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ENHANCING THE EFFICACY OF *ALLIUM* (GARLIC) EXTRACT AND MAIZE-LEGUME INTERCROPPING AGROECOLOGICAL PRACTICES IN MITIGATING THE FALL ARMYWORM DAMAGE ON MAIZE

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Abstract

Several biotic and abiotic variables limit the maize yield in Africa. The fall armyworm (FAW), a new invasive pest in Africa, and particularly in Cameroon, has exacerbated the problem. This study was done to demonstrate the fall armyworm control on maize in an intercrop system with legumes, and the locally made organic *Allium* (garlic) emulsion. In this study, a field experiment was laid out in a randomized complete block design with nine treatments (control, insecticide, *Allium* (garlic), maize dwarf-bean, maize-dwarf bean insecticide, maize-dwarf bean *Allium* (garlic), maize-cowpea, maize-cowpea insecticide and maize-cowpea *Allium* (garlic) and three replicates. Maize vegetative data (plant height, stem girth, and number of leaves) were collected, as well as pest occurrence and severity (fall armyworm) and maize yield. The best outcomes for the fall armyworm control in this study came from maize intercropped with legumes (dwarf bean and cowpea), in combination with either synthetic insecticides or the locally made organic garlic emulsion. Control had the most damaged plants for FAW (14) and the number of damaged plants differed significantly (P< 0.05) across treatments. The highest number of FAW (4 FAW) were found in the control, which differed significantly (P<0.05) across treatments. The maize grain yield ranged from 2.1 tha^{-1} to 5.7 tha^{-1} and differed significantly across treatments (P<0.05), with the highest yields (5.7 tha^{-1}) in the maize-cowpea insecticide and maize-cowpea garlic treatments, and the lowest yields (2.1 tha^{-1}) in the control.

Conclusively, the maize intercrop with legumes and the locally made organic *Allium* (garlic) emulsion served as sustainable alternative to the synthetic pesticide that effectively controlled FAW without jeopardizing environmental sustainability and increased maize yield.

Keywords: *Allium* (garlic) botanical, pest incidence, pest severity, fall armyworm (FAW), yield, maize, intercropping.

INTRODUCTION

One of the most widely grown crops in Sub-Saharan Africa (SSA) is maize (Zea mays) farmed on more than 33 million hectares annually (FAOSTAT, 2015). Maize production has been an important source of income for smallholder farmers, particularly in Cameroon, where production increased from 355,000 tons in 1968 to 2.25 million tons in 2017, expanding at an annual rate of 4.57 percent. Cameroon is one of the world's top 39 maize-producing countries (FAOSTAT, 2017).

Poor soil fertility, poor cultural practices, inadequate sophisticated production technologies, such as varieties and pest management techniques, all contribute to low maize yield (Bulto and Hirpa, 2016; Agbor et al., 2022a). Arthropod pests are one of the major contributors to low maize yields, and they are at the heart of a slew of critical issues plaguing the industry today. Arthropods are thought to destroy 18–26 % of the world's annual crop production, which has a market worth of more than $ 470 billion, despite the use of synthetic pesticides. Before harvest, a bigger percentage of losses (13–16 %) occur in the field, and losses have been greatest in underdeveloped nations (Culliney, 2014). The fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), is one of the most invasive insect pests on maize today, producing significant yield losses (Assefa and Ayalew, 2019; Kenis et al., 2022). Originally from North America, the polyphagous pest known as FAW damages a number of crops, including maize, sorghum, beans, and cotton (Day et al., 2017). According to recent studies, FAW is present in 28 African countries, indicating that the pest is spreading quickly throughout the continent and endangering the food security of millions of people (ibid).

Since FAW first appeared in several African nations, synthetic pesticides have been routinely used as an emergence response to stop its spread and reduce damage to maize crops. It is important to remember that, apart from emergency labelled uses, there are currently no authorized synthetic pesticides for FAW management in African nations, highlighting the urgent need for synthetic insecticide screening (Sisay, 2019). Farmers have expressed dissatisfaction that the current synthetic insecticides are inefficient against FAW, forcing them to use higher doses with frequent treatments, accumulating pesticides in the environment, and accelerating the emergence of resistance (Sisay et al., 2019). Growing concerns and/or a need to find sustainable integrated management options that promote soil fertility and crop protection without jeopardizing environmental sustainability has resulted from this challenge (Suge et al., 2011). As a result, plant extracts which have long been promoted as effective petrochemical insecticide substitutes are seriously being considered. Botanical extracts are environmentally friendly, cost-effective, and biodegradable (Agbor et al., 2022b). Botanicals are inexpensive, widely available, and affordable, all of which are significant characteristics for smallholder farmers in Africa (Reddy and Chowdary, 2021; Ngegba et al., 2022). *Azadirachta indica, Milletia ferruginea, Croton macrostachyus*, *Phytolacea docendra, Jatropha curcas, Nicotina tabacum, and Chrysanthemum cinerariifollium* are just a few of the plants that have been utilized to manage insect pests successfully (Addisu et al., 2014; Chou et al., 2022).

Intercropping is the practice of cultivating two or more crops simultaneously on the same piece of land during the same growing season (Ijoyah and Jimba, 2012). It is an old tradition adopted by smallholder farmers in Africa, India, Sri Lanka and Malaysia in their cropping systems. Intercropping is primarily used to reduce the risk in case one of the companion crops fails owing to weather fluctuations or an increase in pest and disease incidence (Ananthi et al., 2017) the surviving crop should meet the farmer's needs. It has a number of advantages over the solitary cropping such as pest and disease control, multiple harvests, just to name a few. In tropical regions, corn has been used as one of the companion crops in an intercropping system (John et al., 2006). Recently, intercropping has gained recognition as a crop production system with many advantages (Belel et al., 2014). In addition, Hailu et al., (2018), stated that, when combined with other sustainable management approaches, intercropping maize with legumes could be a viable alternative to the push-pull technique for controlling FAW. Furthermore, legumes are a repellent crop and in combination with botanicals become a control tool for the fall armyworm on maize. As a result, this research was planned to exploit garlic's botanical pesticide capabilities in a maize-and-legume (cowpea and dwarf bean) intercrop to combat fall armyworms.

MATERIALS AND METHODS

Research area description

The work was done at the University of Buea. The site is situated in the South West Region of Cameroon, between longitudes 9°12'E and 4°20'E and latitudes 4°3'N and 4°12'N of the equator. Volcanic rocks that have weathered into mainly silt, clay, and sand make up the soil. With an average relative humidity of 85–90 % and a less pronounced dry season, Buea has a monomodal rainfall regime. From October through February is the dry season, whereas between March and September, the rainfall amounts between 2085 and 9086. As the elevation increases from 200 to 2200 meters above sea level, the soil temperature at 10 cm deep drops from 25 ℃ to 15 ℃, while the average air monthly temperature ranges from 19 ℃ to 30 ℃ (Fraser et al., 1998; Manga et al., 2014).

Experimental setup

Three replicates per treatment were used in the randomized complete block design experiment. With the aid of a cutlass, the experimental field was cleared and divided into 27 plots, each measuring 2 m by 2 m. With a hoe, each experimental plot was manually tilled to a height of 30 cm. The replicates were separated from each other by a 1m distance, and each plot within a replicate was separated by a 0.5 m space. A 2 m buffer zone separated the experimental site from the surrounding environment. The experimental design included nine treatments as seen in Table 1. Maize intercropping systems included maize-dwarf bean intercropping system and maize-cowpea intercropping system. Each maize plot had three rows and four columns of maize with 75 cm x 50 cm inter and intra row spacing, resulting in 12 stands per plot, whereas legumes were planted at alternative rows to maize using row intercropping technique at 45 cm x 30 cm inter and intra row spacing with 4 rows and 6 columns of legumes, resulting in 24 stands per intercrop plot (Fig. 1).

Table 1. Codes and meaning of treatments.

codes	Full meaning of treatments
T1	Control Maize
T2	Maize+Insecticide
T3	Maize+ botanical *Allium* (garlic) emulsion
T4	Mazie+dwarf bean intercrop
T5	Maize+dwarf bean intercrop+Insecticide
T6	Maize+dwarf bean intercrop+botanical *Allium* (garlic) emulsion
T7	Maize+cowpea intercrop
T8	Maize+cowpea+insecticide
T9	Maize+cowpea+botanical *Allium* (garlic) emulsion

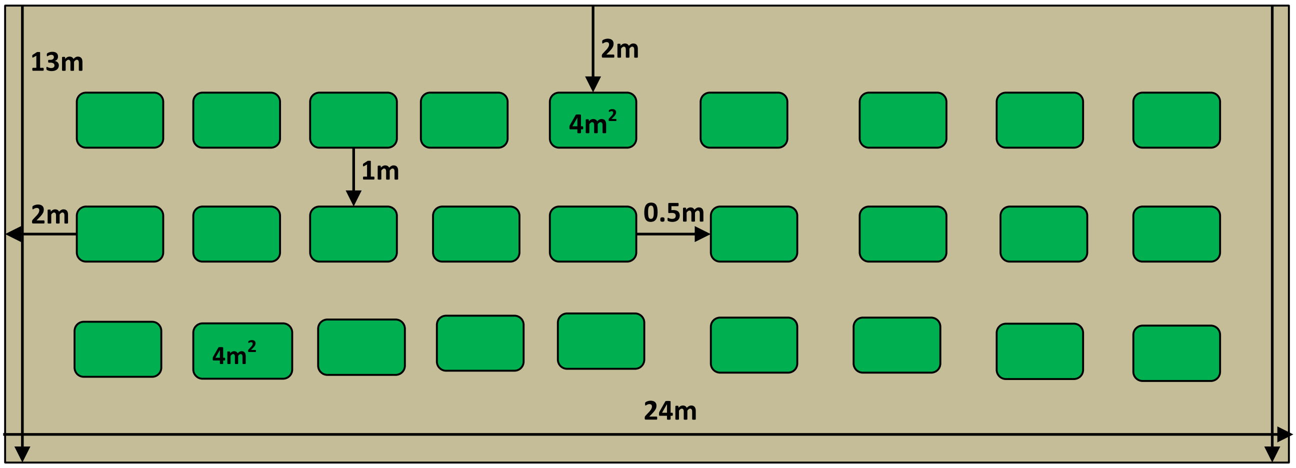

Figure 1. Randomized complete block design with four treatments and four replicate.

Locally produced organic pesticide (Garlic botanical)

The organic amendment was made from fresh garlic bulbs (*Allium sativum*). The outer layers of the matured garlic bulbs were peeled and 250 g of peeled garlic were placed in a kitchen blender with 250 ml of water and blended to obtain garlic liquid extract. The liquid extract was mixed with 1 liter of vegetable oil from groundnut seeds (KING'®, Legos-Nigeria), purchased at a nearby market. A sticky emulsion was made by adding 10 g of detergent (SABA®, Douala, Cameroon), later sieved to make a homogenous extract and kept at room temperature in a plastic container.

The most effective dose for the best field application of the garlic emulsion was established through a laboratory study before being applied in the field. Ten Fall Armyworm 2^{nd} and 3^{rd} Instar Larvae were placed in five Petri dishes, each containing two larvae, for the laboratory experiment performed during the early hours of the day. As a feeding source for the larvae, maize leaves were collected from the nearby corn fields and placed in the Petri dishes. Five concentrations of the organic garlic emulsion were made: 100:15, 80:15, 60:15, 50:15, and 20:15 product: water (ml:l) ratios. The various doses were then injected using a syringe into the five Petri dishes each containing insect larvae. After a one-hour, the dose (80:15 - 100:15 ml:l) was adopted for application in the field based on the assessments and performance.

The organic garlic emulsion was applied in the field during early morning periods with minimal drifting. To achieve homogeneity, 80-100 ml of the garlic emulsion was diluted in a 15 l knapsack sprayer of water and vigorously stirred. The homogenized mixture was uniformly sprayed in the whorl, on maize stems and leaves on all plots that required organic garlic emulsion for treatment on a weekly basis.

Plant cultivation

Following the ridge formation, the field was sprayed with contact herbicide, insecticide, and fungicide to protect the seeds from weeds, insects, and fungal attacks. Sowing was done in accordance with the treatments and the experimental design. Four seeds were sown per stand, which germinated four days later and were thinned to two per stand two weeks later. Three crops were planted: maize as the main crop, dwarf beans and cowpea as companion crops. CMS8704 was the maize variety grown, and the dwarf beans were local large grain beans and Michel variety cowpea. Soaking in water was used to test viability, and those that floated were discarded.

Crop maintenance

Weeding was done with a hoe and a cutlass to remove the grass competing with the crop for space and nutrients while also acting as a breeding ground for pests and diseases. After each weeding operation, the plants were earthed up by covering the rhizosphere with soil to avoid exposing the plant roots, which could harm the crops. All plants were manually irrigated during the dry periods of no rain. This was due to the fact that the experiment was conducted during the rainy season, so the plants were rain fed for growth and development.

The identical kind and quantity of soil fertilizer were added to each experimental plot two weeks following germination. All plots received a uniform application of the compound fertilizer NPK 20:10:10 at a rate of 10 g per stand by ringing at a distance of about 5cm from the plants.

Except for the control plots, all organic plots were treated with the local garlic spray at a rate of 80ml-100 ml/15 l of water, whereas the synthetic plots were sprayed with a contact commercial insecticide (CYPERCAL 12EC with active ingredient as CYPERMETHRINE; SCPA SIVEX international® France) at a rate of 24 ml-36 ml/15l of water and a contact commercial fungicide (COTZEB). The spraying of both organic and synthetic pesticides was aided by the use of a knapsack sprayer and was done on a weekly basis.

Data collection

Vegetative and yield parameters

Data on the maize vegetative and yield parameters as influenced by the maize-legume intercropping system were collected. Three weeks after the planting, four plants from each treatment replicate were randomly selected and tagged for data collection. The plants were evaluated for vegetative parameters (height, stem girth, and leaf number) as well as for yield parameters (maize-grain yield). Growth parameters were collected weekly (5 times) until the plant tasseling began.

To calculate the yield in tons ha-1, the weight of maize grains was measured 12 weeks after the planting by using a top loading balance (Brand MK-01, China).

Fall armyworm (FAW)

The maize plants were examined for fall armyworm infestation three weeks after the sowing, and they were continuously checked for indicators of plant damage. FAW damage was identified by the pin holes, 'windo-panes,' ragged and torn leaves, and the destruction of unfurled leaves in funnels for incidence. Four plants were chosen at random from each plot and observed for the incidence (number of damaged plants) and severity (number of fall armyworms). The data were presented as the number of plants damaged by fall armyworms per treatment and the number of larvae per plant.

Statistical analysis

Data was entered into a Microsoft Excel spreadsheet 2013, and then transferred to compatible software, IBM SPSS Statistics version 20. The impact of treatments (n=9) as categorical predictors of dependent variables including vegetative parameters (plant height, stem girth, and number of leaves), fall armyworm occurrence and severity, and yield parameters (maize grain weight) was examined using a univariate analysis of variance ($P<0.05$). The important data means were compared using Tukey's HSD ($P<0.05$).

RESULTS

Plant performance

Vegetative parameters of maize

According to this study (Table 2), the plant height varied significantly ($F_{2,8} = 3.07$, $P<0.05$) between treatments and ranged from 181.25 cm to 210.67 cm, with the maize-cowpea-insecticide treatment recording the maximum height at 210.67 cm and the control treatment recording the lowest height at 181.25 cm. The stem girth varied between 4.57 and 5.53 cm and was significantly different between treatments ($F_{2,8} = 18.35$, $P<0.05$), with the control treatment having the lowest girth at 4.57 cm and the maize-cowpea-insecticide treatment having the maximum at 5.53 cm. The number of maize leaves per plant significantly varied between 14 and 16 per plant ($F_{2,8} = 8.92$, $P<0.05$) between treatments, with the control treatment 14 having the fewest leaves and the maize-cowpea-insecticide treatment 16 having the most.

Table 2. Effect of treatments on vegetative parameters (mean ± SD).

Treatments	plant height(cm)	stem girth (cm)	number of leaves
Control	181.25±6.31b	4.57±0.09d	14 ±0.14c
Insecticide	195.67±15.09ab	5.10±0.03c	15±0.38b
Allium (garlic)	192.67±3.00ab	5.06±0.08c	15±0.29bc
Maize-dwarf bean	193.92±14.00ab	5.07±0.13c	15±0.43bc
Maize-dwarf bean Insecticide	203.92±8.96ab	5.43±0.21abc	15±0.43ab
Maize-dwarf bean *Allium* (garlic)	200.83±9.80ab	5.24±0.19bc	15±0.29ab
Maize-cowpea	194.67±6.15ab	5.09±0.14c	15±0.14b
Maize-cowpea insecticide	210.67±1.84a	5.74±0.19a	16±0.58a
Maize-cowpea *Allium* (garlic)	207.17±1.28a	5.53±0.06ab	16±0.66ab

Values within columns with different letters are significantly different (P<0.05).

Maize yield

As revealed by this study (Fig. 2), the yield of maize varied between 2.1 and 5.7 tha^{-1} and was significantly different between treatments ($F_{2,8}$ = 5.16, P<0.05). The control treatment had the lowest yield, while the maize-cowpea g (5.53 tha^{-1}) and the maize-cowpea insecticide (5.7 tha^{-1}) had the best yields (2.1 tha^{-1}).

Fall armyworm incidence and severity

Incidence (number of damaged plants)

The number of the damaged plants by the fall armyworm ranged from 2 to 14 plants per treatment and differed significantly ($F_{2,8}$ = 6.95, P < 0.05) across treatments (Fig 3). The highest damage was observed in the control. The least damaged plants were recorded from maize-cowpea-insecticide followed by maize-cowpea-*Allium* and maize-dwarf-bean-insecticide. In addition, maize-dwarf bean-*Allium*, insecticide and *Allium* treatments did not show any significant difference amongst them, but differed significantly from the other treatments.

Severity (number of larvae per plant)

The number of fall armyworm larvae on maize plants ranged from 0 to 4, and there were significant differences between treatments ($F_{2,8}$ = 12.03, P 0.03), (Fig 4).The control treatment had the most larvae (4). The lowest number of larvae was recorded in maize-dwarf bean-insecticide (1), maize-cowpea-insecticide (1) and maize-cowpea-*Allium* (1) followed by maize-dwarf bean-*Allium* (2), insecticide (2) and *Allium* (2) treatments that differed significantly (Turkey's HSD, P = 0.05) from maize-dwarf bean (3) and maize cowpea (3).

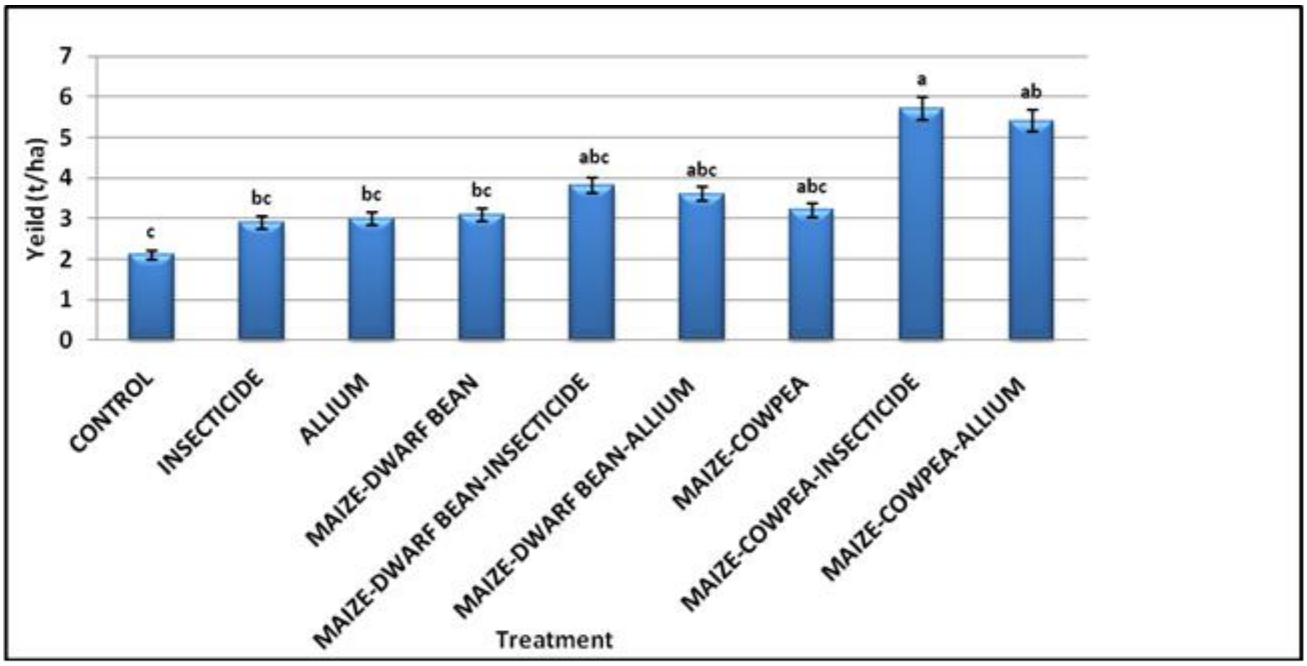

Figure 2. Effect of treatments on maize yield. Data with different letters are significantly different (P<0.05), Tukey's HSD.

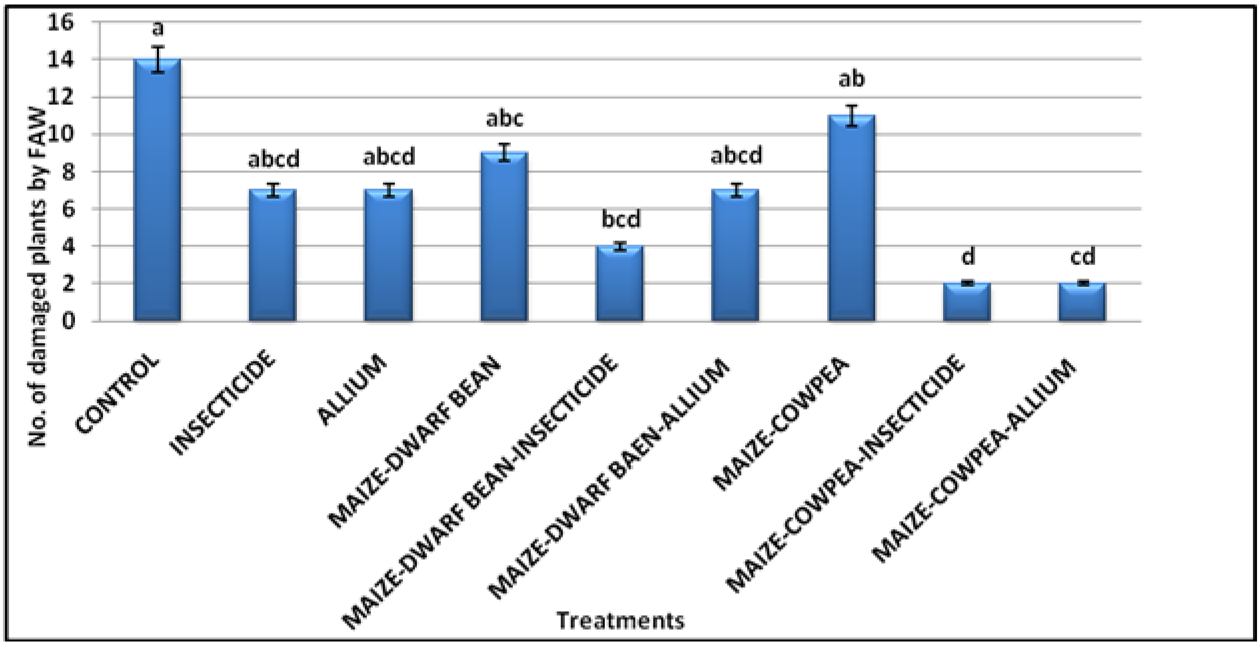

Figure 3. Effect of treatments on the pest incidence. Data with different letters are significantly different (*P*<0.05), Tukey's HSD.

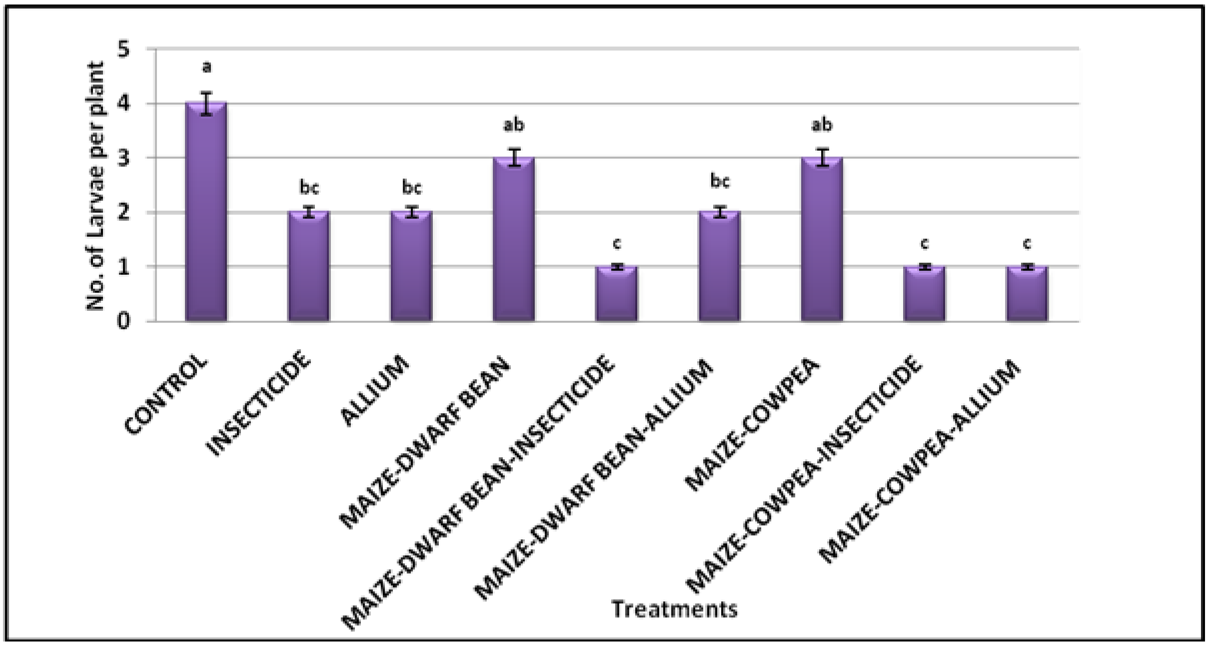

Figure 4. Effect of treatments on the number of fall armyworm larvae on maize plants. Data with different letters are significantly different (P<0.05), Tukey's HSD.

DISCUSSION

Effect of treatments on maize pest (FAW)

The repellent qualities of cowpea, along with the application of the insecticide cypermethrine and the natural Allium emulsion, accounts for the significantly lower pest infestation in maize-cowpea insecticide as well as maize-cowpea-Allium when compared to the significantly high pest infestation in the controlled plot (untreated maize plants) (Asare-bediako et al., 2010). The increasing risk to human health in Africa due to inadequate safety measures, environmental degradation, biodiversity loss, and soil and water pollution is a major issue concerning the use of synthetic insecticides, despite the fact that they are efficient at controlling FAW (Day et al., 2017). In this study, the locally produced organic *Allium* emulsion from garlic extract (bulb) exacerbated a quick knockdown activity against the fall armyworm larvae as seen in the maize-cowpea-botanical *Allium* emulsion treatment (Abdullahi et al., 2020). The demonstrated insecticidal activity of the organic *Allium* emulsion is determined by allicin, a sulfur compound formed as a result of alliinase activity during clove crushing and other sulfur derivatives (Wanyika et al., 2010; Golubkina et al., 2022). Ultimately, the plant extracts are known to contain powerful organic substances that are effective in reducing the population of insect pests comparable to that of the synthetic pesticides. However, Akeme et al., (2021) and Golubkina et al., (2022) reported the efficacy of the garlic extract to combat caryopsis, scoop, whitefly and weevils on cowpea and rice fields. Furthermore, several authors have demonstrated the efficacy of various plant materials as biopesticides for pest control (Agbor et al., 2022b; Tanyi et al., 2020) such as neem, West African black pepper and African nutmeg (Reddy and Chowdary, 2021; Ochieng et al., 2022). This study hypothesis is supported by the observed pest mitigation performance in an intercropping system of maize-cowpea Allium and maize-dwarf bean. Therefore, farmers can manage the fall armyworm, a pest of maize, without endangering the productivity of their crops by intercropping maize with legumes (such as dwarf beans or cowpeas) and by using the organic Allium emulsion made from the garlic extract (bulb).

Effect of intercropping on maize

The less damage of maize plants in the maize-dwarf bean intercropping and the maize-cowpea intercropping compared to the control (untreated maize plants), indicates that legumes (dwarf bean and cowpea) deter maize pests like the African maize stem borer, FAW, as reported by Hailu et al., (2018) and Tanyi et al., (2020).

Effect of treatments on maize vegetative parameters and yield

Most tropical intercropping systems have been found to contain maize as a common element (Ijoyah and Fanen, 2012). According to Adesoji et al., (2013), the nitrogen effects increase maize development by causing an increase in the cell division and expansion as well as an increase in the size of all of its morphological components. Additionally, Belel et al., (2014) and Baijukya et al., (2016) discovered that the yield of maize grains increases following intercropping with legumes. Achieving full maize output in addition to chosen legume yield is the aim of the maximal maize-legume association (Kermah et al., 2017; Masvaya et al., 2017).

The maize vegetative parameters were statistically different due to legumes already rapidly producing nitrogen for maize uptake, dropping legume leaves were decomposing and adding nutrients for maize uptake and reducing maize competition with legume crops for nutrients. When maize and peanut were intercropped in alternating furrows (2:1) with 80 kg ha^{-1} urea, the research results produced by Borghi et al., (2013) showed that a considerable increase in the plant height (190.93 cm) and LAI (2.26 cm^2) were attained. Also the plant is more adapted and tolerant to pest infestation and its rate was reduced due to the botanical *Allium* emulsion and the synthetic pesticide application in addition to the repellent properties of dwarf bean and cowpea (Tanyi et al., 2018; Mochiah et al, 2011) thus increasing growth parameters. The study hypothesis is supported by the rise in the growth metrics seen for intercropping, synthetic pesticides, and botanical Allium emulsion. However, it was shown that when maize and legume crops are intercropped, the amount of vegetative biomass in the farmer's field is at its highest (Isaacs et al., 2016).

The high maize yield in maize-cowpea insecticide and maize-cowpea *Allium* treatments when compared to maize-dwarf bean and cowpea intercropping is consistent with the trend of using botanical *Allium* emulsion and synthetic pesticide for pest infestation, as well as cowpeas' ability to fix more nitrogen for maize uptake than dwarf beans (Legwaila et al., 2012). The higher maize yield in the maize-cowpea intercrop treatment when combined with either botanical *Allium* emulsion or synthetic insecticide emphasizes the need for alternative farm management strategies that integrate below and above ground management, including soil fertility and pest management.

CONCLUSION

This study found that synthetic pesticides and the organic *Allium* emulsion or maize-legume (dwarf bean and cowpea) intercropping had comparable efficacy in controlling maize pests below the economic damage threshold. As a result of the low cost of producing the organic *Allium* emulsion, farmers will be able to increase their maize yield and potentially earn more money. As a result, the locally produced *Allium* emulsion and maize-legume intercropping treatments are the best bets for managing maize pests and stimulating maize performance while minimizing the negative consequences. They are viable substitutes for synthetic pesticides in the maize production systems.

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