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Efficacy of Intercropping and Plant Density in Management of *Earias vittella* and *Helicoverpa armigera* Lepidopteran Insect Pests of Okra (*Abelmoschus esculentus* L. Moench)

[1]Modu, B.C.,[2]Bukar, A., [3]Kumshe, I. B., [4]Sani, M.M. & [5]Mohammed B.M.
[1,4 &5] Department of Agricultural Technology, Federal Polytechnic Monguno, P. M. B. 1066
[2&3]Department of Fisheries Technology, Federal College of Fresh Water Fisheries Technology Baga, P. M. B. 1060 Maiduguri, Borno State.

***Abstract**: Field experiment was carried out to evaluate the efficacy of intercropping and plant density in managing of lepidopteran insect pests of Okra (Abelmoschus esculentus L. Moench). The objectives of this study were to determine the effect of intercropping and plant density on the incidence and abundance of lepidopterous insect pests of okra, crop damage caused by these pests; evaluate the relationship between intercropping and plant density on crop damage or fruit yield/loss and determine the cost-benefit of using intercropping and plant density to manage lepidopterous insect pests of okra. The experiment was conducted during the 2023 dry season under irrigation in Monguno, Borno State, Nigeria. The was laid out in a split-plot design, with the main plot consisting of okra variety and the sub-plot consist of nine different crop level of intercrop and a control (okra monocrop). Data were collected on the population of insects, shoot damage, and fruit damage. The results showed that intercropping okra with soybean at a 4:1 ratio significantly reduced the population of E. vitella (13.22 larvae/10 plants) and H. armigera (6.96 larvae/10 plants) compared to other intercrop options and the okra monocrop. Shoot damage and combined fruit damage caused by these pests were also lowest (16.07% and 16.51%, respectively) in the okra-soybean intercropping system. The reduced pest pressure and crop damage in the intercropping system were attributed to the creation of a more diverse and complex agroecosystem, which disrupted the pests' host-finding ability, provided alternative food sources and habitats for natural enemies, and enhanced the plant's defense mechanisms. In conclusion, the adoption of the okra-soybean intercropping system (4:1 ratio) is recommended as an effective and sustainable pest management strategy for okra cultivation. Further research on optimal spatial arrangements and integration with other agroecological practices can contribute to the development of holistic and environmentally-friendly approaches to managing insect pests of okra.*

***Keywords:** Okra; Intercrop; Plant density; Insects; Management*

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Introduction

Okra (*Abelmoschusesculentus* L. Moench), also known as lady finger, is an important vegetable crop cultivated mainly in the tropics (Schippers, 2000). It belongs to the family *Malvaceae*, and is believed to have originated in Africa (Aladele *et al*., 2008). It is a leading fruit in the Nigerian market on the basis of land area, production and value (Taylor, 1996). it is a tropical plant which grows best in warm climates (Salau *et al.,* 2012). Cultivation of the crop is done mainly by the poor- resource farmers in Northern Nigeria who usually intercrop it with other crops (Anaso, 2003, Degri *et al.,* 2012). It is cultivated alone or intercropped with field crops like maize, Sorghum, yams and cassava (Mumford and Baliddawa, 1982; Muoneke and Asiegbu, 1997; Ijoyah *et al*., 2012). In Nigeria, the improved varieties grown include Clemson spineless, White velvet, Green velvet, Long pod, Lady's finger, Dwarf green pod (Udoh *et al*., 2006). Varieties grown in Borno State include Mboke, Jere, Chalawa, Uba, Kanuri local and Yar kwadan and Lady's finger (Askira and Degri, 2012). It is widely grown as a garden or commercial crop for its fresh leaves, buds, flowers, stems, pods and seeds (Schippers, 2000). It is one of the important crops cultivated in Nigeria (Alimi, 2005). Young fruits can be eaten raw and serves as soup thickener. Okra Pods and seeds are rich in phenolic compounds with important biological properties (Adetuyi and Osagie*,* 2011).

Insect pests are a major setback for commercial production of the crop (Hugar and Palled 2008; Ijoyah, 2012). Pests and diseases are major constraints to the quality and quantity of okra produced with total losses of about 35–40% (Gandhi *et al.*, 2016). More than 72 insect pests attack the crop, infesting it from the seedling through the harvest stage. Some significant pests that harm okra include the shoot and fruit borer (*Earias* vittella), fruit borer (*Helicoverpa armigera*), leaf roller (*Sylepta derogata*), leafhopper (*Amrasca biguttula biguttula*), whitefly (*Bemisia tabaci*), aphid (*Aphis gossypii*), solenopsis mealy bug (*Phenacoccus solenopsis*) (Mansion *et al*., 2022).

For the management of insect pests and diseases many options such as chemical, cultural, mechanical, biological etc. are available. Among available control methods, cultural method is considered to be the safest and environment friendly. Many cultural practices can be usually employed in an IPM scheme such as sanitation or destruction of debris, destruction of alternate hosts and volunteer plants, changing dates of planting and harvesting to avoid pest attack, crop rotation to avoid built of pests, tillage practices, habitat diversification, cropping systems or intercropping, plant density, trap crops, water management, *etc*. (Shraddha *et al*., 2022). Newsom (1975) pointed out that the rediscovery of the importance of cultural control tactics has provided highly effective components of pest management systems. The Use of intercropping can be an ecofriendly tool. The resource concentration hypothesis, evinced that intercropping system have more diverse habitat and thus creates barrier for insect pest movement and colonization. However, in monocropping there is no such implication. plant spacing help in the prevention of exposure to harmful organisms, an element of the first principle of integrated pest management (Andow, 1991, Barzman *et al.*, 2015). Roome (1971) suggested that increasing plant diversity in cropping systems by intercropping crops carrying nectars could enhance effectiveness of natural enemies. The greatest limiting factor in increasing the productivity of okra is the range of insect pests with which they are associated. Okra is susceptible to damage by foliar insects and fruit boring insects. Due to the prohibitive cost of synthetic pesticides and the problems of environmental pollution caused by continuous use of chemicals which is posing threat to the environment, non-target organisms and human being and leads to the development of new atrategies to reduce the impact of the insect pest infestation using intercropping. There is a renewed interest in the use of ecofriendly measures for crop protection. The objectives of the study were to determine the effect of intercropping and plant density on management of incidence and abundance of lepidopterous insect pests of okra.

Experimental Location

The experiment was carried out during the 2023 dry season under irrigation scheme at Federal Polytechnic Monguno Teaching and Research Farm. Monguno is located between latitude 12^0 40'N and 13^0 36'E in the Sudan Savannah belt of Nigeria.

Treatments and Experimental Design

The experiment was laid in a Split plot design. The main plot consist of okra variety. A single okra cultivar (Clemson spineless) was intercropped with maize, groundnut, sorghum, sesame, pearl millet, sunflower, cowpea, and okra as sole crop. The sub-plot will consist of one levels of intercrop densities and a control or okra intercrop. The levels of okra densities was very low 4:1 for all the crops. Control density was okra monocrop sown at recommended spacing of 60cmx40cm. Each treatment was replicated three times per plot measuring 2m*3m, a spacing of 0.5m was use between the plot and 1m alleys.

Seed sources and varieties

Seed of okra (Clemson spineless), maize (oba-98 hybrid white maize), soybean (TGX 1904-6F), groundnut, sorghum, pearl millet, sunflower, and cowpea was obtained from BOSADP.

Land Preparation

The experimental land was cleared of all debris, stumps, stone and grasses with rake and tilled with tractor. The soil was marked out using hoe, tape, rope and pegs. The soil was well levelled to avoid water logging and also ensure uniform distribution of nutrient and adequate root penetration.

Sowing

Sowing was done when land is fully irrigated. Four seeds was sown per hole and thinned to two stand weeks after germination. Three to four seeds of the okra, maize and soya bean was sown per hole, okra, maize and soybean Seedlings was thinned to two plants per stand three weeks after sowing. The pepper was sown on the nursery bed at the Mohamed college of Agriculture and later transplant to the research plot.

Weeding

Weeding was done manually using hoe and hand pulling to reduce the negative impact of weeds on okra. First and second weeding was done manually two and six weeks after sowing.

Data Collection

Plant infestation

Five plants was checked weekly per plot for lepidoperous larva attack. Percentage plant infestation per specie was estimated as the level of infestation.

Insect species density

The number of lepidopterous insects was counted per plant and fruit. Counting was done weekly, and early in the morning and evening when the insects are generally less active. Number of insects per fruit: All fruits at the time of harvest that were damaged was collected and assessed for lepidopterous larval entry or exit holes on okra fruits and were determine for the larval population and identification. Counts were done immediately after fruit were harvest early in the morning.

Crop damage

The number of plant leaves damaged by each lepidopterous insect pest was counted weekly. Percentage leaves damage was estimated. Harvested fruits per plant, undamaged and damaged by each lepidopterous insect pest, was counted at weekly interval and weighed using the sensitive weighing balance. Percentage fruits damage per species was estimated as the level of fruit damage. All larva entry or exit holes per plant was counted.

Statistical Analysis

All data collected was subjected to statistical analysis of variance (ANOVA) using the statistix software. The differences among the means was separated using the Duncan Multiple Range Test (DMRT) as reported by Gomez and Gomez (1984).

Results and Discussion

Effect of Intercropping on the Population of *Earias vitella* on *Abelmoschus esculentus*

The data presented in Table 1 suggests that the population of *Earias vitella*, a major pest of *Abelmoschus esculentus* (okra), is influenced by the type of intercrop. When *Abelmoschus esculentus* was intercropped with soybean at a 4:1 ratio, the E. vitella population was lower (13.22 larvae/10 plants) compared to when it was intercropped with other crops like pearl millet (16.12 larvae/10 plants), sesame (17.89 larvae/10 plants), sunflower (18.88 larvae/10 plants), and maize (19.30 larvae/10 plants). The maximum population of E. vitella (22.90 larvae/10 plants) was observed when *Abelmoschus esculentus* was grown as a sole crop without any intercrop. This finding is supported by several studies that have demonstrated the benefits of intercropping in reducing pest populations. Intercropping can create a more diverse and complex agroecosystem, which can disrupt the pest's ability to locate and colonize the host plant effectively. The presence of non-host plants can also act as physical barriers, altering the microclimate and making it less favorable for the pest's survival and reproduction (Lithourgidis *et al*., 2011; Brooker *et al*., 2015). Additionally, the presence of companion crops can provide alternative food sources and habitats for natural enemies, thereby enhancing their effectiveness in controlling the pest population (Gurr *et al*., 2016).

Table 1: Population of shoot and fruit borer, *Earias vitella* in intercropping systems

Intercropping system	Number of larvae of *Earias vitella*/10 plants					**Mean**
	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	
Okra + Groundnut (4 : 1)	14.55 (3.77)d	18.54 (4.28)f	21.41 (4.58)c	24.58 (4.84)de	21.22 (4.59)c	20.06 (4.59)^{e}
Okra + Maize (4 : 1)	12.94 (3.55)c	17.89 (4.14)de	20.56 (4.56)c	24.56 (4.85)de	20.56 (4.56)c	19.30 (4.52)^{de}
Okra + Sorghum (4 : 1)	12.87 (3.64)c	17.52 (4.09)d	20.34 (4.56)c	23.55 (4.79)d	20.12 (4.57)c	18.88 (4.40)^{d}
Okra + Soy bean (4 : 1)	9.42 (2.94)a	11.82 (3.31)a	13.46 (3.60)a	15.56 (3.86)a	15.84 (4.01)a	13.22 (3.55)^{a}
Okra + Sesame (4 : 1)	12.65 (3.43)c	15.42 (3.86)c	20.42 (3.61)c	22.54 (4.68)c	18.42 (4.38)b	17.89 (4.16)^{c}
Okra + Pearl millet (4 : 1)	11.56 (3.29)b	13.52 (3.59)b	18.42 (4.38)b	20.62 (4.58)b	16.52 (3.98)a	16.12 (3.96)^{b}
Okra + Sunflower (4 : 1)	14.87 (3.79)d	18.54 (4.19)de	22.52 (4.67)c	25.64 (5.00)f	22.32 (4.66)c	20.77 (4.53)^{e}
Okra + Cowpea (4 : 1)	14.63 (3.72)d	18.88 (4.23)ef	21.56 (4.61)c	24.57 (4.92)ef	21.45 (4.56)c	20.21 (4.54)^{de}
Sole Okra	15.65 (3.85)e	20.87 (4.46)g	24.32 (4.90)d	28.12 (5.27)g	25.54 (5.11)d	22.90 (4.69)^{f}
SE±	0.0726	0.0494	0.0573	0.0452	0.0583	0.0721
CV (P=0.05)	0.1538	0.1047	0.1215	0.0959	0.1236	0.1529

Mean of three replications

In a column means followed by same letter(s) are not significantly different by DMRT (P= 0.05)

Effect of Intercropping on Shoot Damage of *Abelmoschus esculentus* by *Earias vitella*

The data presented in Table 2 shows that the shoot damage of *Abelmoschus esculentus* caused by *Earias vitella* was reduced when the crop was intercropped with other plants. When *Abelmoschus esculentus* was intercropped with soybean at a 4:1 ratio, the shoot damage was the lowest at 16.07%, followed by intercropping with pearl millet at 18.41%. In contrast, the shoot damage was the highest (26.61%) when *Abelmoschus esculentus* was grown as a sole crop. The reduced shoot damage in intercropping systems can be attributed to the same mechanisms that explain the lower pest population in Table 1. The presence of companion crops can disrupt the pest's host-finding ability, create physical barriers, and provide alternative food sources and habitats for natural enemies (Lithourgidis *et al*., 2011; Brooker *et al*., 2015; Gurr *et al*., 2016). Additionally, intercropping can enhance the plant's defense mechanisms, either through the production of secondary metabolites or by altering the plant's architecture, making it less suitable for the pest's development and feeding (Ratnadass *et al*., 2012). The choice of companion crops is crucial, as different crops may have varying effects on the target pest. In this case, soybean and pearl millet appear to be more effective in reducing the shoot damage caused by *E. vitella* compared to other intercrop options.

Table 2: Shoot damage of *Earias vitella* in intercropping systems

Intercropping system	% Shoot damage*					
	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	Mean
Okra + Groundnut (4 : 1)	16.21 (23.22)[d]	20.54 (27.26)[c]	25.22 (30.01)[d]	24.88 (29.99)[c]	27.41 (32.06)[f]	22.85 (28.01)[cd]
Okra + Maize (4 : 1)	15.86 (22.75)[c]	19.86 (26.54)[b]	25.41 (30.56)[d]	24.42 (29.44)[c]	27.63 (31.88)[ef]	22.63 (28.14)[cd]
Okra + Sorghum (4 : 1)	15.56 (22.80)[c]	19.22 (26.44)[b]	24.21 (30.05)[d]	24.12 (29.44)[c]	26.52 (30.75)[d]	21.92 (27.53)[c]
Okra + Soy bean (4 : 1)	12.62 (20.80)[a]	15.24 (23.66)[a]	17.14 (24.51)[a]	18.54 (25.00)[a]	16.84 (23.57)[a]	16.07 (23.76)[a]
Okra + Sesame (4 : 1)	15.22 (20.17)[c]	18.41 (26.03)[b]	22.54 (27.91)[a]	22.54 (27.10)[b]	24.52 (29.56)[c]	20.64 (27.45)[c]
Okra + Pearl millet (4 : 1)	13.65 (22.62)[b]	16.54 (24.50)[b]	19.22 (25.71)[b]	22.12 (28.26)[b]	20.55 (26.50)[b]	18.41 (25.96)[b]
Okra + Sunflower (4 : 1)	16.42 (20.77)[d]	20.53 (27.49)[c]	25.54 (30.22)[d]	26.52 (31.53)[d]	27.54 (31.27)[de]	23.31 (28.54)[d]
Okra + Cowpea (4 : 1)	16.55 (23.50)[d]	20.12 (27.42)[c]	2542 (29.86)[d]	26.41 (31.46)[d]	27.58 (31.33)[de]	23.21 (28.41)[d]
Okra pure crop	19.52 (26.80)[e]	23.36 (28.75)[d]	28.51 (31.87)[e]	30.12 (33.59)[e]	31.54 (33.53)[g]	26.61 (30.71)[e]
SE±	0.3638	0.3040	0.3001	0.3827	0.3331	0.3497
CV (P=0.05)	0.7711	0.6444	0.6361	0.8113	0.7061	0.7412

*Mean of three replications

In a column means followed by same letter(s) are not significantly different by DMRT (P= 0.05).

Effect of Intercropping on the Population of *Helicoverpa armigera* on *Abelmoschus esculentus*

The data in Table 3 demonstrates the impact of intercropping on the population of *Helicoverpa armigera*, another major pest of *Abelmoschus esculentus*. When *Abelmoschus esculentus* was intercropped with soybean at a 4:1 ratio, the *H. armigera* population was the lowest at 6.96 larvae/10 plants. Intercropping with pearl mill*et al*so resulted in a lower *H. armigera* population (7.76 larvae/10 plants) compared to when *Abelmoschus esculentus* was grown as a sole crop (14.57 larvae/10 plants). The reduced pest population in the intercropping systems can be explained by similar mechanisms as discussed for Table 1 and Table 2. The presence of companion crops can disrupt the pest's host-finding ability, provide alternative food sources and habitats for natural enemies, and enhance the plant's defense mechanisms (Lithourgidis *et al*., 2011; Brooker *et al*., 2015; Gurr *et al*., 2016; Ratnadass *et al*., 2012). The choice of soybean and pearl millet as companion crops appears to be particularly effective in suppressing the population of *H. armigera* in the *Abelmoschus esculentus* ecosystem. This is consistent with the findings from previous studies that have reported the benefits of these intercrop options in reducing the population and damage of lepidopteran pests in various crop systems (Altieri and Nicholls, 2004; Reddy and Willey, 1981).

Table 3: Population of *Helicoverpa armigera* in intercropping system

Intercropping system	**Number of larvae of *Helicoverpa armigera*/10 plants***					**MEAN**
	30 DAS	**40 DAS**	**50 DAS**	**60 DAS**	**70 DAS**	
Okra + Groundnut (4 : 1)	7.52 (2.73)^{c}	10.63 (3.14)^{b}	11.14 (3.27)^{c}	11.88 (3.32)^{b}	14.21 (3.73)^{c}	11.07 (3.29)^{e}
Okra + Maize (4 : 1)	6.58 (2.66)^{c}	9.88 (3.13)^{b}	10.56 (3.29)^{c}	11.52 (3.34)^{b}	12.63 (3.44)^{b}	10.23 (3.31)^{d}
Okra + Sorghum (4 : 1)	5.94 (2.49)^{b}	9.54 (3.19)^{b}	10.44 (3.30)^{c}	10.88 (3.34)^{b}	12.84 (3.46)^{b}	9.92 (3.16)^{c}
Okra + Soy bean (4 : 1)	4.67 (2.23)^{a}	5.17 (2.42)^{a}	7.21 (2.82)^{a}	8.24 (3.01)^{a}	9.55 (3.21)^{a}	6.96 (2.66)^{a}
Okra + Sesame (4 : 1)	5.88 (2.50)^{b}	6.52 (2.50)^{a}	9.58 (3.15)^{bc}	10.15 (3.22)^{b}	10.88 (3.30)^{a}	8.60 (2.86)^{b}
Okra + Pearl millet (4 : 1)	5.11 (2.40)^{b}	5.89 (2.44)^{a}	8.41 (3.04)^{b}	8.87 (3.10)^{a}	10.54 (3.34)^{a}	7.76 (2.76)^{ab}
Okra + Sunflower (4 : 1)	8.64 (3.03)^{d}	11.96 (3.31)^{b}	12.63 (3.43)^{d}	14.51 (3.71)^{c}	15.54 (3.97)^{d}	12.65 (3.50)^{f}
Okra + Cowpea (4 : 1)	7.87 (2.88)^{d}	11.85 (3.30)^{b}	12.12 (3.47)^{d}	14.23 (3.75)^{c}	15.23 (3.97)^{d}	12.26 (3.41)^{f}
Okra pure crop	9.65 (3.16)^{e}	13.88 (3.59)^{c}	15.42 (3.97)^{e}	16.52 (3.98)^{d}	17.42 (4.20)^{e}	14.57 (3.77)^{g}
SE±	0.0663	0.0891	0.0745	0.0904	0.0705	0.0751
CV (P=0.05)	0.1406	0.1890	0.1579	0.1916	0.1495	0.1593

*Mean of three replications

In a column means followed by same letter(s) are not significantly different by DMRT (P= 0.05).

Effect of Intercropping on Fruit Damage of *Abelmoschus esculentus* by *Earias vitella* and *Helicoverpa armigera*

The data presented in Table 4 shows that the combined fruit damage caused by *Earias vitella* and *Helicoverpa armigera* was the lowest (16.51%) when *Abelmoschus esculentus* was intercropped with soybean at a 4:1 ratio. In contrast, the fruit damage was the highest (28.56%) when *Abelmoschus esculentus* was grown as a sole crop. The reduced fruit damage in the intercropping system can be attributed to the same mechanisms that led to the lower pest population and shoot damage as discussed in the previous tables. The presence of soybean as a companion crop appears to be particularly effective in disrupting the pest's ability to locate and colonize the *Abelmoschus esculentus* plants, as well as enhancing the plant's defense mechanisms and providing habitats for natural enemies (Lithourgidis *et al*., 2011; Brooker *et al*., 2015; Gurr *et al*., 2016; Ratnadass *et al*., 2012). The findings from this study are consistent with the growing body of evidence that supports the use of intercropping as an effective pest management strategy in various crop systems. By incorporating a diverse array of companion crops, growers can create a more complex and resilient agroecosystem that is less susceptible to pest infestations and damage, thereby reducing the need for synthetic pesticides and promoting sustainable agriculture.

Table 4: Per cent fruit damage by *Earias vitella* and *Helicoverpa armigera* in intercropping system

Intercropping system	% fruit damage 60 DAS
Okra + Groundnut (4 : 1)	21.55 (27.27)[c]
Okra + Maize (4 : 1)	20.78 (27.47)[c]
Okra + Sorghum (4 : 1)	20.22 (27.18)[c]
Okra + Soy bean (4 : 1)	16.51 (24.30)[a]
Okra + Sesame (4 : 1)	18.56 (25.32)[b]
Okra + Pearl millet (4 : 1)	25.41 (30.13)[e]
Okra + Sunflower (4 : 1)	24.32 (29.41)[d]
Okra + Cowpea (4 : 1)	18.21 (29.52)[b]
Okra pure crop	28.56 (32.00)[f]
SE±	0.2821
CV (P=0.05)	0.5979

*Mean of three replications

In a column means followed by same letter(s) are not significantly different by DMRT (P= 0.05)

Conclusion and Recommendations

Conclusion:

The present study has demonstrated the efficacy of intercropping in reducing the population, shoot damage, and fruit damage caused by the major pests of *Abelmoschus esculentus* (okra), namely *Earias vitella* and *Helicoverpa armigera*. The results indicate that intercropping *Abelmoschus esculentus* with soybean at a 4:1 ratio is the most effective in suppressing the pest populations and damage compared to other intercrop options like pearl millet, sesame, sunflower, and maize.

The reduced pest pressure in the *Abelmoschus esculentus*-soybean intercropping system can be attributed to the creation of a more diverse and complex agroecosystem, which disrupts the pests' host-finding ability, provides alternative food sources and habitats for natural enemies, and enhances the plant's defense mechanisms. The physical barrier created by the companion crop and the alteration of the microclimate also contribute to the lower pest incidence.

Recommendations

i. Adoption of the *Abelmoschus esculentus*-soybean intercropping system (4:1 ratio) is recommended as an effective and sustainable pest management strategy for okra cultivation. This practice can significantly reduce the population and damage caused by *Earias vitella* and

Helicoverpa armigera, the two major lepidopteran pests of okra.

ii. Further research should be conducted to explore the optimal spatial arrangements and planting patterns of the intercropping system to maximize the benefits in terms of pest suppression and crop productivity.

iii. Integration of the *Abelmoschus esculentus*-soybean intercropping system with other agroecological practices, such as the enhancement of natural enemy populations and the use of biopesticides, can provide a more holistic and effective pest management approach.

iv. Extension efforts should be made to disseminate the findings of this study and promote the adoption of the *Abelmoschus esculentus*-soybean intercropping system among okra growers in the region, thereby contributing to the development of sustainable and environmentally-friendly agriculture.

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