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Effects of intra-row spacing and weeding frequency on leaf caterpillar (*Hymenia recurvalis* F.) infestation on amaranth (*Amaranthus* sp.) in Wukari, Taraba State, Nigeria

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ABSTRACT

Plant spacing and weeding are among the key factors determining leafy vegetable growth and yield through maximum utilization of space, nutrients, water and sunlight. *Amaranthus* species is a popular and very important leafy vegetable crop that is infested and damaged by the arthropod pests in Nigeria. Therefore, this study identified the optimum spacing and proper weeding regime required for the control of leafy caterpillars (*Hymenia recurvalis* F.) and ensuring the potential yield of amaranths. Field experiments were conducted to evaluate the effects of plant spacing and weeding frequency in the control of leafy caterpillar infestation and damage on amaranths (*Amaranthus* sp.). Four intra-row plant spacing (10 x 10 cm; 20 x 20 cm, 30 x 30 cm and 40 x 40 cm) and four weeding frequencies (0, 1, 2 and 3) were assessed using split-plot laid in randomized complete block design (RCBD) replicated three times. Results showed that 40 x 40 cm intra-row plant spacing and three weeding were found to be effective in reducing the infestation of *H. recurvalis* on *Amaranthus* sp. Results further showed that these combined management practices improved the growth and yield of the crop by 35% during the 2020 and 2021 cropping seasons in the study area. The study showed that combining appropriate plant spacing with three weedings is recommended for the control of amaranths leaf caterpillar (*H. recurvalis*) to poor resource farmers in the study area.

Keywords: Intra-row, frequency, amaranth, *Hymenia recurvalis*, weeding, plant spacing.

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INTRODUCTION

Amaranth (*Amaranthus* sp.) is a leafy vegetable that is an essential component of the daily food intake for both rural and urban dwellers in Nigeria.

Amaranth (*Amaranthus* sp.) is believed to have originated from central and South America where it has been cultivated for more than 8,000 years (IITA, 2005). It has now become cosmopolitan, spreading to and becoming established in Africa, Asia, Russia, parts of Eastern Europe and South America (Smith and Eyzaguime, 2007; Ebert et al., 2011) and it's now grown by a large number of farmers over the past few decades (IITA, 2005).

Amaranth provides the much-needed minerals, vitamins, and supplementary proteins for the majority of the populace that depends largely on starch staples. It’s a leafy vegetable that has been widely accepted as the dietary constituent more popular in Nigeria (Aderolu et al., 2013). It has been produced and utilized all over Nigeria (IITA, 2005). Nigeria is the largest producer and consumer of Amaranth followed by Ghana, Benin Republic and Senegal in West Africa; Kenya, Uganda, Cameroon, Gabon, Tanzania and Ethiopia in East and

Central Africa; South Africa, Zambia and Zimbabwe in Southern Africa (IITA, 2005; Ebert et al*.,* 2011; Smith and Eyzaguime, 2007). Vegetable Amaranth is cultivated and consumed in many parts of the world. The popularity of the vegetable Amaranth is due to its earliness to maturity, palatability, high nutritive value, protein content, and rich minerals and vitamins (Akubugwo et al., 2007; Palada and Chang, 2013). The regular consumption of vegetable amaranth reduces blood pressure, cholesterol level and improve the body's antioxidant status and immunity (Oke et al., 2015).

Despite all the economic and nutritional benefits of vegetable amaranth in Nigeria, its productivity is limited by a range of insect pests with which they are associated and the level of losses suffered in unimproved and improved agricultural practices (James et al., 2010; Lawan et al., 2016; Borisade et al., 2019). According to Ezeh et al. (2015), Aderolu et al. (2013) and Borisade et al. (2019) insect pests of various orders namely, Coleoptera, Hemiptera, Lepidoptera and Orthopthera attack and damage vegetable amaranth in Nigeria. Lepidopterous insect pests of amaranth include the Leaf caterpillar *(Hymenia recurvalis* F.), *Helicoverpa amigera, Spodeptera litura* and *Psara bipunctalis* (Kagali et al., 2014).

The leaf caterpillar or beetworm moth (*Hymenia recurvalis* F.) (Lepidoptera: Pyralidae) causes severe losses to *Amaranthus* species. The caterpillar rolls the leaf into a distinctive leaf shelter and voraciously feeds on the green matter. Severe attack refuels in complete skeletonization and drying up in the leaves within a short time (James et al., 2010; Aderolu et al., 2013; Ezeh et al., 2015; Oke et al., 2015). This complex of insect pests associated with vegetable amaranth has necessitated the need to control the leaf caterpillar (*Hymenia recurvalis*) of Amaranthus species.

The control of this insect pest has been through the use of synthetic insecticides which pose health risks to humans, animals, wildlife, birds, and fish, and result in environmental pollution (Okunlola et al., 2008). Research towards evaluating and identifying non-synthetic methods of insect pest control which are safe, cheap, easy to apply and accessible to farmers are being carried out in Nigeria (Seni, 2018).

Different methods have been used for controlling the insect pests and stabilizing the productivity of the cropping systems, the effect of plant spacing and weed control treatments are some of the crop management practices that minimize the infestation and damage of insect pests on field crops (Abouziena et al., 2008; Ahmed et al., 2010; El-Naim and Ahmed, 2010; El-Naim et al., 2010; Kumar, 2009; Tijani-Eniola, 2002). Management of field crops row spacing and population density has been used to increase crop productivity (Dalley et al., 2006, Yusuf et al., 2015; Takim and Uddin II, 2010; Degri, 2014). El-Naim et al. (2010) reported that regular weeding and crop spacing play an important role in improving crop growth and yield. They reported that narrow row spacing affects the weeds and increases crop yield. Regular weed control in vegetables is beneficial to the crops and minimizes the effect of weed competition with the crop; as they alter environmental factors within the crop. According to Abouziena et al. (2008), Takim and Uddin II (2010) and Degri (2014) the presence of weeds can serve as a source of pests of crop plants. In amaranth cultivation, weeds reduce growth, leaf quality and biomass apart from being a food resource for insects and pathogens. The presence of weeds in crops is detrimental to insect management. Frequent weeding in crops and proper crop spacing help eliminate or control at the earliest possible stage potential insect vectors, insect pest infestation and damage (Mustapha et al., 2001). The spacing of crops alone without timely and adequate weeding cannot control insect pest infestation (El-Naim et al., 2011; Degri and Buba, 2022). This is because of the increase in weed incidence which sets the stage for insect pests that are attracted to these weeds to also feed on the crops thus affecting the growth and yield of crops. This study therefore was conducted to assess the effect of row plant spacing and weeding on the leaf caterpillar infestation and damage on growth and yield of vegetable amaranth in the study area.

MATERIALS AND METHODS

Experimental Site

Field experiments were conducted during the 2020 and 2021 cropping seasons at the Teaching and Research farm of the Faculty of Agriculture and Life Sciences, Federal University Wukari, Taraba State. The research aimed to evaluate the effects of intra-row plant spacing and weeding frequency on leaf caterpillar (*Hymenia recurvalis* Fab.), infestation and damage to the growth and yield of amaranth (*Amaranthus* sp.). The main annual rainfall of the area is 180mm and the main annual temperature of 30ºc. The rainy season starts from April to October while the dry season is experienced between November and April. The soil was loamy with a pH of 6.8.

Source of Experimental Material and Design

Amaranth seeds used for the experiment were purchased from a reputable agricultural input distributor in the new Wukari market. The organic fertilizer (cow dung) used was collected from the animal pen of the Department of Animal Health and Production (AHP), Faculty of Agriculture and Life Sciences, Federal University Wukari, Taraba state. The experiment was laid down in a split plot fitted into a randomized complete block design (RCBD) with a plot size of 4.0 x 4.0 m (gross plot) and 3.0 x 2.5 m (net plot) plot within replication was separated by a 1.5m alley while replications between plots were separated by a 2.0m alley and were replicated 3 times, the main plot was assigned to the weeding frequencies (0,1,2, and 3) while plant spacing was allocated to subplot (10 x10 cm, 20 x 20 cm 30 x 30 cm and 40 x 40 cm).

Land Preparation, Treatment Application and Transplanting

The experimental land was cleared and hoe-tilled to make a seed bed 2.00 x 2.00m (4.00m²) the amaranth seeds used for the study were medium height, annual type cultivated for food and commercial purposes. It is well adapted and grown by farmers in the Savanna ecological zone of Nigeria under rainfall and irrigated conditions. Amaranths (*Amaranthus* sp.) seeds were planted in well prepared seedbed and watered once for three weeks before transplanting. The seedling was raised and managed under shade to reduce high solar heat that may likely cause scorching. When the seedlings were ready for transplant, they were watered before removing the good, healthy and vigorous ones to the field for transplanting. The transplanting was done during cool evening weather and gently with a ball of earth around the roots to avoid exposure to extreme and harsh weather conditions and to reduce damage to the roots. After the seedling transplant, the plants were watered when the need arose.

The selected and uprooted seedlings were carefully and gently transplanted in the already prepared and laid out field at the designed intra-row plant spacing by 60 cm inter-row spacing. After the amaranth seedlings were established, gaps were filled one week after transplanting to maintain the plant population as designed in the experimental plot. The experimental plots were weeded according to the design of the treatment (0, 1, 2, and 3 weeding after transplanting). Well-decomposed cow dung manure was applied in the field.

Data collection

During the experiment, data were collected on the following parameters:

The number of leaf caterpillars *(Hymenia recurvalis* F.) Per plant: data on leaf caterpillars on amaranth was done weekly on five tagged plants commencing from when the leaf caterpillar population was becoming high. The *H. recurvalis* numbers were collected from the young and old amaranth leaves with signs of silk web and perforated leaves. The leaf caterpillars were collected, counted and recorded per plant.

Number of amaranth leaves damaged by *H. recurvalis*: young and old leaves with signs of silk web and perforations were visually assessed from the five randomly tagged plants from the middle rows of each plot were counted per plant and recorded.

Number of amaranth leaves undamaged by *H. recurvalis*: The number of leaves without signs of silk web and perforations were visually counted per plant and recorded.

Plant Height: The height of the five tagged amaranth plants from the middle rows of each plot was measured using the graduated meter rule from the base of the plant to the tip. The height of each plant was taken and recorded accordingly in centimetres (cm).

Amaranth weight and yield: All amaranth plants from each treatment were harvested by cutting from the base using a sharp knife tied and weighed with a meter electronic weighing scale. The weight of the amaranth was recorded against each treatment in kilograms (Kg). The yield per treatment was extrapolated to kilogram per hectare (kg\ha) by multiplying by the plant population of each treatment.

Data analysis

Data collected was analyzed statistically using analysis of variance (ANOVA). The differences in treatment means were identified in Duncan's multiple range test (DMRT) at a 5% level of probability ($P \geq 0.05$).

RESULTS

The result presented in Table 1 indicates that there was a significant difference between the intra-row plant spacing and weeding frequency. Intra-row plant spacing 40 x 40 cm and three weeding frequencies significantly ($P \leq 0.05$) reduced the number of *H. recurvalis* during the study period. The reduction of the pest population was closely followed by 30 x 30 cm spacing and two weeding frequencies while 10 x 10 cm spacing and zero and one weeding frequencies had the highest infestation and damage during the same period in 2021 and 2022 cropping seasons.

Amaranths plant heights were significantly ($P \leq 0.05$) higher in plots with 40 x 40 cm intra-row spacing and three weeding frequency (Table 2), while plant heights were lower in plots with 10 x 10 cm intra-row spacing and one weeding frequency. Zero weeding frequency had the least plant heights. There was no significant difference between the interaction of intra-row spacing and weeding frequency in both the 2021 and 2022 cropping seasons.

Table 3 shows the results of the influence of intra-row plant spacing and weeding frequencies of amaranth on

Table 1. Mean number of *H. recurvalis* as influenced by plant spacing and weeding frequency of *Amaranthus* sp. in 2021 and 2022 cropping seasons.

Treatments	Mean No. of *H. recurvalis*					
	2021			2022		
Plant spacing (cm)	2WAT	4WAT	6WAT	2WAT	4WAT	6WAT
10 x10	1.16	1.18	1.29	1.14	1.17	1.30
20 x20	1.13	1.20	1.24	1.18	1.20	1.22
30 x30	1.10	1.13	1.16	1.09	1.11	1.19
40 x 40	0.16	0.15	0.14	0.13	0.12	0.17
SE±	0.05	0.07	0.06	0.04	0.10	0.13
Weeding frequency						
1	1.18	1.24	1.30	1.16	1.22	1.20
2	0.75	1.18	1.17	1.07	1.09	1.17
3	0.55	0.14	0.16	0.11	0.12	0.15
SE±	0.06	0.08	0.04	0.05	0.09	0.15
Interaction PS X WF	NS	NS	NS	NS	NS	NS

Table 2. Leaf caterpillar effect on *Amaranthus* sp. plant height as influenced by plant spacing and weeding frequency during the 2021 and 2022 cropping seasons.

Treatments	Plant Height (cm)					
	2021			2022		
Plant spacing (cm)	2WAT	4WAT	6WAT	2WAT	4WAT	6WAT
10 x 10	5.06	17.18	20.26	4.96	18.08	20.23
20 x20	5.81	18.11	23.98	5.83	18.10	23.92
30 x 30	7.26	22.67	24.01	7.26	22.67	24.01
40 x 40	11.08	26.77	28.56	11.28	26.72	28.51
SE±	1.28	1.79	2.44			
Weeding Frequency						
0	4.76	18.18	20.24	4.86	18.28	20.44
1	5.85	18.09	23.88	5.65	18.29	23.68
2	7.26	22.67	24.01	7.28	22.64	24.11
3	11.18	26.79	28.53	11.16	26.71	28.73
SE±						
Interactions Ps X WF	NS	NS	NS	NS	NS	NS

damaged and undamaged leaves caused by *H. recurvalis* during the 2021 and 2022 rainy seasons. More amaranths leaves were damaged by *H. recurvalis* in plants spaced 10 x 10 cm and 20 x 20 cm and weeded once while plants spaced at 40 x 40 cm and weeded thrice had significantly (P<0.05) lower damaged leaves and higher undamaged leaves, both 2021 and 2022 rainy seasons.

Results presented in Table 4 showed that amaranths yield was significantly (P<0.05) higher in 40 x 40 cm and three weeded treatments while 10 x 10 cm intra-row plant spacing weeded once had significantly (P<0.05) lower yield during the study period. The amaranth leaf yields interaction between intra-row plant spacing and weeding frequency were not significantly different during the two rainy seasons in the study area.

Table 3. Influence of plant spacing and weeding frequency of *Amaranthus* sp. on damaged and undamaged leaves caused by *H.recurvalis* during the 2021 and 2022 cropping seasons.

Treatments	Damaged Leaves/Plant						Undamaged leave/plot					
	2021			2022			2021			2022		
Plant spacing (cm)	2WAT	4WAT	6WAT	2WAT	4WAT	6WAT	2WAT	4WAT	6WAT	2WAT	4WAT	6WAT
10 x 10	10.14	10.61	12.61	10.10	11.11	12.61	6.09	5.55	5.622	6.18	5.66	5.71
20 x20	9.0	9.08	9.02	9.06	9.08	9.02	8.06	8.08	9.02	8.02	7.70	7.17
30 x 30	6.47	5.88	5.69	5.49	5.91	5.55	10.17	10.11	10.16	10.14	9.89	10.23
40 x 40	4.84	4.61	4.66	4.80	4.65	4.71	10.87	10.76	10.81	10.78	10.55	10.91
SE±	8.48	6.51	7.11	8.21	6.47	7.18	9.07	7.43	6.14	8.89	7.39	7.11
Weeding frequency												
0	10.11	10.41	12.67	11.06	10.14	12.31	6.17	5.58	5.52	6.18	5.69	5.81
1	9.06	9.08	9.02	9.06	9.08	9.02	8.06	8.08	9.02	8.02	7.70	7.17
2	6.47	5.88	5.69	5.49	5.91	5.55	10.17	10.11	10.16	10.14	9.89	10.23
3	4.84	4.61	4.66	4.80	4.65	4.71	10.87	10.76	10.81	10.78	10.55	10.91
SE±	8.48	6.51	7.11	8.21	6.47	7.18	9.07	7.43	6.14	8.89	7.39	7.11
Interaction Ps X WF		NS			NS			NS			NS	

Table 4. Mean Yield of Amaranth plant spacing and weeding frequency as influenced by *H. recurvalis* in 2021 and 2022 cropping seasons in Wukari.

Treatments	Mean yield (Kg/ha)	
	2021	2022
Plant spacing (cm)		
10 x 10	16.84	17.20
20 x 20	17.54	17.58
30 x 30	28.11	28.61
40 x 40	48.97	47.67
SE±	3.95	4.18
Weeding frequency		
0	16.87	17.13
1	17.66	17.80
2	28.17	28.69
3	49.27	48.96
SE±	4.75	4.08
Interactions Ps X WF NS	NS	NS

DISCUSSION

Plant spacing and weeding are two agronomic management practices for controlling insect pests and weeds on field crops (Banjo et al., 2003; Philip et al., 2010; Oke et al., 2015, Ezeh et al., 2015). This study showed that the main problem limiting the production of leafy amaranth is good cultural practices, especially the practice of recommended intra-row plant spacing as well as regular weeding. If regular weeding is practiced and crop spacing recommendations are adhered to, then the weeds that compete with crops and served as alternative hosts and vectors can be significantly reduced. Weeding thrice had the lowest pest infestation and highest plant height. Weeding facilitates plants to have more resources for growth and yield (El-Naim et al., 2010, El-Naim and Jabereldar, 2010). Mustapha et al. (2001), Palada and Chang (2013) and Yusuf et al. (2015) found that increasing weeding frequency and using correct intra-row plant spacing of amaranths lowered insect pest infestation, increased plant height and increased yield than when they are closely planted and left weedy due to inefficient weed control. This is the reason closely spaced amaranths had a higher infestation, dwarf plants and lower yield than widely spaced plots. Amaranth plots weeded three times were found to have lower *H. recurvalis* infestation, higher plant heights, lower damaged leaves, higher undamaged leaves and higher yield compared to once and twice weeding. This implies that weeds increased pest infestation and plant damage while decreasing growth performance, plant height and yield. This result may be attributed to vigorous plants with less competition for light, nutrients and free space in weed-free environments. This agreed with the findings of Aderolu et al. (2013) who reported that weed control in amaranths led to increased plant height and decreased insect pest occurrence, abundance and infestation compared to unweeded plants. Increased weeding frequencies decrease pest attacks and increase the number and size of leaves. This is due to better control of weeds which reduced competition and increased availability of resources like nutrients, soil water moisture, light and barrier within plants. This result conforms with the findings of El-Naim et al. (2010), Degri et al. (2017) and Seni (2018).

The increase in plant height, undamaged leaves and yield per plant with increasing intra-row plant spacing observed in this study concur with many researchers in different crops (Dalley et al., 2006; Abouziena et al., 2008; Kumar, 2009; El-Naim and Jabereldar, 2010; El-Naim et al., 2010; Philip et al., 2010; Ahmed et al., 2011). They reported that closer spacing reduced the number of leaves per plant, plant height and general growth and yield performance of crops. This result may be attributed to the competition between plants and between the different parts of the individual plant under a high planting population.

Decreasing plant spacing increased *H. recurvalis* infestation, damaged leaves and decreased plant height, and increased plant spacing increased undamaged leaves and yield of amaranth during the study period. The population density of a crop determines to a great extent its performance in terms of growth and yield. Plant spacing should be done in such a way not only to ensure that each crop has an equal chance to grow but also to create a barrier that will make pest infestation uncomfortable and unconducive while creating a conducive and comfortable environment for the crop to thrive well. Amaranths spaced closer yield lower while those spaced wider and weeded regularly yield higher. This is because increasing plant density reduces individual plant growth and yield. It also determines the chances or otherwise of insect pest occurrence, abundance and infestation and hence their growth and yield performance. This concurs with the findings of Degri (2014) who reported that decreasing plant population significantly reduced insect pest infestation and increased plant height, number of undamaged leaves and yield, but increasing plant population increased significantly insect pest attack, and reduced plant height and yield. This was also reported by El-Badawy and Mehasen, 2012). Islam et al. (2011) also reported that the spacing of sweet pepper (*Capsicum annum* L.) produced significantly higher and better yield per plot and yield per hectare.

This wide space allowed the crop to obtain enough nutrients, light, water and carbon dioxide for its growth and yield. The higher yield recorded at 40 x 40 cm spacing could be attributed to a lack of intra-specific competition and the ability to capture more environmental resources. The lower yield recorded at closer (10 x 10 cm and 20 x 20 cm) spacing could be attributed to intra-specific competition of individual plants for growth resources such as available water, light, and nutrients in addition to weed competition. This finding concurs with Philip et al. (2010) who reported that good growth invariably leads to high yield at a wider spacing and attributed this to less competition for environmental resources including solar radiation and therefore were more photosynthetically active.

Andrade et al. (2002) and Ufoegbune et al. (2015) observed that proper spacing ensures optimum plan growth through adequate utilization of environmental resources. Amaranths cultivated with recommended intra-row spacing and weeding regimes could also be free from insect pests, they could also be safer, healthier and tastier (Yusuf et al., 2015; Sokoto and Johnbosco, 2017). Tara et al. (2009) reported that leafy vegetables such as Amaranths can grow and perform better if they are weeded more frequently and spaced at their recommended distance. This is the reason amaranths spaced at 40 x 40 cm and weeded thrice had significantly lower *H. recurvalis* attacks, grew higher, had lower damaged leaves per plant and had higher yields during the two seasons in the study area.

The growth and yield of wide-spaced crops increased radiation interception (Kagali, 2014; Mureithi et al., 2017) thereby increasing their growth and yield. Close spacing in amaranths could lead to a serious build-up of *H. recurvalis* that feed on the leaves, therefore the higher damaged leaves on plots with close spacing and not weeded frequently. This conforms to the work of Capinera (2005), Norris and Kogan (2000) and James et al. (2010). Degri and Buba (2022) reported that regular weeding helps in breaking the relationship between weeds and insect pests, thereby optimizing insect pest control in crop production (Stagnari and Pisante, 2011, Rai and Yadav, 2015). Uncontrolled weed growth interferes with the growth and yield of amaranths.

Regular weed control and adequate intra-row spacing of amaranths are beneficiary to the crop and minimize the effect of weed competition with the crop, as they alter environmental factors within the crop (James et al., 2010). In leafy vegetable cultivation, weeds reduce leaves yield and quality by 60-90% apart from being a food resource for insects and disease pathogens (Philip et al., 2010). The presence of weeds and close spacing effects are detrimental to insect management. Frequent weeding and adequate intra-row spacing in crops help reduce at the earliest possible stage potential insect pests, vectors and damages (Tijani-Eniola, 2002)

The lower *H. recurvalis* infestation, higher plant height, lower plant leaves damaged and higher leafy yield recorded in plot spaced 40 X 40 cm apart and weeded thrice indicates that there was total removal of weeds on the plots and creation of enough barriers within the crop which effectively reduce competition and insect pest infestation. This implies that weed control and adequate intra-row spacing managed *H. recurvalis* and healthy amaranths to have more assimilates available to support the crop growth and development and thus lower leave damage and higher yield. This implies that these two agronomic practices were good control measures for amaranth production.

Conclusion

This present study showed that the amaranth caterpillar (*Hymania recurvalis* F.) is a major insect pest of amaranths in the study area. It was found to cause serious leaf damage and reduce plant growth and yield. It is therefore a major constraint to leafy amaranth cultivation. The practice of adequate intra-row spacing and regular weeding was found to be effective in minimizing *H. recurvalis* infestation in the 2021 and 2022 cropping seasons in the study area. The combination of these strategies significantly reduced the pest attack, and leaf damage and improved amaranth growth and yield during the study period. These strategies are therefore recommended for the control of *H. recurvalis* in the study area.

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