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ASSESSMENT OF HOT PEPPER (*Capsicum annuum* L.) INTERCROPPING FOR ENHANCING THE GROWTH, YIELD AND INSECT PEST MANAGEMENT OF SOYBEAN (*Glycine max* L.)

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ABSTRACT
Intercropping hot pepper with soybean offers several benefits including increased land use efficiency, enhanced pest and disease control through plant-plant interactions, and potential yield improvements for both crops when managed optimally. This study investigated the effects of intercropping soybean and hot pepper on growth parameters, insect pest population, and grain yield of soybeans in southwestern Nigeria. The experiment was conducted using a randomized complete block design with three replications during the 2022 cropping season at YABATECH Teaching and Research Farm. A trial of 12 experimental plots with 60 ridges was arranged as alternate, strip, border, and sole cropping. The results showed that alternate intercropping significantly ($P \leq 0.05$) improved soybean growth, yield (12.52±5.01), and reduction in insect infestation (3.56±0.11) compared to other intercropping patterns and sole cropping (0.09±0.01; 6.34±0.11). This adaptable, environmentally friendly, and cost-effective technology is highly recommended for small-scale farmers in Nigeria, who produce the majority of soybean and hot pepper crops. The findings also provide valuable insights into the potential benefits of intercropping soybean and hot pepper to include sustainable insect pest management and improved crop productivity among others.

Keywords: *Soybean, intercropping patterns, hot pepper, insect pests*

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is a legume belonging to the *Fabaceae* family. It is an excellent source of protein, carbohydrates, and oil, making it a valuable crop for human nutrition and feeding of farm animals (Adu-Dapaah *et al.*, 2004). It has an average content of 40% protein, 30% carbohydrate and 20% oil (MoFA and CSIR, 2005). Its high protein content and ability to fix nitrogen make it an attractive crop for cultivation. Soybean production in Nigeria has been gaining momentum, with farmers increasingly recognizing its potential as a cash crop and a food source. As a result, production has been on the rise, driven by growing domestic and export demand (Ajala & Ajav, 2020). However, its production is affected by insect pests and diseases, leading to economic losses (Patel & Rahul, 2020). Hot Pepper (*Capsicum annuum* L.), available locally, is a valuable crop used as a spice, condiment, and vegetable (Acquaah, 2004). It has antioxidant and hypoglycemic properties, making it a nutritious addition to various dishes (Loizzo *et al.*, 2015). It also possesses potential applications in traditional medicine, perfumery, preservatives and insecticides (Rosulu *et al.*, 2022). Intercropping pepper with soybean can enhance soil fertility, reduce pest infestation, and increase crop yields (Zhang *et al.*, 2013) by promoting biodiversity, deterring pests that target soybean through the production of capsaicin in hot pepper as well as providing farmers with multiple revenue streams, hence reducing dependence on a single crop (Ogunniyi & Akinola, 2015). However, few researches have been carried out to improve soybean in areas of intercropping and insect pest management. Thus, this study was undertaken to assess the intercropping of soybean and hot pepper to enhance the growth, yield and insect pest management of soybean.

MATERIALS AND METHODS

Experimental site: The field experiment was conducted at the Teaching and Research Farm of Yaba College of Technology, Epe Campus, during the 2022 wet season. The site is located at Longitude 3°58'0560"E and Latitude 6°38'0360"N, with an elevation above sea level (Google Earth, 2022). It is a lowland rainforest vegetation zone with an annual rainfall of 1506.6 mm (Rosulu *et al.*, 2022). The soil texture is sandy loam.

Research materials: Soybean seeds were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, while hot pepper seeds were sourced from the Lagos State Input Supply Company (LIASCO), Epe depot. Hot pepper seeds were nursed in trays for 4 weeks before transplanting.

Experimental protocol: The experimental design followed the previously described methods of Oparaeke, (2005); Rosulu *et al.*, (2022) and Rosulu *et al.*, (2024). Land clearing and preparation, stumping, ploughing, harrowing and ridging were done. 12 experimental plots (5m x 3.75m) were demarcated, each with 5 ridges (totaling 60) with 0.7m spacing. Interspaces between adjacent plots and blocks were 1.5m. Thus, the net plot for data collection was 18.75m^2 while the gross plot size was 474.38m^2. The experiment employed a Randomized Complete Block Design (RCBD) with 4 treatments and 3 replications arranged as Alternate Intercropping of hot pepper and soybean, Strip cropping (hot pepper and soybean), Border cropping (hot pepper and soybean) and Sole cropping of soybean.

The spacing for intercropping was 60cm x 45cm, while the sole cropping of soybean was spaced at 25cm apart, with 2 seeds per hole.

Data collection: Data on soybeans were collected based on the following parameters:

i. **Growth parameters of soybean at 2, 4 and 6 weeks after planting:** 20 plants per plot were selected and tagged. The number of leaves was visually counted at 2, 4 and 6 weeks after planting while plant height was measured in centimetres (cm) using tape rule from ground level to the apical bud from 20 stands per plot selected randomly from middle rows where crop component interactions were assumed to be highest.

ii. **Pest population:** The pest population was sampled very early in the morning (6:30 am – 9:00 am) when the insect pests were less active one day before and one day after spaying. Insects were visually counted using the direct method, enabling quantitative estimation of pest incidence using the Tilton formulas as enunciated by Okunlola *et al.*, (2008) and Rosulu *et al.*, (2022).

$$\text{Efficacy (\%)} = 1 - \left[\frac{T_a}{C_a} \times \frac{sC_b}{T_b}\right] \times 100$$

Where: T_a = Infestation in the treated plot after application, C_a = Infestation in the check plot after application, T_b = Infestation in the treated plot before application, sC_b = Infestation in the check plot before application

iii. **Assessment of thrips (*Megalurothrips sjostedti*) and Legume pod borer (*Maruca vitrata*):** 20 flowers were sampled from each plot and placed in vials containing 30% alcohol. The flowers were sampled between 0800 and 1030h to minimize loss of thrips flying off after disturbance (Ngakou *et al.*, 2008). Flowers were dissected, and thrips and legume pod borers were counted under a binocular stereomicroscope according to methods described by Ahmed *et al.*, (2009) and Rosulu *et al.*, (2022).

iv. **Assessment of legume pod borer (*Maruca vitrata*) and pod-sucking bugs (*Clavigralla tormentosicollis*):** Sampling was done using the direct count method by carefully walking along 2 middle rows of each plot (as described by Nampala *et al.*, (1999) and enunciated by Rosulu *et al.*, (2024)) and recording the number of bugs seen.

v. **Pod damage:** At plant maturity, shriveling, twisting, stunting and constriction were assessed by counting the number of damaged pods per plant and dividing by the total number of pods produced per plant in a random sample of 20 plants per plot. This was expressed in % by multiplying by 100 as described by Rosulu *et al.*, (2022).

vi. **Grain Yield:** Grain yield was recorded from each plot after harvesting (at maturity), threshing and winnowing by weighing all the seeds from the 20 sampled plants per plot. Grain yield data was

converted to kg/ha before ANOVA using the following formulas (Rehaja, 1976) as enunciated by Rosulu *et al.*,(2022).

Yield (kg/ha) = $\frac{a \times 10{,}000}{b \times 10{,}000}$

Where: a = plot yield, b = net plot size

vii. **Yield loss:** Yield loss was calculated using the Judenko, (1973) formula of assessing yield loss on the field as enunciated by Rosulu *et al.*, (2022):

AL = (a – b) x NAT

Where: AL = Actual loss, a = mean yield of the unattacked plant

b = mean yield of attacked plant, NAT = Number of attacked plant

Data analysis: All data were obtained in triplicate and subjected to two-way ANOVA using SPSS version 16.0. Means were separated using Tukey's comparison post-hoc test) at a 5% probability level.

RESULTS

Effect of intercropping of soybean and hot pepper on growth parameters at 2, 4 and 6 weeks after planting (WAP): This is presented in Table 1. Values obtained for the number of leaves at 2, 4 and 6 weeks after planting did not vary significantly ($p > 0.05$). However, alternate cropping had a higher number of leaves at 4 (18.53±1.27) and 6 (51.54±4.75) weeks after planting as compared to other intercropped plots and sole cropping. Values obtained for plant height at 2 and 6 weeks after planting varied significantly with sole cropping having the highest values (9.20±0.26 and 28.29±1.09). The lowest plant height was recorded in border cropping at 2, 4 and 6 weeks after planting (8.22±0.26, 14.98±1.08 and 22.60±1.09).

Table 1: Effect of intercropping of soybean and hot pepper on growth parameters at 2, 4 and 6 weeks after planting (WAP)

Treatments	No. of Thrips	No. of LPB	NYMPH LPB	ADULT LPB	NYMPH PSB	ADULT PSB
ALT CRP	9.83±1.89^{a}	1.33±0.30^{a}	2.33±0.53^{a}	2.67±0.50^{a}	2.33±0.53^{a}	2.33±0.46^{a}
STR CRP	7.50±1.89^{a}	1.67±0.30^{a}	2.00±0.53^{a}	2.67±0.50^{a}	2.00±0.53^{a}	3.00±0.46^{a}
BOR CRP	8.33±1.89^{a}	1.33±0.30^{a}	2.33±0.53^{a}	2.33±0.50^{a}	2.33±0.53^{a}	2.33±0.46^{a}
SOL CRP	10.17±1.89^{a}	2.00±0.30^{a}	1.67±0.53^{a}	3.00±0.50^{a}	1.67±0.53^{a}	2.33±0.46^{a}

Values represent least square means (LS-means) ± standard error. LS-means were separated using Tukey-Kramer Comparison and LS-means within a column followed by different letters are significantly different at P≤0.05. ALT CRP= alternate cropping, STR CRP= strip cropping, BOR CRP = border cropping, SOL CRP = sole cropping.

Effect of intercropping of soybean and hot pepper on thrips, legume pod borers and pod-sucking bugs: Intercropping soybean with hot pepper proved to be effective by reducing the insect population. Results obtained did not vary significantly ($p > 0.05$) between intercropped and sole cropping plots (table 2). However, sole cropping had the highest number of thrips (10.17±1.89) and legume pod borer (2.00±0.30) while strip cropping recorded the highest number of adult pod-sucking bugs (3.00±0.46). Strip cropping also recorded the lowest number of thrips (7.50±1.89) and nymphs of legume pod borer (2.00±0.30). The lowest number of legume pod borer (1.33±0.30) and adult of pod sucking bug (2.33±0.46) were recorded in alternate and border cropping.

Table 2: Effect of intercropping of soybean and hot pepper on thrips, legume pod borers, legume pod borer and pod-sucking bugs

Treatments	Growth Traits					
	No. of Leaves (2 wks)	Plant Height (cm) (2 wks)	No. of Leaves (4 wks)	Plant Height (cm) (4 wks)	No. of Leaves (6 wks)	Plant Height (cm) (6 wks)
ALT CRP	6.98±0.31^{a}	8.68±0.26^{ab}	18.53±1.27^{a}	17.72±1.08^{a}	51.54±4.75^{a}	24.10±1.09^{b}
STR CRP	6.77±0.31^{a}	8.76±0.26^{ab}	16.27±1.27^{a}	15.59±1.08^{a}	47.58±4.75^{a}	23.38±1.09^{b}
BOR CRP	7.03±0.31^{a}	8.22±0.26^{b}	16.48±1.27^{a}	14.98±1.08^{a}	40.43±4.75^{a}	22.60±1.09^{b}
SOL CRP	7.29±0.31^{a}	9.20±0.26^{a}	16.60±1.27^{a}	15.82±1.08^{a}	50.04±4.75^{a}	28.29±1.09^{a}

Values represent least square means (LS-means) ± standard error. LS-means were separated using Tukey-Kramer Comparison and LS-means within a column followed by different letters are significantly different at P≤0.05. ALT CRP= alternate cropping, STR CRP= strip cropping, BOR CRP = border cropping, SOL CRP = sole cropping, No. Thrip = number of thrips, No. LPB = number of legume pod borer, NYMPH LPB – nymph of legume pod borer, ADULT LPB = adult of legume pod borer, NYMPH PSB = nymph of pod sucking bug, ADULT PSB = adult of pod sucking bug

Effect of intercropping of soybean and hot pepper on pest population: Shown in table 3 is the effect of soybean and hot pepper intercropping on soybean pest population. Result indicated that alternate intercropping significantly ($p < 0.05$) lowered pest population (1.83±0.32) as compared to other intercropped plots and control while sole cropping had the highest pest population (2.83±0.32).

Table 3: Effect of intercropping of soybean and hot pepper on pest population

Treatments	Pest Population
ALT CRP	1.83±0.32^{a}

STR CRP	1.67±0.32[b]
BOR CRP	1.50±0.32[b]
SOL CRP	2.83±0.32[b]

Values represent least square means (LS-means) ± standard error. LS-means were separated using Tukey-Kramer Comparison and LS-means within a column followed by different letters are significantly different at P≤0.05. ALT CRP= alternate cropping, STR CRP= strip cropping, BOR CRP = border cropping, SOL CRP = sole cropping

Effect of intercropping of soybean and hot pepper on pod damage, grain yield and yield loss: Results of these parameters are recorded in Table 4. It showed that there was no significant difference (p > 0.05) in values obtained for damaged pods among intercropped and control plots with alternate cropping having the lowest pod damage (2.71±1.85) and sole cropping having the highest pod damage (6.45±1.85). Values obtained for grain yield and yield loss varied significantly (p < 0.05) among intercropped and control/sole cropped plots with sole cropping having the highest grain yield (35.73±3.54) and yield loss (1286±355.07). Border cropping recorded lowest grain yield (10.80±3.54) and yield loss (57.6±355.07).

Table 4: Effect of intercropping of soybean and hot pepper on pod damage, grain yield and yield loss

Treatments	POD DAMAGE	GRAIN YIELD	YIELD LOSS
ALT CRP	2.71±1.85[a]	12.28±3.54[b]	67.7±355.07[b]
STR CRP	5.98±1.85[a]	13.48±3.54[b]	208.9±355.07[b]
BOR CRP	4.21±1.85[a]	10.80±3.54[b]	57.6±355.07[b]
SOL CRP	6.45±1.85[a]	35.73±3.54[a]	1286.4±355.07[a]

Values represent least square means (LS-means) ± standard error. LS-means were separated using Tukey-Kramer Comparison and LS-means within a column followed by different letters are significantly different at P≤0.05. ALT CRP= alternate cropping, STR CRP= strip cropping, BOR CRP = border cropping, SOL CRP = sole cropping

DISCUSSION

The findings of the study support the attainability and effectiveness of intercropping as reported in multiple studies (Fersia-Djidjonri *et al.*, 2021; Rosulu *et al.*, 2022; 2024). It offers several benefits including pest reduction, increased yield and land use efficiency (Rosulu *et al.*, 2024).

Intercropped plots had a higher number of leaves and plant heights at 4 and 6 weeks after planting with alternate cropping performing better than other intercropped plots. This study found that intercropping of soybean with hot pepper, particularly in alternate intercropping significantly reduced the population of key insect pests such as thrips, legume pod borers, pod-sucking bugs, aphids, grasshoppers and bean leaf beetle. This finding is consistent with previous studies which reported a significant reduction in insect pest population in intercropped plots (Rosulu *et al.*, 2022; 2024). Intercropping is known to be one of the key cultural practices in pest management (Bruce *et al.*, 2005) thereby reducing the harm caused by pest and diseases and lowering the need for pesticides (Mir *et al.*, 2022).

Insect pests are less likely to infest intercropped crops than main crops (Mir *et al.*, 2022) as reported in this study with alternate cropping recording the lowest insect pest infestation as compared to control. By increasing crop diversity within a given agroecosystem, intercropping could serve as a potential strategy for pest management by lowering the insect population and the frequency with which it attacks individual plants (Mir *et al.*, 2022).

There was a significant reduction in the damaged pod and yield loss of soybean and an increase in grain yield due to alternate intercropping of hot pepper and soybean. This supports the finding of Rosulu *et al.*, (2022; 2024) who reported that chili pepper intercropped with leguminous crops significantly reduced the pest population, thus increasing grain yield by acting as a trap crop or a companion crop. Existing intercropping research has shown that intercropping improves crop growth and production compared with mono-cropping systems (Ben-Chan *et al.*, 2022; Naser *et al.*, 2023).

This study suggests that intercropping has a prospect to serve as a cultural practice-based approach for pest management which can contribute to sustainable agriculture and improve crop yields (Mohd *et al.*, 2022).

CONCLUSION AND RECOMMENDATION

Intercropping is an additional workable strategy for warding off insect pests in crops. Diversifying crops in a given agroecosystem can help lower the insect population and, in turn, the risk of attack, making it a promising cultural practice for pest management. The choice of companion crops and their additional valuation after harvest, as well as the farmers' knowledge and the mechanization, practised, play a role in the success of intercropping for pest management. This study highlights the benefits of intercropping systems, particularly in reducing pests and disease incidence and ranks alternate intercropping of soybean and hot peppers exceptional and a rational approach for improving crop production, reducing yield loss and promoting sustainability.

Poor resource farmers are encouraged to adopt alternate intercropping of soybean with hot pepper as a non-capital intensive and uncomplicated method of control. Future research should focus on determining the Land Equivalent Ratio (LER) to quantify the benefits of intercropping and provide a more comprehensive understanding of its advantages. Extension services should promote the adoption of intercropping systems, particularly among small-scale farmers, to improve crop production and promote sustainability.

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