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Effect of intercropping on the incidence and severity of damage of fall armyworm (*Spodoptera frugiperda* J.E. Smith) on maize (Zea mays l)

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Abstract

The fall armyworm (Spodoptera frugiperda J.E. Smith) is an invasive and destructive pest that came into Nigeria recently, where it has established itself as one of the maize's most important insect pests. The effect of intercropping on the incidence and severity of damage to maize was investigated, where maize was intercropped with five different crops, namely, cowpea, groundnut, soya bean, sorghum and roselle, and controlled plots with sole maize. Randomized Complete Block Design was used, and the treatments were replicated four times. Parameters taken were number of damaged leaves per plant, severity of damaged on leaves, number of damaged ears per plot, severity of damage on ears and yield per plot. The result of the study had shown that plots where maize was intercropped with soya bean had, significantly (P<0.05), the lowest incidence (17.5 %) and severity of damage (2.8) compared to plots with sole maize, that had the highest incidence (43.8 %) and severity of damage (5.5). The percentage of damaged tassels was the highest in plots where maize was a sole crop (17.5 %), followed by maize and sorghum (15 % each). The lowest percentage of damaged tassels was recorded on maize that was intercropped with soya bean (5.0%), and was significantly (P< 0.05) lower than the rest of the five treatments. Similarly, the percentage of damaged ears was the highest with maize as a sole crop (15 %) and lowest on maize intercropped with soya bean (3.7 %). Highest yield was also recorded in plots where maize was intercropped with soya bean (7.43 tons/ha), followed by maize-cowpea intercropped plots (6.44 tons/ha) and maize-groundnut intercropped plots (5.23tons/ha) and plots where maize was a sole crop had, significantly the lowest yield (P< .05) The result of this study is indicative of the potentials of using intercropping, especially when legumes such as soya bean, are included, as a management tactic against fall armyworm on maize. This will reduce a total reliance on synthetic insecticide to manage the insect pest by small holder maize farmers in Nigeria.

Key words: *Damage severity, Fall armyworm, Incidence, Intercropping, Maize,*

Introduction

Fall armyworm (FAW) (Spodoptera frugiperda Smith) is an invasive and damaging pest native to tropical and subtropical America. The pest arrived in to Sub-Saharan Africa (SSA) in 2016 at a time when the region is challenged to feed its rapidly growing population, which has now spread throughout the continent, reaching Asia, and therefore, global (Geogen et al, 2016; Hruska, 2019; Kassie et al.,2020). It has a wide host range. It was reported that the larvae of fall armyworm attack 353 host plant species belonging to 76 plant families with the most significant number in family Poaceae (106 texa), Asteraceae and Fabaceae (31 texa each) Mentezaro et al., (2018),

How the pest was introduced into

Africa from its native habitat in the Americas is unclear. However, such invasive pests as the fall armyworm are known to across continents either through infested commercial grain or through jet streams across oceans. Many fall armyworm moths have been collected in the Gulf of Mexico as far as 250 km from land, indicating the possibility of seasonal trans-Gulf migration between the United States and the tropics. It is particularly hard to control, as the moths are strong flyers, breed exponentially, and the larvae can feed on a wide variety of plant species. In addition, it can quickly develop resistance to pesticides if they are not used judiciously. The larvae burrow into the growing point of the maize plant and destroy it or clip the leaves. They also burrow into the ear and feed on kernels. (CIMMYT, 2016).

Already, the impact of the fall armyworm is being felt across Africa. Estimates from 12 African countries indicated that the pest is causing annual maize losses of between 8 and 21 million tonnes, leading to monetary losses of up to US$ 6.1 billion, while affecting over 300 million people in Africa, who, directly or indirectly, depend on the crop for food and well-being. The pest's impact is likely even higher when its damage to other crops is quantified (ICIPE, 2017). FAW-induced economic impacts can include reduction of income due to reduced maize sales; reduced food consumption because of reduced food availability from both crops and livestock, as crop residues are primary livestock feed source in rural areas; higher medical treatment expenditure for people exposed to insecticides and environmental damage related to insecticides contamination (Denberg and Jiggins, 2007; Midingoyi et al., 2018).

The main management methods used in the Americas against fall armyworm were synthetic pesticides such as pyrethroids, organophosphates and carbamate as well as genetically modified crops, and studies had shown that the pest was resistant to both synthetic and GM maize (Abrahams et al., 2017; Houngo et al., 2021), Similarly in Nigeria, Lamda-cyhalothrin, permethrin and chlorprifos were used to control the insect pest with little success and some residues of the chemicals were found in soils. (Togola et al, 2018). This can therefore be detrimental to the well-being of the environment, farmers and other beneficial animals. However, there were several reports on the effectiveness of intercropping in reducing the insect pest (Hailu et al., 2018). Intercropping maize and legumes such as climbing beans and cowpea, in addition to increasing nitrogen content of the soil, has also reduced the population of stem borers and fall armyworm compared to monocropped maize with volatile emission as the major mechanism for the reduction effect (Tanyi, et al., 2020, Sheidegger et al., 2021)). This study was, therefore, aimed at determining the effect of using legume intercrops, such as cowpea, soyabean and groundnut to manage the pest in a sustainable integrated pest management (IPM) programme.

Materials and Method

Study Area

The experiment was carried out in the experimental field of Samaru College of Agriculture, Ahmadu Bello University, Zaria, Nigeria (7° 6´E; 11°2´N).

Description of the field and experiment layout

The total area used was 0.12 ha., which was ploughed, harrowed and ridges made at 70 cm apart. Randomized Complete Block Design (RCBD) was used, with six treatments that were replicated four times. Each treatment was allocated four plots of

32.4 m with one meter alley between plots. Five crops were used as intercrops with maize (SAMMAZ 14), namely; cowpea, groundnut, soya bean, sorghum and roselle. Therefore, the six treatments were; maize + cowpea, maize +groundnut, maize +soya bean, maize + sorghum, maize + roselle and sole maize. Each treatment had ten ridges of 6 m length were allocated to each plot (One ridge of intercrop and two ridges of maize), where 1st, 4th, 7th and 10th ridges were planted with the intercrops, and 2nd, 3rd, 5th, 6th , 8th and 9th ridges were planted with maize.

Planting and Agronomic Practices

Maize was planted on the 5th June at two seeds per hole and intra –row spacing of 25 cm apart on ridges. One week later the intercrops were planted at two seeds per hole for groundnut, cowpea and soya bean and four seeds per hole was adopted for sorghum and roselle, which were later thinned to two plants per stand. Weeding was done 2 weeks after planting of Maize and NPK fertilizer was applied at the rate of 120 kg/ha N, 60 kg/ ha of P2O5 and 60 kg/ ha of O Six weeks later Urea fertilizer was applied at the rate of 100kg/ ha before earthing up. The intercrops were also fertilized as recommended.

Data Collection

In each plot, 20 plants were sequentially inspected for fall armyworm damage from the 5th and 6th ridges that contain the maize plants. The damaged and undamaged plants were recorded from two weeks after sowing and the percentages of damages plants were calculated. The severity of damaged on leaves were determined using modified Davis and Williams (1992) scale 0f 0-7, where 0 signified no damage leaves;1,presence of lesion on leaves; 2, <50 % of leaves where damaged; 3, 6-25 % of laves were damaged; 4, 26-50 % of eaves here damaged; 5, 51-75% of leaves were damaged; 6, 76-100% o leaves were damaged and 7, whorls were completely damaged and te plant is dying. The severity of damaged was explained using Prasanna et al (2018) methods, where 1-3signified as low damage severity; 4-5 moderate damage severity and 6-7 high damage severity. Damage and undamaged ears and tassels were also recorded and percentage incidence calculated.

Harvesting

At maturity cobs from each plot were harvested, sundried for two weeks and put in separate labeled bags. Ten cobs were randomly selected from each bag, number of rows per cobs and weight of cobs were recorded. Damage and undamaged cobs were recorded and percentage incidence was calculated. The severity of damage on cobs were determined by using a scale of 0-5 as adopted from Prasanna et al., (2018), where 0 signified, No damage on ear; 1,<5 % of kernels damaged; 2, 6-25 % of kernels damaged; 3, 26-50 % of kernels damaged; 4, 51-75 % of kernels damaged; 5, 76-100 % of kernels damaged. The cobs were returned into their initial bags and the content of each bag was threshed when the moisture content was 13.5-15 % (Akhtaruzzaman et al, 2017). After threshing, one thousand grains were counted from each plot bag and the weights were recorded using a weighing balance (Camry 434812). Total weights of grains per plots were recorded and converted to the yield per hectare (Tanzi and Mutengwa, 2020) using the following formula:

Wight of grains per ha = Y2

To convert to ton/ hectare, Y2 was divided by 1000

Where, Y1 = Yield per plot

A = plot area

Y2 = Yield per hectare

Data analysis

The data of the two field experiments were summed and average were taken and evaluated by Analysis of Variance (ANOVA). The means were separated using Duncan New Multiple Range Test (DMRT) at 5 % level of significance. Statistical Analysis System (SAS version 9) was used as a statistical programme. Data on yield were converted into tons per hectare before analyzing.

Results

The incidence of FAW on maize intercropped with other crops was studied at early whorl stage (1-4 weeks after planting) in 2018 as shown in Table 1. The percentage of damaged leaves was highest in maize that was planted as sole crop (17.5 %), followed by maize that was intercropped with sorghum (17.3 %), and the lowest percentage of damaged leaves was recorded in the plot where maize was intercropped with Soya bean. However, there was no significant difference ($P< 0.05$) among the damage percentages of incidence across all the treatments. Similar trend was observed on the severity of damage on maize, in which severity of damage was the highest in sole maize crop plots (2.8a), and it differed significantly ($P< 0.05$) from plots of maize intercropped with groundnut. The lowest severity of damage was found from plots where maize was intercropped with Soya bean (1.5), followed by when maize was intercropped with cowpea (2.3) and when maize was intercropped with Roselle (2.3). However, highest severity of damage was obtained where Maize was a sole crop (2.8).

Incidence and severity of damage were also studied at late whorl stage (5-8 weeks after sowing) and shown in Table 2. Sole maize crop plots had the highest damage incidence and severity (43.8 % and 5.8 respectively), followed by maize intercropped with sorghum (M+S) (33.3 % and 5.5 respectively), and there was no significant difference ($P< 0.05$) between them. The plots of maize intercropped with soya bean has the lowest incidence (17 %), followed by maize and groundnut (22.5 %), and there was no significant difference ($P< 0.05$) between the two. The damage severity rating of the two treatments was the same (2.8 each).

The Fall armyworm larvae were found damaging the tassel and ears (Table 3). The percentage of damaged tassels was the highest in plots where Maize was a sole crop (17.5 %), followed by Maize and sorghum, and maize and groundnut (15 % each). The lowest percentage of damaged tassels was recorded on maize that was intercropped with soya bean (5.0%) and, was significantly ($P< 0.05$) lower from the rest of the five treatments. Similarly, the percentage of damaged ears (plate 9) was the highest with maize as a sole crop (15 %) and lowest on maize intercropped with soya bean (3.7)

Yield and yield components are presented (Table 4). The number of kernel rows was the highest in maize intercropped with soya bean (15.0), and it was significantly ($P<0.05$) higher than the remaining five treatments. Lowest number of rows was found in maize grown as sole crop (12.7). Grain weight per cob and 1000 grain weight was also the highest in maize intercropped with soya bean. The lowest grain weight per cob and 1000 grain weight were the lowest in maize grown as sole crop (109.4 g and 278.3 g respectively). While the highest grain weight per cob and 1000 grain weight, were obtained where maize was intercropped with soya bean (158.9 g and 321g respectively). Similarly, the yield per hectare was the highest in the plot where maize was intercropped with soya bean (7.43 tons/ha), followed by maize and cowpea (6.44tons/ha), and there was no significant difference ($P<0.05$) between the two treatments. Lowest yield per hectare was recorded in plots where maize was cultivated as sole crop (2.84 tons/ha), followed by maize and roselle (3.91 tons), maize and sorghum (3.98 tons/ha) and maize and groundnut (5.23 tons/ha).

Table 1: Effect of intercropping on the incidence and severity of damage by fall armyworm on maize at early whorl stage in Samaru Zaria in 2018

Treatment	Number of damaged leaves	Percentage of damage leaves	Damage severity
M + G	2.5^{a}	13.8^{ab}	2.0^{a}
M + C	2.7^{a}	15.0^{ab}	2.3^{a}
M + SB	2.3^{a}	11.3^{b}	1.5^{a}
M + S	3.3^{a}	17.3^{a}	2.5^{a}
M + R	3.0^{a}	15.0^{ab}	2.3^{a}
M	43.3^{a}	17.5^{a}	2.8^{a}
CV	28.30	19.56	47.91
SE±	0.80	2.93	1.06

Means in the column accompanied by the same letter(s) are not significantly different (P< 0.05), using New Duncan Multiple Range Test (DMRT).

M+G-Maize and Groundnut; M+C-Maize and Cowpea; M+SB- Maize and Soyabean; M+S-Maize and Sorghum; Maize and Roselle; M-Maize alone.

Table 2: Effect of intercropping on the incidence and severity of damage by fall armyworm on maize at late whorl stage in Samaru Zaria

Treatment	Number of damaged leaves	Percentage of damaged leaves	Damage severity
M + G	4.5^{cd}	22.5^{cd}	2.8^{c}
M + C	4.75^{cd}	23.8^{cd}	3.5^{b}
M + SB	3.50^{d}	17.5^{d}	2.8^{c}
M + S	6.75^{b}	33.8^{b}	5.5^{d}
M + R	5.50^{bc}	27.5^{bc}	3.8^{b}
M	8.75^{a}	43.8^{a}	5.8^{d}
CV	15.98	15.98	27.48
SE±	0.89	4.50	1.15

Means in the column accompanied by the same letter(s) are not significantly different (P< 0.05), using New Dun can Multiple Range Test (DMRT).

Table 3: Effect of intercropping on incidence of fall armyworm on tassels and ears of maize in Samaru, Zaria.

Treatment	Percentage of damaged tassels	Percentage of damaged ear
M + G	15.0^{ab}	8.75^{bc}
M + C	10.0^{bc}	10.0^{ab}
M + SB	5.0^{c}	3.75^{c}
M + S	15.0^{ab}	10.0^{ab}
M + R	12.5^{ab}	12.5^{ab}
M	17.5^{a}	15.0^{a}
CV	30.98	35.36
SE±	3.88	3.54

Means in the column accompanied by the same letter(s) are not significantly different (P< 0.05), using New Dun can Multiple Range Test (DMRT).

Table 4: Effect of intercropping on yield and yield components of Maize in FAW infested field in Samaru, Zaria in 2018 and 2019

Treatment	No of rows /cob	Grain weight/cob (grams)	1000 grain weight (grams)	Yield (ton/ha)
M+G	14.3^{b} .	123.9^{bc}	296.5^{c}	5.23^{b}
M+C	13.4^{b}	141.5^{b}	304.0^{b}	6.44^{a}
M+SB	15.1^{a}	158.9^{a}	321.0^{a}	7.43^{a}
M+S	13.0^{b}	115.9^{c}	290.8^{d}	3.98^{c}
M+R	13.1^{b}	119.9^{cd}	290.3^{d}	3.91^{c}
M	12.7^{c}	109.4^{d}	278.3^{e}	2.84^{d}
CV	4.01	3.24	1.27	39.69
SE±	0.81	12.43	3.78	13.67

Means in the column accompanied by the same letter(s) are not significantly different (P< 0.05), using New Dun can Multiple Range Test (DMRT).

Discussion

The result of this study had revealed the effects of using intercropping to manage FAW in maize field. Incidence and severity of damage were studied when maize plant was at early and late whorl stage. There was no much damage at early whorl stage, probably at this period the population of FAW was low. However, at late whorl stage the damage on the leaves was higher and the effects of the intercrops were also visible. Intercrops usually help in reducing incidence and severity of damage in maize caused by FAW in many ways, including repelling the FAW adult, attracting the natural enemies of FAW, confusing the FAW adult in finding the appropriate host as well as increasing soil fertility, which help the crop to compensate FAW feeding (FAO, 2018; Mediga et al., 2017 Cokola et al., 2020). Highest incidence and severity of damage were found on maize that was planted as monocrop, and it was followed by the plot where maize was intercropped with sorghum. Previous findings had revealed the two crops as the primary hosts of FAW. (Dimas et al., 2015). However, incidence and severity of damage were the lowest in plots where maize was intercropped with soya bean, followed by plots where maize was intercropped with cowpea. Interestingly, both the intercrops where low incidence and severity were recorded were legumes crops. Tanyi et al. (2020) demonstrated how beans, a legume crop has reduced the incidence and severity of FAW in an intercropped field. The percentage of larvae was also the lowest in maize-soya bean intercropped plot.

The adult FAW are responsible for locating and selecting suitable host on which they lay their eggs. Probably in the Maize-Legume intercrop, the legume crop might had released some semiochemicals that had confused the pest, hence the presence of fewer larvae in maize-soya bean intercrop plots. (McGraw and Koppenhofer, 2010; Khan et al., 2010). In addition, barrier effects, repellent volatiles, emission and enhanced enemy abundance could be the key mechanism that reduced the damaged caused by the insect pest (Otim et al., 2021). Similar result was reported by Tanyi et al. (2021) when Maize was intercropped with Cowpea, which is a legume crop.

Damaged tassels and ears were recorded in the intercropped plots, where the percentages of damaged tassels and ears were the highest where maize was a monocrop. The lowest percentages of damaged tassels and damaged ears were recorded in plots where Soya bean was an intercropped However, there was no significant difference in terms of damaged tassel and damaged ear for plots where maize was intercrop with sorghum and Maize as a monocrop. Sorghum is another preferred host of FAW which may have attracted more adult FAW with similar semi chemicals emitted by maize. The insect preference and best performance for grasses has been previously demonstrated by other researchers, which showed Spodoptera frugiperda preferred grasses such as maize, sorghum and bermuda grass, which are C4 plants, as oppose to C3 plants such as cotton and soya bean (Buntin, 1986; Lewter et al, 2006; Nagoshi et al.,2007).

The yield was highest in plots where maize was intercropped with Soya bean, followed by the plot where maize was intercropped with cowpea and groundnut. This has revealed how the three legumes in this study had significantly increased the yield of maize in a field infested by FAW. Soya bean increase in yield of about two folds, was also reported by Midega et al. (2018) when *Demodiun intortum*, a legume crop, was included as an intercropped in a Push-pull experiment to manage fall armyworm in Kenya. However, the increase in yield of maize intercrop in this study may not solely be attributed to controlling FAW. Because legumes biomass contributes significant amount of Nitrogen via biological nitrogen fixation that enhance soil fertility and plant nutrition which might have also enhanced the maize yield in the intercropped plots (Midega et al., 2018; Hailu et al., 2018). In summary, therefore, the yield recorded in this study might be as a result of low incidence and severity of FAW damage as well as improved maize nutrition resulting from nitrogen fixation by the companion legume crops (Midega et al., 2018; Tanyi et al, 2020; Sheidegger et al., 2020).

Conclusion

The finding of this study had shown that legumes, especially soya bean when intercropped with maize (1 ridge of soya bean to 2 ridges of maize) can reduce the incidence and severity of damage of fall armyworm on maize, largely due to volatile emissions that repel adult fall armyworm. The maize-legume combination had also increased the yield of maize due to nitrogen fixing capability of soyabean. Therefore, soya bean should be used in a maize-legume combination to sustainably, manage fall armyworm in an integrated pest management (IPM) strategy against the pest.

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