this period, the damage incidence gradually increased for most treatments, indicating a progressive escalation in damage caused by pod-sucking bugs. Among the treatments studied, the Control treatment consistently exhibited the highest levels of damage incidence across all three weeks. This suggests that without any specific interventions or fertilization regimes, the plants were more vulnerable to pod-sucking bugs. On the other hand, the NIT+CLB+YLI and YLI+CLB+NIT treatments consistently demonstrated the most effective protection against pod-sucking bugs, as they maintained the lowest levels of damage incidence across all three weeks. These fertilization regimes appeared to be highly successful in mitigating the impact of the pests and preserving the plant's health.

The YLII+CLB+0FERT, 0FERT+CLB+YLII, and TSP+0FERT treatments generally exhibited moderate damage levels, with some fluctuations observed from week to week. These treatments showed a varying degree of protection against pod-sucking bugs, with occasional fluctuations in damage levels during the study period.In summary, the overall trend indicated that damage incidence tended to peak during weeks 13 and 14, indicating a critical period where pod-sucking bug activity and damage were at their highest. Conversely, weeks 12 and 13 had the lowest or moderate damage incidence, signifying a period of relatively lower pest activity and damage. Notably, the NIT+CLB+YLI and YLI+CLB+NIT fertilization regimes consistently demonstrated the best protection against pod-sucking bugs, maintaining the lowest damage incidence throughout the study.

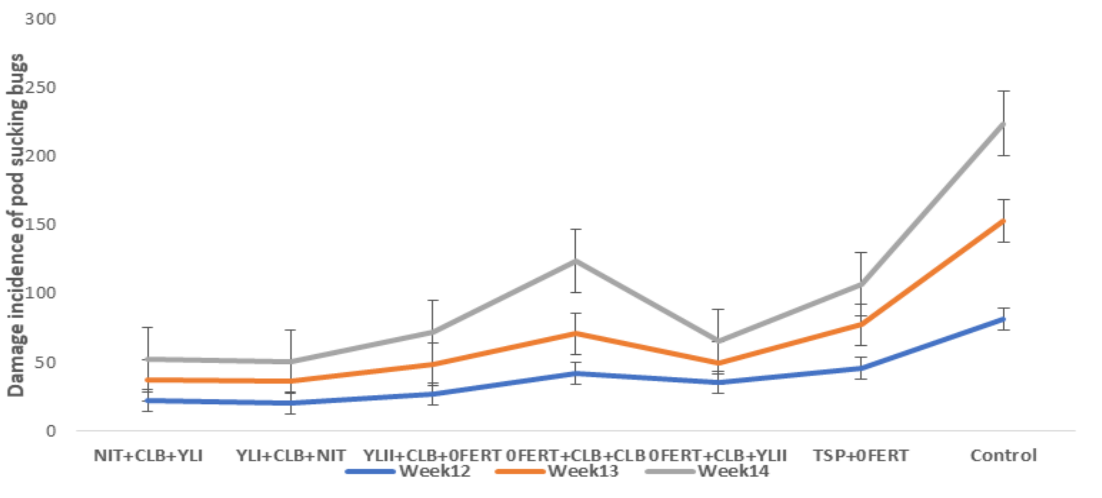

Figure 5: Trend of damage incidence of pod sucking insects on soybeans under the fertilization regimes

Impact of Fertilization on Soybean Grain Yield and Quality

The study conducted revealed a significant influence of fertilization regimes on soybean grain yield (P < 0.001) (Figure 6). The grain yield varied from 663 kg/ha in the control treatment to 4,507 kg/ha in the NIT+CLB+YLI treatment. The control treatment resulted in a significantly lower grain yield compared to all other treatments. The order of grain yield for all treatments was Control < TSP+0FERT < 0FERT+CLB+YLII < 0FERT+CLB+CLB < YLII+CLB+0FERT < YLI+CLB+NIT < NIT+CLB+YLI. Although the grain yield in TSP+0FERT was statistically similar to that of 0FERT+CLB+YLII and 0FERT+CLB+CLB, it was significantly higher than the control treatment. Similarly, the grain yield of YLII+CLB+0FERT, YLI+CLB+NIT, and NIT+CLB+YLI was also statistically similar and significantly higher than all other treatments. However, NIT+CLB+YLI treatment resulted in significantly higher grain yield than any other treatment. The average yield increase over the control treatment was 354%, 363%, 435%, 527%, 559%, and 580% for TSP+0FERT, 0FERT+CLB+YLII, 0FERT+CLB+CLB, YLII+CLB+0FERT, YLI+CLB+NIT, and NIT+CLB+YLI treatments, respectively.

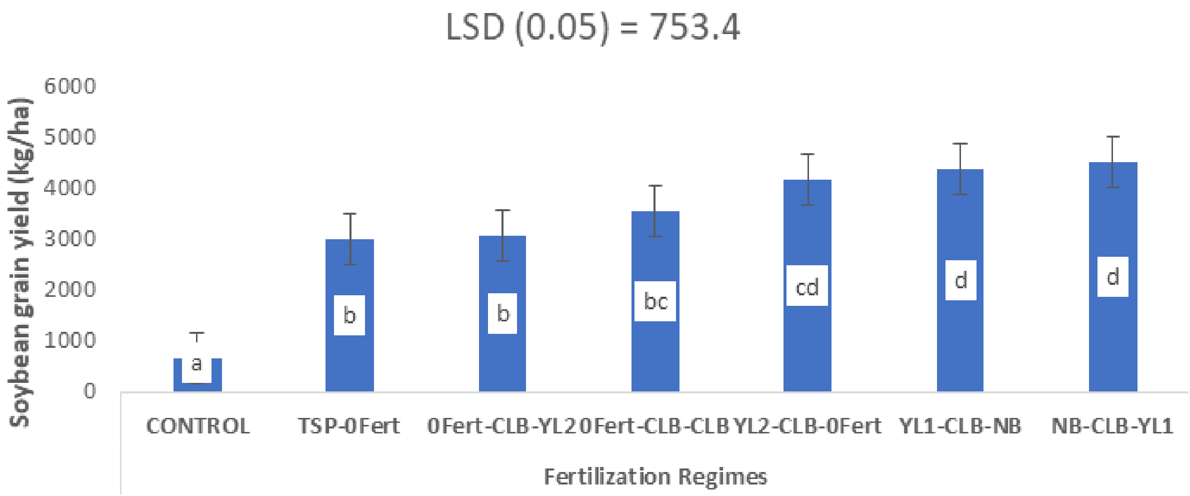

Figure 6: Soybean grain yield under the fertilization regimes

Discussion

POD-Sucking Bug Species Infesting Soybean

The major pod-sucking bug species identified in this study predominantly included Nezara viridula, Mirperus jaculus and Riptortus dentipes. All the pod-sucking bugs identified were largely significantly abundant at both experimental locations, especially at 10,11,12,13 and 14 weeks after planting. The abundance of these specific pod-sucking bugs had been corroborated, although with limited explorations (1, 4, 6, 7). A significant abundance of the pod sucking bugs was observed at 8,9,10,11,12,13 an4 14 weeks after planting. This observation further agrees with assertions and findings by [4], revealing that N. viridula is a significant pest of soybean and was found to be the second most common insect pest of soybean in Ghana. N. viridula was also reported to have been predominant in the guinea savannah ecological region according to a study conducted by [15] which revealed that the abundance of N. viridula was significant and could cause significant damage to soybean pods. While M. jaculus is not considered an agricultural pest, it is an important predator of insects and other arthropods in many ecosystems, including agroforestry systems in Ghana. While there is limited research on the population dynamics of M. jaculus in Ghana, one study found that it was one of the most common insect species in cocoa agroforestry systems in the country [5,6]. However, significant damage caused by M. jaculus on soybean in the guinea savannah ecology classifies the insect as an important pod-sucking bug [15].

R. dentipes are known to feed on the pods and seeds of soybean plants, leading to reduced quality and quantity of the harvest [6]. Farmers in Ghana have reported an increased incidence of R. dentipes in recent years, leading to growing concern over its impact on soybean production [15]. According to [9], R. dentipes were identified as one of the major pests of soybean in Ghana. The study found that R. dentipes infestation was highest during the reproductive stage of soybean growth, with up to 90% of soybean plants being infested in some areas. [3] reported similar findings, with R. dentipes being identified as one of the major insect pests of soybean in Ghana. The study found that R. dentipes infestation significantly reduced soybean yields, with an average yield loss of 27%.

Impact of Fertilization on POD-Sucking Bug Infestations

All the pod-sucking bugs identified were largely significantly abundant at the experimental location, especially at 10 to 14 weeks after planting. The abundance of pod-sucking bugs began at the reproductive stage of the plants and increased in population until the 14th week after planting. In the fertilized treatments, flower development was relatively delayed as compared to that of the unfertilized treatments. Nevertheless, flower blooming, pod development and growth were comparatively more produced in these treatments, particularly in treatments including NIT+CLB+YLI, YLI+CLB+NIT and YLII+CLB+0FERT. Pod-sucking bug infestation in fertilized treatments including NIT+CLB+YLI, YLI+CLB+NIT and YLII+CLB+0FERT were mostly similar with corresponding high yields over TSP+0FERT, 0FERT+CLB+YLII, 0FERT+CLB+CLB and Control. Infestation in these treatments (NIT+CLB+YLI, YLI+CLB+NIT and YLII+CLB+0FERT) was also significantly high between 8 -14 weeks after planting.

The use of mineral fertilizers could have direct and indirect effects on pod-sucking bug infestation in soybean crops. In terms of direct impact, mineral fertilizers can affect the growth and development of soybean plants. A study by [11] revealed that mineral fertilization can influence the susceptibility of plants to pod suckers. It is worth noting that even though soybean as a leguminous crop fixes nitrogen into the soil, it may not be able to assimilate the nitrogen fixed for its use towards pod growth and development. Also, nitrogen is only fixed from the point of nodulation and as a result soybean crops will need starter nitrogen to boost their growth process, especially under poor soil conditions [11]. The treatments with significant infestation levels of pod-sucking bugs were NIT+CLB+YLI, YLI+CLB+NIT and YLII+CLB+0FERT. NIT (Nitrabor), a Nitrogen-calcium based fertilizer contained 15.4% N, 26% Ca and 0.3% B. CLB (CropLift Bio), a micronutrient foliar fertilizer contained 8.5% N, 3.4 % P, 6% K, 0.02% B, 0.1% Cu, 0.003% Mn, 1% Mo and 0.6% Zn. YLI (YaraLegume), a compound fertilizer blend for legumes contained 0% N, 18% P, 13% K, 31% Ca, 4% S and 2% Mg. YLII (New YaraLegume), is also a compound fertilizer blend, but with starter Nitrogen added. This contained 4% N, 18% P, 13% K, 31% Ca (insoluble), 6% Ca (Soluble), 3% Mg, 3% S and 0.075% B. The availability of N at the early stages of growth could have subsequently contributed to rapid and vigorous pod development, making plants treated with NIT+CLB+YLI, YLI+CLB+NIT and YLII+CLB+0FERT a hotspot for pod sucking bugs (Fernandes et al., 2014).

Impact of Fertilization on POD-Sucking Bug Infestations

There was a significant effect of fertilization regimes on grain yield, with the highest grain yield in NIT+CLB+YLI at the on-station experiment and 0FERT+CLB+CLB at the on-farm experiment. Additionally, soybean crops generally witnessed relatively higher yields in NIT+CLB+YLI treatment than in other treatments. Soybean grain yield at the on-station experiment in NIT+CLB+YLI also shared similarity with YLI+CLB+NIT, 0FERT+CLB+CLB and 0FERT+CLB+YLII. Largely, the role of N, P, K, soluble Ca and B could have resulted in the impact on yield, since all treatments were exposed to the same factors, except the varied fertilization regimes. The inclusion of micronutrients in CropLift Bio (CLB) could have also played a major role in further and optimising the assimilation of other nutrients by the soybean plants for growth. The nutrients included in CropLift bio were more specifically, the provision of N at the initial growth stages could have played a major role in the growth and development of the plants. A study by [12] indicated that until modulation, soybean plants depend on soil nitrogen for growth. This suggests that soybean grain yield was boosted because of the added starter nitrogen provided. This assertion, although backed with some similar provisional projections of the beneficial effects of starter N may not be the only plausible scientific inference based on the results obtained in the experiment.

The inclusion of micronutrients in the fertilizer formulations seemed to have accounted largely for yield increase over the control treatment. Micronutrients play a crucial role in achieving high soybean yield by promoting plant growth, development, and overall health. According to [13], soybean plants require several micronutrients, including zinc, iron, boron, manganese, copper, and molybdenum, for optimal growth and yield. For instance, zinc plays a crucial role in the synthesis of several enzymes and proteins involved in various physiological processes, including photosynthesis, respiration, and nitrogen fixation [20]. In addition, boron plays a significant role in soybean yield by promoting seed development, flower fertility, cell elongation and root growth [18]. Moreover, manganese is necessary for soybean plants' chlorophyll synthesis and is also involved in the activation of several enzymes required for various metabolic processes [25]. Copper and molybdenum are also required for soybean plants' growth and yield, as they are involved in various metabolic processes, including nitrogen fixation. Therefore, it is crucial to ensure that soybean plants receive adequate amounts of these micronutrients to achieve high yields. Applying micronutrient fertilizers or using micronutrient-enriched soils can help provide the required nutrients to soybean plants and improve yield [13].

Micronutrients could also play an important role in soybean resistance to damage at the podding stage of growth. The highest yield attained was in 0FERT+CLB+CLB and this treatment was solely formulated with micronutrients. The results of high yield could also be due to repeated or multiple applications of micronutrients. Also, other treatments with similar yields in both the on-station and on-farm trials had micronutrients in CLB added to the formulation. According to [23], micronutrient deficiencies can make soybean plants more susceptible to various biotic and abiotic stresses, including pests and diseases. Inadequate levels of micronutrients such as zinc, manganese, and copper can weaken soybean plants, making them more vulnerable to damage at the podding stage. For example, zinc is essential for the development of healthy plant tissues, and deficiency can result in weak cell walls, making plants more susceptible to disease and pest damage [21]. Manganese is also important for plant growth and development and plays a role in protecting plants from oxidative stress. A deficiency of manganese can make plants more vulnerable to oxidative damage, leading to reduced yield and quality [16].

Conclusion

The study demonstrated the potential of Yara legume fertilizer products in enhancing adaptation to pod-sucking insect infestations and grain yield in soybean. Application of YaraLegume I @185 kg/ha or Nitrabor @ 185 kg/ha could be explored for mitigating pod-sucking bugs problem and for maximum grain yield in soybean. However, for the smallholder situation where double application may be a challenge, YaraLegume fertilizers applied as basal with CropLiftBio at 2.0 l/ha supplementation would give moderate adaptation to pod-feeding pests and grain yield. Sole application of CropLiftBio fertilizer is not recommended for mitigating pest problems for maximizing soybean productivity. Despite the possibility of pest abundance on well-nourished fields, farmers will be better off applying starter nitrogen to their soybean fields. For further work, there is the need to evaluate the effect of the fertilizer formulations on resistance of different soybean varieties to the major field pests under varying planting times within the season.

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