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Influence of Enhanced Efficiency Fertilization on Fall Armyworm (*Spodoptera frugiperda J. E. Smith*) Infestations and Agronomic Performance of Maize (*Zea mays L.*)

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Abstract:
Fall armyworm (FAW), still remains an important pest of many agricultural crops including maize. There is the need to use environmentally friendly approaches to address this current menace. Field experiment was laid in randomized complete block design with three replications, using eight different fertilization regimes to evaluate eight different fertilization regimes on the larval abundance and damage incidence of FAW, its impact on maize yield in the Savanna ecology of Ghana. The economic viability of the treatments on maize production was also assessed. Fertilization significantly influenced FAW larval abundance and damage incidence. Unfertilized plot recorded significantly lower larval numbers and damage incidence compared to fertilizer treatments. Among the fertilization regimes, UNIK 15 (NPK 15:15:15)-Amidas (AMI) and Actyva (ACT)-sulfan (SUL) recorded significantly higher larval abundance and damage incidence whilst the least were recorded from CLB-CLB (CropLift Bio) and UNIK 15-Sulphate of ammonia (SOA) + insecticide spray (IS). Among the fertilization regimes, CLB-CLB recorded significantly lower grain yield, with UNIK 15-URE (Urea) and ACT-AMI yielding the highest. All the fertilization regimes yielded more profit compared to the unfertilized plots, among the fertilization regimes, CLB-CLB yielded lowest profit and cost-benefit ratio, whilst the highest profit and cost-benefit ratio was obtained from UNIK 15-URE. Application of UNIK 15-URE or ACT-AMI is recommended for better management of FAW, maximized yield, as well as higher profit.

INTRODUCTION

The fall armyworm (FAW) (*Spodoptera frugiperda* J. E. Smith) is a major pest that has wide host range, with a strong preference for maize (FAO, 2017). Across Africa, the economic impacts of FAW on agricultural productivity are essential. Without proper control methods, yield losses to maize caused by the FAW is estimated to have ranged from 8.3 to 20.6 metric tonnes annually from 12 sampled maize producing regions across the African continent. Between US$2.48 billion and US$6.19 billion was estimated as the value of these losses (CAB International, 2017; Day *et al.*, 2017). FAW has become a serious threat to maize production in Africa, due to the availability of a diverse range of host plants throughout the year and favourable climatic conditions for its growth and development (Nboyine *et al.*, 2021). The management of FAW appears challenging due to its short life cycle, wide host range, rapid multiplication and ability to spread across large geographical areas (Day et al. 2017; Prasanna et al. 2018).

Currently, there is a little knowledge of proper tactics to prevent and avoid FAW, and attempts to limit the pest population mostly depended on the synthetic pesticides use, sometimes in an improper way with ability to bring about danger to human, animals and the environment (Prasana *et al*., 2018). Aside the cost involved in the control of this pest using insecticides, the penetration of this pesticides in to the whorl of the maize is another problem, as the pest (larvae) hide inside the whorl of the maize plant and need regular application (Yu *et al*. 2003). It has been reported of FAW building resistance to a number of individual classes of insecticides including carbamates, benzoylureas and pyrethroids (Diez-Rodrigues and Omoto, 2001; Yu *et al*., 2003). The negative impact of synthetic insecticides on non-target organisms within the agroecosystem calls for the need to explore environmentally friendly approaches to manage the pest.

Mineral nutrients are important for plant growth and development. Discoloring of the leaf surfaces by nutritional deficiencies increases susceptibility to pests. These nutrients usually served as food for plants essentially for better growth and yield yet, mineral nutrition also impacts growth and yield by influencing resistance and susceptibility of plants to insects and pathogens (Schumann *et al*., 2010). Plant development depends on nutrients availability (Gogi *et al*., 2012). According to Schumann *et al*. (2010), supply of a balanced nutrients ensures optimal plant growth. As well, plants with an optimum nutritional status have a maximum resistance (tolerance) to pests and diseases to nutrient deficient plants. Mineral nutrition can impact two primary mechanisms of resistance: The mechanical barriers formation (in essence through the development of thicker cell walls) and the combination of natural defense compounds, (for instance phytoalexins, flavonoids, and antioxidants) which issue defense against pathogens. According to Altieri and Nicholls (2003), the vital plant physiological features for hold out against pests and diseases is healthy plants and vigorous plant growth. As there is a likelihood of FAW staying, medium and longstanding responses are essential, along with actions to address the instantaneous crises that farmers are facing (CABI, 2017).

In Ghana, YARA is the largest importer of bulk fertilizer (estimated to account for around 70,000-80,000 tones in 2008) (Arthur, 2014). Also, YARA Vita (Croplift Bio) being a newly formulated foliar fertilizer with both the macro (NPK+B small quantity) and micro nutrients (Cu, Mn, Mo and Zn) can improve nourishment to the plants to boost it immunity to be able to withstand (tolerance/resistance) insect-pests infestation especially FAW. However, there is a little research finding available on the influence of fertilization on FAW infestation and yield of maize in Ghana. Hence, there is the need to use YARA formulated fertilizers with the Croplift Bio to improve the health and vigorous growth of plants to be able to withstand the FAW infestation. This study sought to evaluate eight different fertilizer protocols from YARA Ghana Limited on the larval abundance and damage incidence of FAW, and its impact on maize yield in the Guinea savanna ecology of Ghana. The economic viability of the treatments for maize production was assessed.

MATERIALS AND METHODS

Study Area

The study was conducted at the University for Development Studies Research Field, Nyankpala. The area has a unimodal rainfall pattern which has a mean annual rainfall ranging from 800 mm to 1200 mm (Kombiok *et al*., 2012). The area has a warm climate of mean minimum temperature of 25 ^{o}C and a maximum temperature of 35 ^{o}C (SARI, 2001). The soil is sandy loam to loamy sandy (Yidana *et al*., 2011). According to Yidana *et al*. (2011), the area is a low-lying grassland with few spread perennial woody species.

Experimental Design, Planting and Treatment Application

The experiment was a single factor experiment with ten treatments, arranged in a randomized complete block design with three replications. The variety of maize used was Obatanpa. Plot size of 4 m × 4 m (16 m²) were used. Buffer zones of 2.0 m were created between blocks and 1.0 m within plots on the same block. The experiment covers a land area of 16 m × 49 m (784 m²). Eight treatments were based on YARA Ghana limited protocol provided, one treatment was non-YARA fertilizer and a control. Application of the treatments was done using deep placement method. A dibbler was used to puncture a hole about 2 cm from the plant, after which the fertilizer was then put in to the hole and covered with soil to prevent it from carrying away by rain water. Table I shows the treatments and their descriptions.

Table 1: Fertilizer treatment protocols used for the trial

Treatments	Description	
	2 weeks after planting	**4 weeks after planting**
ACT-AMI	YARA Mila Actyva (NPK 23-10-5+2MgO+3S+0.3ZN) @ 250kg/ha	YARA Vera Amidas (40N-5.6S) @ 125kg/ha
ACT-SUL	YARA Mila Actyva (NPK 23-10-5+2MgO+3S+0.3ZN) @ 250kg/ha	YARA Bela Sulfan (24N-6S) @ 125kg/ha
ACT-URE	YARA Mila Actyva (NPK 23-10-5+2MgO+3S+0.3ZN) @ 250kg/ha	YARA Urea (46%N) @ 125kg/ha
UNIK-AMI	YARA Mila UNIK 15 (NPK 15-15-15) @ 250kg/ha	YARA Vera Amidas (40N-5.6S) @ 125kg/ha
UNIK-SUL	YARA Mila UNIK 15 (NPK 15-15-15) @ 250kg/ha	YARA Bela Sulfan (24N-6S) @ 125kg/ha
UNIK-URE	YARA Mila UNIK 15 (NPK 15-15-15) @ 250kg/ha	YARA Urea (46%N) @ 125kg/ha
NPK-SOA+IS	(non-YARA) NPK (15-15-15) @ 250kg/ha with insecticide spray	Sulphate of Ammonia (SA 21%) 125kg/ha with insecticide spray
CLB-CLB	YARA Vita CropLift Bio (NPK 8.5-33.4-6+B+Cu+Mo+Zn) @2.5 l/ha	YARA Vita CropLift Bio (NPK 8.5-33.4-6+B+Cu+Mo+Zn) @2.5 l/ha
CONTROL	No fertilization	No fertilization

During the third week of May, the field was disc-ploughed and leveled with a hand weeding hoe. The Obatanpa (late maturity maize variety) obtained from Ganorma agrochemicals in Tamale, Ghana, was used for planting. The field was planted on the fourth week of June 2021. They were a sowing spacing of 40 cm between plants and 75 cm between rows. There was a construction of bunds around each plot before application of the treatments to prevent drift of the fertilizer into adjacent plots. The control of the weeds was undertaking at three weeks and six weeks after planting. K-optima (insecticide) was used to control pest in NPK + SOA +IS plots and that of No fertilization plots to control pests. The insecticide was applied two weeks, four weeks and six weeks after emergency and after the application of the treatments.

Assessment of FAW Abundance and Damage Incidence

FAW larval abundance was assessed using 2×3 m (6 m²) at the middle of each plot. This was done to avoid the border effect. In the course of each data collection, the maize plants that fall within the 6 m² were rigorously hunted for the existence of the larvae and the number existed were then counted and recorded. Leaf and whorl defoliation was assessed using the Davis rating scale from 0 to 9 to score FAW damage incidence on plants (Davis and Williams, 1992). Assessment of pest population and damage were done at 4 WAP (week after planting), 6 WAP and 8 WAP.

Estimation of Maize Yield
The harvesting was done in plot bases manually while each harvested plot was put into the various experimental sacks. Six meters square (6 m²) in the middle of each plot was harvested, de-husked and de-grained. The grains were allowed to further dry to 12% moisture content before aerial winnowing to take out the chaffs from the grains. The resulting grains were then weighed on a Camry digital weighing scale and extrapolated to kilogram per hectare for each treatment. Hundred (100) seeds were also counted and weighed.

Resistance/Tolerance Level of *S. frugiperda*
Foliar damage caused by FAW infestation was evaluated by scoring each infested crops on 1-9 scale (Davis and Williams, 1992) modified by Prasanna *et al*. (2018). This scale assessment was based on degree of foliar damage, where highly resistant plants were graded with 1 (no visible damage) whilst 9 rated as highly susceptibility crops (completely damaged).

Statistical Analysis and Partial Budget Analysis
The data collected were transformed using √y+0.5 where y is the response variable, before subjected to repeated measures analysis of variance (ANOVA) in GenStat Statistical Programme (12th edition). Treatments means were separated at the probability level of 5% using least significant difference (LSD) test.

Partial budget analysis was employed to evaluate the net benefit as a result of fertilization and net returns to FAW control. This were to assess the economic view of investment in FAW management compared to no fertilization. Both chemicals, maize and the fertilizer market prices were employed in landing at the value of production and cost of production respectively. The assumption was that, all other cost were constant whilst the cost that differ were therefore applied to calculate the input cost. The value of yields increment due to fertilization were calculated using mean grain yield of maize with the following formula:

$$Value\ of\ increased\ yield\ due\ to\ fertilizer = Price\ \times\ Increased\ yield\ over\ control$$
$$V_{yield} = P_{makt}\ \times (Q_{treatment} - Q_{control})$$

Where $P_{market}$the market is price of maize (GHS) and $Q_{treatment}$ is the output of treated plot (kg/ha) and $Q_{control}$ is the output of control plot (kg/ha).

The total variable cost of fertilizer application was calculated as:

$$TVC_{faw} = \left(P_{mf} \times Vol_f\right)$$

Where $TVC_{faw}$is the total variable cost (GHS), P_{mf} is the market price of fertilizer used, Vol_f is the volume of fertilizer used (lha^{-1}).

The net benefit is calculated using the following:

$$Net\ benefit\ due\ to\ fertilization = V_{yield} - TVC_{faw}$$

Where V_{yield} is the value of increased yield due to fertilization and TVC_{faw} is total variable cost of fertilizer.

The returns to fertilization were then calculated using the following:

$$Returns\ to\ fertilizer\ use = \frac{Value\ of\ increased\ yield\ over\ control(GHS/ha)}{Total\ variable\ of\ fertilizer\ application(GHS/ha)}$$

RESULTS

FAW Larval Abundance and Population Dynamics

FAW larval abundance was significantly affected ($P < 0.05$) by the fertilization regimes as shown in figure 1. Control recorded significantly lower larval abundance than ACT-SUL, UNIK 15-AMI, UNIK 15-URE and ACT-URE. Comparing the fertilization regimes, ACT-SUL and UNIK 15-AMI recorded significantly higher larval abundance. Also, UNIK 15-URE and ACT-URE recorded significantly higher larval abundance than NPK-SOA+IS and CLB-CLB when compared.

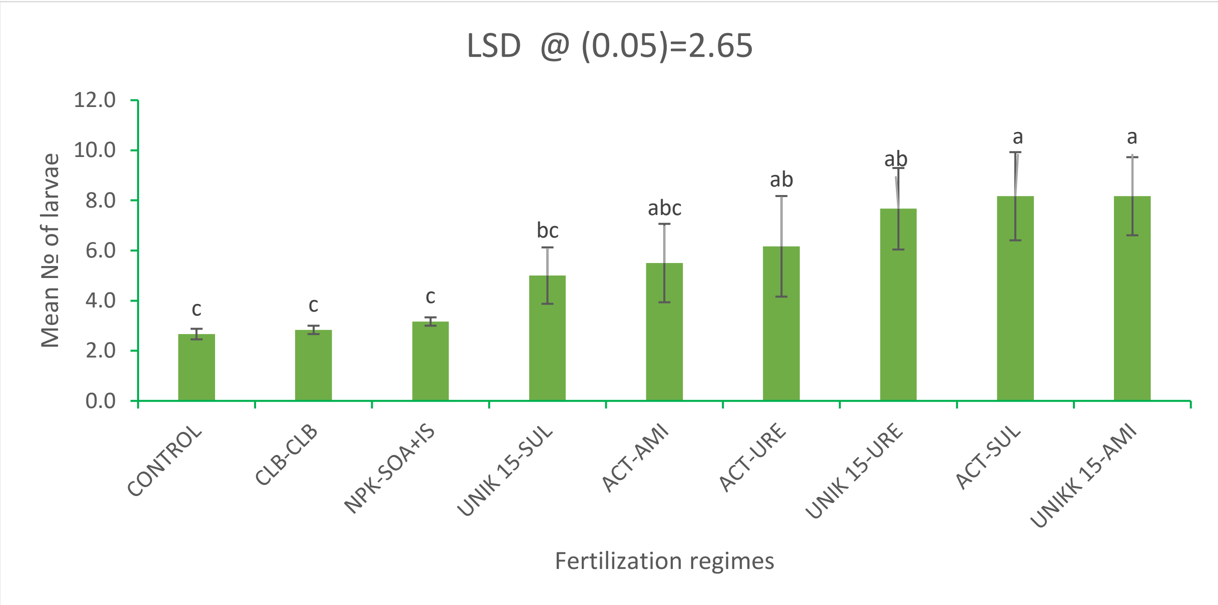

Figure 1: Effect of fertilization regimes on FAW larval abundance

The population dynamics of *S. frugiperda* was affected significantly by the fertilization regimes as presented in figure 2. At 4 WAP, UNIK 15-AMI recorded the highest larval mean number while ACT-SUL recorded the second highest followed by UNIK 15-URE. However, CLB-CLB, control and NPK-SOA+IS recorded the least larval mean number.

At 6 WAP, ACT-SUL and UNIK 15-URE recorded the first and second highest mean number of larval populations followed by UNIK 15-AMI, while the least number recorded from CLB-CLB and control.

There was a similar trend of 8 WAP to that of 4WAP where UNIK 15-AMI recorded the highest, followed by ACT-SUL and UNIK 15-URE. However, control recorded the lowest mean larval number followed by CLB-CLB and NPK-SOA+IS.

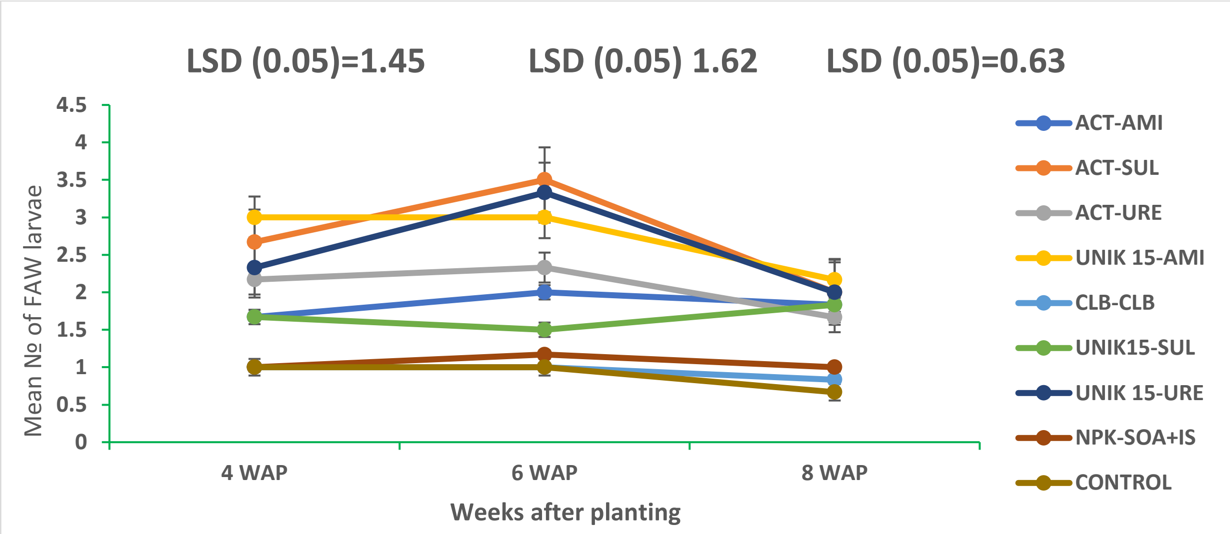

Figure 2: Effect of fertilization regimes on FAW population dynamics

FAW Damage and Trend of Damage Incidences on Maize

There was a significant variation (*P* < 0.05) in FAW damage incidence among the fertilization regime (Figure 3). Apart from NPK-SOA+IS and CLB-CLB, control recorded significantly lower damage incidence than the rest of the fertilization regimes. Among the fertilization regimes, UNIK 15-AMI and ACT-SUL recorded significantly higher damage incidence than ACT-AMI, CLB-CLB and NPK-SOA+IS. Significantly, CLB-CLB and NPK-SOA+IS recorded the lowest damage incidence.

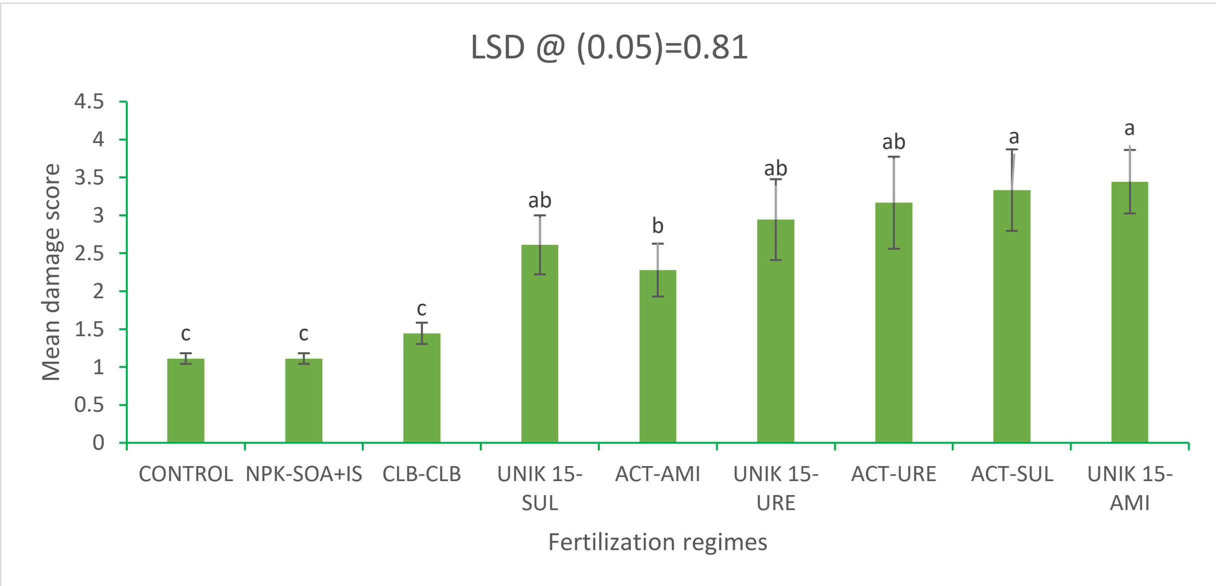

Figure 3: Effect of fertilization regimes on damage incidence of FAW to maize

The trend of damage was affected significantly by the influence of fertilization regimes (figure 4). At 4 WAP, with the exception of NPK-SOA+IS, control recorded the least trend of damage than the rest of the fertilization regimes. The highest damage incidence recorded in UNIK 15-AMI followed by ACT-SUL while NPK-SOA+IS recorded the least damage incidence among the fertilization regimes.

At 6 WAP, control recorded the lowest damage incidence compared to the fertilization regimes. Among the fertilization regimes ACT-URE (3.67) placed at the highest damage incidence level whilst ACT-SUL, UNIK 15-AMI and UNIK 15-URE recorded (3.5 each) the second highest. However, the least damage incidence was recorded from NPK-SOA+IS (1.33).

At 8 WAP, with the exception of CLB-CLB and NPK-SOA+IS, control recorded the least damage incidence compared to the fertilization regimes. Among the fertilization regimes, NPK-SOA+IS recorded the lowest damage incidence while ACT-SUL (2.83) recorded the highest damage score.

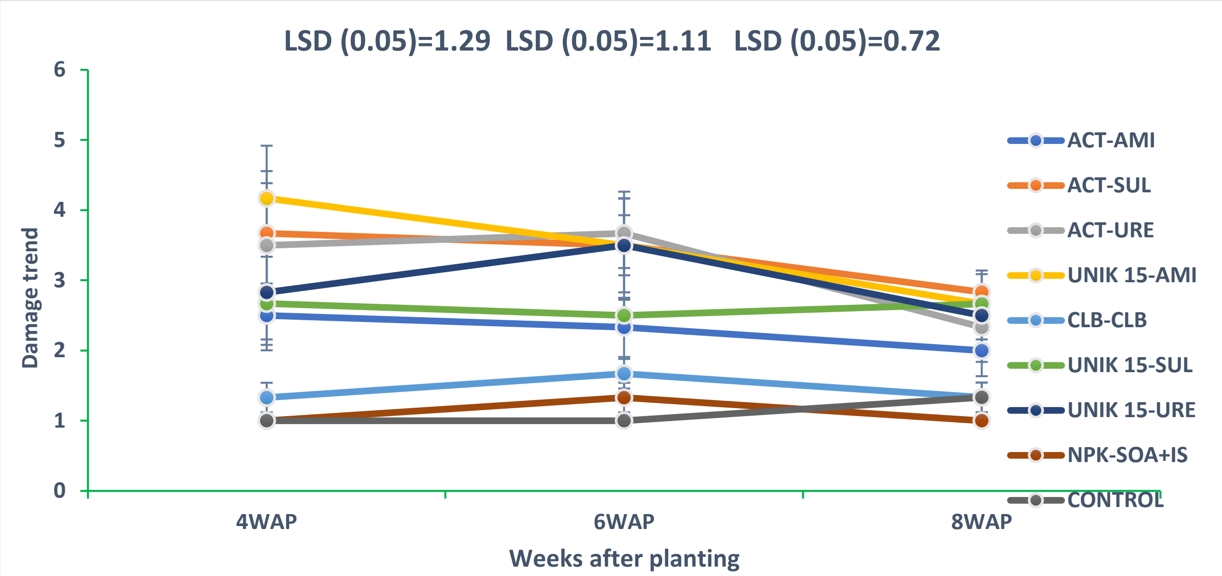

Figure 4: Trend of FAW damage incidence on maize as affected by the fertilization regimes across the sampling weeks

Resistant/Tolerance Level of Maize to FAW Infestation

There was an influence of the resistant levels of maize by the fertilization regimes as presented in Table 2. The fertilization regimes were able to tolerate/resist the FAW infestation by obtaining a varying damage score below four (4) and confirming by obtaining the expected output.

Table 2: Resistance status of maize to FAW infestation as influenced by YARA fertilizer formulations

Fertilization regimes	Damage score	Description	Resistance status
CLB-CLB	1.44	No visible leaf feeding damage	Highly resistant
ACT-AMI	2.29	Few pin holes on older leaves.	Resistant
ACT-URE	3.17	Several shot-holes injury on a few leaves	Resistant
UNIK 15-AMI	3.44	Several shot-holes injury on a few leaves	Resistant
ACT-SUL	3.33	Several shot-holes injury on a few leaves	Resistant
UNIK 15-SUL	2.61	Several shot-holes injury on a few leaves	Resistant
UNIK 15-URE	2.94	Several shot-holes injury on a few leaves	Resistant

Grain Yield and 100 Seed Weight

The grain yield of maize was significantly affected ($P < 0.05$) by the fertilization regimes (figure 5). Maize grain yield ranged from 582 kg/ha in the control to 3,773 kg/ha in UNIK 15-URE respectively. All the maize plots treated with fertilizer, recorded significantly higher grain yield compared to control except CLB-CLB. Among the fertilization regimes, grain yield was in the order, UNIK 15-

URE, ACT-AMI, UNIK 15-AMI, UNIK 15-SUL, ACT-URE, ACT-SUL, NPK-SOA+IS and CLB-CLB. However, apart from CLB-CLB which recorded significantly lower maize grain yield, there was no significant variation among the rest of the plots treated with fertilizer.

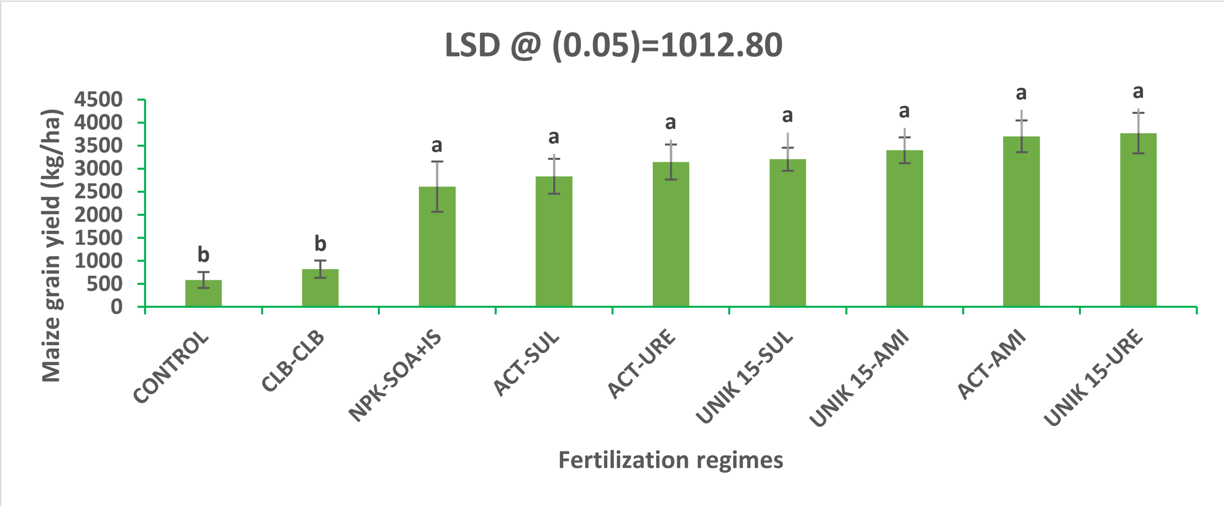

Figure 5: Effect of the fertilization regimes on grain yield (kg/ha) of maize

Hundred (100) seed weight of maize was found to be significantly affected ($P < 0.05$) by the fertilization regimes (Figure 6). Mean seed weight obtained from all the fertilizer treated plots was found to be significantly higher than control except CLB-CLB. Among the plots treated with fertilizer, UNIK 15-URE (26.8) and ACT -AMI (26.3) obtained significantly higher maize grain weight than CLB-CLB (23.0).

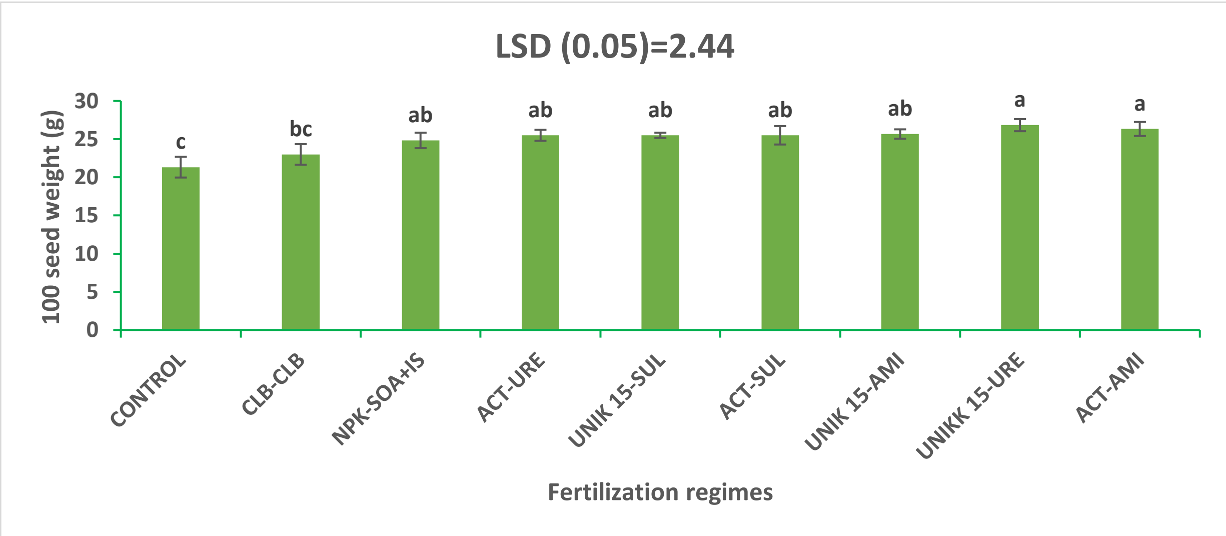

Figure 6: Effect of fertilization regimes on 100 seed weight of maize

Partial Budget Analysis from Maize Grain Yield

The results of partial budget analysis showed a positive value of grain yield increment for all the fertilization regimes compared to no fertilization plot (control). The net benefit of using YARA formulated fertilizers for FAW management were positive and these net returns on investing in YARA formulated fertilizers were higher than unity. Among the fertilizer treatments used, UNIK

15-URE had the highest net benefit and net returns compared to other treatments as presented in Table 3.

Among the fertilization regimes, UNIK 15-URE recorded the highest profit (GH¢ 10,986/ha) closely followed by ACT-AMI with a profit of (GH¢10,488/ha). UNIK 15-AMI (GH¢ 9,614/ha), UNIK 15-SUL (GH¢ 9,143/ha) and ACT-URE (GH¢ 8,873) yielded third, fourth and fifth highest profit. However, with the exception of CLB-CLB (GH¢ 640/ha), NPK-SOA+IS (GH¢ 6758/ha) gave the lowest profit compared to YARA formulated fertilizers.

The cost-benefit analysis shows that UNIK 15-URE provided the highest cost-benefit ratio (GH¢ 10.1) while UNIK 15-SUL provided the second highest (GH¢ 7.9). The third highest was obtained from ACT-AMI with cost-benefit ratio of GH¢ 7.8, which was closely followed by UNIK 15-AMI (GH¢ 7.5). ACT-URE was lower with cost-benefit ratio (GH¢ 7.2) than UNIK 15-AMI (GH¢ 7.5) but higher than ACT-SUL (GH¢ 6.1). NPK + SOA + IS obtained GH¢ 5.0, while CLB-CLB (2.1) recorded the least.

Table 3: The profit and cost-benefit ratio accrued from the maize grain yield obtained from the fertilization regimes in FAW management.

Fertilization regimes	**Outputs**			**Inputs**		
	Yield kg/ha	**Increased yield due to fertilization over control kg/ha**	**Value of increased GH¢/ha**	**Cost of fertilizer GH¢/ha**	**Net benefit due to fertilization GH¢/ha**	**Net returns due to fertilization**
CONTROL	582	–	–	–	–	–
ACT-AMI	3,703	3,121	12,484	1,423	11061.5	7.8
ACT-SUL	2,835	2,253	9,012	1,273	7739.5	6.1
ACT-URE	3,144	2,562	10,248	1,249	8999.5	7.2
UNIK 15-AMI	3,399	2,817	11,268	1,324	9944.5	7.5
CLB-CLB	817	235	940	300	640.0	2.1
UNIK 15-SUL	3,205	2,623	10,492	1,174	9318.5	7.9
UNIK 15-URE	3,773	3,191	12,764	1,149	11615.5	10.1
NPK-SOA+IS	2,609	2,027	8,108	1,350	6758.0	5.0

K-Optima (250ml) = GH¢50, Unik 15 (50kg) = GH¢175, Actyva (50kg) = GH¢195, Amidas (50kg) = GH¢155, Urea (50kg) = GH¢85, Sulfan (50kg) = GH¢95, NPK 15-15-15 (50kg) = GH¢190, SOA (50kg) = GH¢160, Croplift Bio (1L) = GH¢30, maize (1kg) = GH¢3.20. These prices were for 2022 cropping season.

DISCUSSION

Effect of the fertilization on FAW infestation

This research revealed that the abundance of *S. frugiperda* was significantly affected by various fertilization regimes (Figure 1). However, the abundance of *S. frugiperda* on UNIK 15-AMI, ACT-SUL and UNIK 15-URE could be due to the balance of nitrate and ammonium nitrogen in ACTYVA, in combination with SULFAN that has nitrate and ammonium of which the N is immediately available to the plants compared to SA, the unique combination of UNIK 15 that give a well and true proportion of NPK 15-15-15 in combination with high efficiency of the sulfur that improves N efficiency by reducing N volatilization losses in AMIDAS, in combination with the high quality urea that promote green leafy growth and make the plant look lush. This is in line with Shah (2017) who reported that, nutrients application to the soil help crops to produce more succulent, broad and fresh leaves which serves a surface suitable for egg-laying by the varying pests.

The low abundance of *S. frugiperda* on control, CLB-CLB and NPK-SOA+IS could be attributed to plants starved by nutrients and also, the insecticide treated in the control plots. According to Gogi *et al*., (2012), plants development depends on nutrients availability while that of insect-pests depends on the availability of quality food from its host plants. The low abundance of *S. frugiperda* on CLB-CLB (8.5N, 3.4P, 6K+B+Cu+Mn+Mo+Zn) treatment could be the effect of the foliar fertilizer that scared off the FAW larval feeding. Leuck *et al*. (1974) proved that foliage of 'Coastal' Bermuda grass, (*Cynodon dactylon* (L.) person), corn, or sorghum, (S*orghum bicolor* (L.) Moench), sprayed with 14 chemical fertilizers could scare off FAW larval feeding. Nonetheless, the low abundance of FAW in the NPK-SOA+IS plots is due to the pesticides (K-optima) sprayed on those plots that scared off the FAW larvae. Research proofed that, the larval of FAW inflict excessive leaf feeding damage in unsprayed maize than those treated with pesticides (Babendreier *et al*., 2020; Nboyine *et al*., 2021).

Generally, the results from population dynamics of FAW shown that, population increases from the 4 WAP to 6 WAP and finally dropped at the 8 WAP (Figure 2). Normally FAW moths lay their eggs at the early stages of maize growth, therefore damage is limited. The succulent growth stage is the time that the infestation becomes great and the damage duplicated, while during and after tasselling leaf become unpalatable for feeding, that is when the leaf became old. This is in corroboration with Igyuye *et al*. (2018) that, larval feeding behavior was studied by Pannuti *et al*. (2015), and described that despite the fact that vegetative stage (young leaf tissue) is favourable for growth and survival, the leaf tissue is unpalatable on more older plants. Consequently, the leaves of maize are unsuitable for the development of early instars after the VT and reproductive growth stages (Nboyine *et al*., 2021).

The analysis of variance indicated that there was a significant variation on the damage incidence among the fertilization regimes (Figure 3). The high damage incidence on UNIK 15-AMI and ACT-SUL may be due to their combinations (UNIK 15 with Amidas or Actyva with Sulfan) that turned to give the high concentrated nutrients especially N that invites the pests (FAW). As reported by Martin *et al*. (1980) that, Coastal Bermuda grass in particular was susceptible to FAW when pastures are heavily fertilized. More so, as reported by Wiseman *et al*. (1973), that maize plants applied with N fertilizer was the most susceptible to this pest. Further, adding more N to any NPK combination increases the susceptibility of 'Antigua' corn (*Zea mays* L.) foliage to FAW larval feeding greatly. Further reported by Chang *et al*. (1985), that both the larval number and the leaf damage related with FC (fertilized every two weeks) was significantly greater than the larval number and leaf damage of NC (non-fertilized) during all the three observational periods of centipedegrass**.** However, the low damage incidence recorded from NPK-SOA+IS treatments was due to the insecticide's treatment. This is in conformity with Babendreier *et al*. (2020) who stated that, leaf feeding damage incident caused by FAW larvae was higher in corn that was not protected compared to those with insecticides protection.

The weekly trend of FAW damage incidence generally moves from high to low, though some treatments move from low to high and back to low (Figure 4). This incidence could be attributed to the fact that, at the early stages the plants are succulent and palatable for their consumption but at the latter stages leaf becomes tough and unpalatable for consumption. This corroborates with Pannuti *et al*. (2015) that, maize leaf age impacts quality parameters like availability of water, nitrogen and toughness; these may give on to high mortality of the neonate even if the same leaves are consumable for older instars.

Resistance/Tolerance Level of Maize to FAW Damage

The fertilization regimes without insecticides were able to withstand FAW infestation (Table 2). The resistance level of the fertilization regimes might be influenced by the high-quality nutrients that gives a smooth and continuous flow at the righteous proportion and at the righteous hour to the plants when required, the ability to resist the pest damage through thicker cell wall development and or natural defense compounds. This corroborates with Singh *et al*. (2011) who stated that, mineral nutrition safeguards the crops from varying hurdles and greatly execute a unique aspect during the plant's whole life cycle. Also reported by Schumann *et al*. (2010) that, plants with an optimum nutritional status have a maximum resistance (tolerance) to pests and diseases to nutrient deficient plants. And added that, Mineral nutrition can impact two primary mechanisms of resistance: The mechanical barriers formation, (in essence through the development of thicker cell walls) and the combination of natural protection compounds, (for instance phytoalexins, flavonoids, and antioxidants) which issue defense against pathogens. Moreover, fertilization regimes in combination with the CLB-CLB that made up of 8 chemical fertilizers can also influence plant ability to tolerate the damage incidence of FAW. As reported by Leuck *et al*., (1974) that foliage of 'Coastal' Bermuda grass, (*Cynodon dactylon* (L.) person), corn, or sorghum, (*Sorghum bicolor* (L.) Moench), sprayed with 14 chemical fertilizers could scared off FAW larval feeding. Further, some of the nutrients such as S, Mn, Cu and Zn can aid in plants ability to defend itself from the FAW infestation. This corroborates with Fernando *et al*. (2009) that, manganese contributes in the manufacturing of phenolic compounds and some crop protection mechanisms.

Impact of the Fertilization on Maize Grain Yield

This result indicated that, fertilization has a significant effect on maize grain yield (Figure 5). The low maize grain yield received from control could be accredited to inadequate nutrition to the plants as there was no fertilizer applied to the control plots. This correspond with Arthur (2014) that, grain yield among plants in the fertilizer treated plots were significantly higher than those in the no fertilizer treated plots. Among the fertilization regimes, CLB-CLB treated plots obtained significantly low grain yield. This might be caused by insufficient macro-nutrients applied to the crops as the NKP concentration in CLB-CLB is not adequate for the plant to give good yield. This corroboration with Adu *et al*. (2014), who reported that, nutrients requirements of corn is high particularly NPK. Further, observation by Memon *et al*. (2012) reported that, the yields of grain were affected by a variety of fertilizer treatments.

Among the fertilization regimes, there was no significant variation though, the highest grain yield recorded from UNIK 15-URE (3,773 kg/ha) followed by ACT-AMI (3,703 kg/ha) and UNIK 15-AMI (3,399 kg/ha) demonstrated that, the maize grain yield increased in the company of increasing of N concentration. The increment of the grain yield might be influenced by the concentration of N content in the fertilizer formulations applied as a top-dressing after applying NPK as basal. Urea (46% N content) applied as top-dressing recorded highest grain yield followed by YaraVera (Amidas) (40% N content with 5.6% S). This correspond with Adu *et al*. (2014) that, among the primary nutrients that most often limits yield is N, the quantity of leaves the plant produces and the seed quantity per cobs is determined by the N and thereby determines the potential of the yield. Further, reported by Harrison *et al*., (2019), that inorganic fertilizer can lead in increased yield in spite of higher pressure of the pest, as a result of better plant growth.

Partial Budget Analysis from Maize Grain Yield

As shown from the partial budget analysis, it will be most profitable managing FAW in maize field for grains using YARA formulated fertilizers compared to unfertilized field (Table 3). All the YARA formulated fertilizers yielded more profit than the non-YARA formulated fertilizer with insecticide spray (NPK-SOA+IS) except CLB-CLB. The highest profit and cost-benefit ratio obtained from UNIK 15-URE (GH¢11615.5) among the fertilizer treatments may be due to its high yielding and low input cost associated with the production. Though ACT-AMI (GH¢11,061.5) and UNIK 15-AMI (GH¢9,944.5) yielded second and third highest profit per hectare, the cost-benefit ratio (7.8 and 7.5 respectively) obtained from its use was lower than that of UNIK 15-SUL (GH¢ 9,318.5) cost benefit ratio (7.9). This high cost-benefit ratio of UNIK 15-SUL could be associated with the low cost of sulfan to that of amidas. However, CLB-CLB (GH¢641.0) lowest profit and cost-benefit ratio (2.1) obtained could be attributed to the inadequate nutrients supply. This correspond to Teetes, (1980) and Listinger, (1993), who stated that plants that get adequate nutrients are healthier, stronger and generally capable to pay back for the pest damage better compared to those under nutritional deficiency.

CONCLUSION

Generally, there was significant variation in FAW larval abundance in various fertilization regimes. Apart from CLB-CLB, control recorded significantly lower larval abundance compared to fertilization regimes. Among the fertilization regimes, UNIK 15-AMI and ACT-SUL obtained statistically higher larval abundance whilst CLB-CLB recorded the least. There was some level of tolerance offered to maize plants against FAW infestations by the fertilization regimes. Control obtained significantly lower damage incidence compared to fertilization regimes except NPK-SOA+IS and CLB-CLB. Among the fertilization regimes, UNIK 15-AMI and ACT-SUL obtained statistically higher damage incidence when compared. All the fertilizer plots yielded significantly higher grain yield compared to control. Among the fertilization regimes, CLB-CLB recorded significantly lower grain yield, though there were no significant variations among the rest of the treatments, UNIK 15-URE, ACT-AMI and UNIK 15-AMI was in the order of high to low. The partial budget analysis demonstrated a positive value of profit increment for all the fertilization regimes compared to control. Among the fertilization regimes, CLB-CLB yielded less profit and cost-benefit ratio, whilst the highest profit and cost-benefit ratio was obtained from UNIK 15-URE. The second and third profit was recorded from ACT-AMI and UNIK 15-AMI respectively. Though UNIK 15-SUL recorded fourth in terms of profit yet, it cost-benefit ratio was higher compared to ACT-AMI and UNIK 15-AMI respectively. It is recommended that, farmers apply UNIK 15 at basal and urea or amidas as topdressing for management of FAW, better yield as well as high profitability per hectare.

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