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Influence of Plant Spacing on Insect Population, Growth and Yield of Okra in Sierra Leone

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Abstract: Okra is a very important vegetable in the field of nutrition and health care in Sierra Leone. The major limiting factors in okra production are incidence of insect pests and improper plant spacing. The present field research was undertaken at the Department of Crop Protection, School of Agriculture, Njala University to evaluate the effect of plant spacing on insect pest population, growth and yield, and profitability of okra production in Sierra Leone from 2017 to 2018 main cropping seasons. Five levels of plant spacing 50 cm × 40 cm (50,000 plants per hectare), 60 cm × 30 cm (55,556 plants per hectare), 60 cm × 40 cm (41,667 plants per hectare), 70 cm × 30 cm (47,619 plants per hectare), and 70 cm × 40 cm (35,714 plants per hectare) were adopted as treatments with three replications in randomized complete block design. The results of analysis of variance revealed that plant spacing were significant ($P < 0.05$) on insect population, plant height, leaf area, damage leaves, yield and yield components of okra at 4 and 8 weeks after planting (WAP) during 2017 and 2018 main cropping seasons. Okra cropped in plant spacing 50 cm x 40 cm (Recommended rate) inclined the highest number of insects, plant height, leaf area, damage leaves and yield at 4 and 8 WAP in both years followed by 60 cm x 40 cm plant spacing, while the reverse also holds true with 70 cm x 40 cm plant spacing. The profitability analysis revealed that the recommended plant spacing of okra (50 cm x 40 cm) produced the highest gross margins of Le 18,333,000.00 plants per hectare (ha^{-1}) and Le 21,363,000 plants per hectare (ha^{-1}) respectively during 2017 and 2018 main cropping seasons of okra production. In conclusion, increasing the plant spacing above the recommended plant spacing (50 cm x 40cm) could reduce insect population and leaf damage on okra, but will significantly decrease okra growth and yield, and profitability. Hence, in order to achieve maximum productivity of okra in the Njala area, the Clemson spineless variety of okra should be planted at a plant spacing of 50 cm x 40 cm. However, integrating plant spacing with other cultural methods of controlling insect pests of okra should be investigated in order to determine a sustainable and cost-effective method of controlling insect pests of okra.

Keywords: Okra Production, Insect Pest, Plant Spacing, Gross Margin, Growth and Yield

1. Introduction

Okra belonging to the family of Malvaceae is an essential vegetable crop grown in Sierra Leone as a result of high malnutrition rates, but there is no clear record on production area and productivity of the crop. Okra has multipurpose uses, the tender pods, leaves and succulent shoots are consumed either in fresh or dried forms [1]. Okra consumption among other fruit vegetables is found to be beneficial in moderating blood pressure, rich in vitamins, calcium, potassium and other minerals [2]. Okra leaves are also sometimes used as basis for poultices, as an emollient, sudorific or antiscortic, in antioxidants and to treat dysuria [3].

Okra production and yield maximization has not been achieved in Sierra Leone due to lack of suitable production practices such as ideal plant spacing. The various insect pests in Sierra Leonean okra fields include lepidopterous worms, leafhoppers, plant-hoppers, aphids, whiteflies, mealy bugs, flea beetles, thrips and mites. These pests infest leaves, stems, branches, flowers and pods [4]. In addition, inappropriate plant spacing used by okra growers has often led to poor plant growth, pod quality, and low yields, which are insufficient to offset production costs that results in substantial losses of yield. Moreover, several synthetic insecticides have been recommended for the control of okra insects, but due to their residual effects and environmental hazards, extreme precautions are needed for their use. The indiscriminate and repeated use of these synthetic pesticides has caused toxicity to non-target beneficial organisms resulting in the development of pest resistance to the chemical pesticides, resurgence of new strains of pests and environmental pollution.

Research studies on insect pests and plant spacing of okra under Sierra Leonean conditions have gained major attention in recent years, because they are one of the greatest limiting factors in attempting to increase the productivity of okra farmers. Minimal attention has so far been given to the development of improved agronomic management practices like plant spacing that would reduce insect pest population, thus increase the productivity of the crop in the region. Information about crop protection techniques and methods is generally scarce especially among rural communities, smallholder farmers, field workers and local extension staff. Therefore, the present investigations were initiated to fill up the gaps for revealing information on the development of sound, stable, eco-friendly and viable management practices to manage insect pest infestation in okra.

Therefore, the objective of the study was to evaluate the effect of optimum plant spacing on insect pest population, growth and yield, and profitability of okra production.

2. Research Methodology

2.1. Description of Study Area

The research was conducted under field trial conditions at the Department of Crop Protection, School of Agriculture, Njala University (N 08.06, W 12.06 and altitude: 63m), located in the southern region of Sierra Leone during 2017 and 2018 main cropping seasons. The predominant vegetation and landform of the study area is secondary bush and drainage depressions, undulating plains, and low plateau respectively. The soils at the experimental site were loamy, with low soil organic carbon, total nitrogen and available phosphorus. The climatic condition of the study area is the same as the rest of the country with rainy season (May-October) and dry season (November-April). The climatic weather data was collected using the WatchDog weather station (model: 2000 series) during 2017 and 2018 cropping seasons (Table 1).

Table 1. *Climatic weather from June - September 2017 and 2018 main cropping seasons.*

Month	Weather condition					
	2017			2018		
	RH (%)	Temp. (°C)	Rainfall (mm)	RH (%)	Temp. (°C)	Rainfall (mm)
June	85.79	26.15	400.60	86.53	25.95	379.00
July	88.20	25.40	340.70	90.85	25.18	528.50
August	91.00	25.20	552.20	90.24	25.18	272.10
Sept.	88.54	25.89	367.20	88.03	25.57	503.90

RH = Relative humidity; Temp. = Temperature.

2.2. Experimental Design and Treatments

The experiment was a single factor trial laid out in a randomized complete block design (RCBD) with three replications. The treatments in each replication consisted of five different plant spacing namely 50cm × 40cm with (50,000 plants ha^{-1}), 60cm × 30cm (55,556 plants ha^{-1}), 60cm × 40cm (41,667 plants ha^{-1}), 70cm × 30cm (47,619 plants ha^{-1}) and 70cm × 40cm (35,714 plants ha^{-1}). The experiment comprised of 15 plots, each measuring 3.6m × 3.0m, 1 m between replications and within plots given an area of 243.2 m^2 (0.02432 ha).

2.3. Cultural Practices

The experimental field was thoroughly cleared, ploughed to a depth of 10 cm and levelled using local farm tools. Seeds of the okra variety (Clemson spineless) was acquired from the Crop Science Department, School of Agriculture, Njala University and sown on 13th June 2017 and 2018 cropping seasons. Two seeds were sown $hill^{-1}$, thinned two weeks after germination to achieve the required plant populations. Nitrogen was applied in the form of urea in three splits: 23 kg ha^{-1} at emergency of plants, 46 kg ha^{-1} at active growth stage and 69 kg ha^{-1} at pod initiation. The plots were kept weed-free by hoe weeding at 3, 6 and 9 weeks after planting.

2.4. Data Collection Procedures and Measurement

2.4.1. Insect Population and Leaf Damage

Five randomly selected plants from the middle rows of each plot were used to determine the average number of insects and damaged leaves $plant^{-1}$ at various intervals. The total number of adult insect pests from the five plants in each plot were counted and divided by five to determine the number of insect $plant^{-1}$. Furthermore, leaves from five randomly selected plants from each plot were assessed based on the number of holes on the leaves to determine the number of damaged leaves $plant^{-1}$.

2.4.2. Growth and Yield Parameters

Okra height (cm) was measured from five randomly selected plants in each plot from the middle rows using measuring tape stretching from the soil surface to the terminal end of the plant.

Leaf area (cm^2) of 5 randomly selected plants from the middle rows of each plot was determined using a leaf area meter (T – area) meter model (mk^{-2}).

The number of fresh pods $plant^{-1}$ was counted at every harvesting day from five randomly selected plants in each plot. The total number of pods gotten from the selected plants was divided to get the mean number of pods $plant^{-1}$.

The harvested fresh pod weight (t ha^{-1}) was determined in each net plot area of 4 m^2 using a digital balance.

2.4.3. Profitability Assessment

Gross margin was computed using partial budgeting analysis to compare the profitability of okra production as influenced by plant spacing. The gross margin for each treatment was computed using this formula:

$$\text{Gross Margin} = \text{TR} - \text{TVC} \tag{1}$$

Where:

TR = Total revenue generated from sales of okra pods (yield x farm gate price).

TVC = Total variable costs (cost of okra seeds + labour for planting okra seeds).

2.5. Statistical Analysis of Data

The data were subjected to analysis of variance (ANOVA) appropriate to randomized complete block design technique using the PROC GLM procedure of Statistical Analysis System (SAS) computer software programme, version 9.4. The Student Newman-Keuls (SNK) test was used to compare treatment means at 0.05 level of probability.

3. Results and Discussions

3.1. Insect Population and Damaged Leaves

The impact of insect pests' population on growth performance and yield of okra as influenced by plant spacing revealed a significant difference ($P < 0.05$) in the number of insects at 4 and 8 WAP (Table 2) during 2017 and 2018 main cropping seasons. Okra cropped in plant spacing 50 cm x 40 cm (Recommended rate) inclined the highest number of insects at 4 and 8 WAP in both years followed by 60 cm x 40 cm plant spacing, whereas the lowest population of insects were observed in plots treated with 70 cm x 40 cm plant spacing. The differences in abundance of insect pests at varying plant spacing may be attributed to the variations in climatic weather conditions. Thus, total rainfall (1,683.5mm), average temperature (25.7°C) and relative humidity (88.91%) from June to September in 2018 main cropping season was greater than 2017 main cropping season (rainfall 1,660.7mm, temperature 25.6°C and relative humidity 88.38%) respectively. This result is in conformity with [5], who indicated that an average temperature of 20°C to 30°C is considered optimum for growing, flowering and fruiting of okra. On the contrary, there was no significant difference ($P > 0.05$) on insect population of okra crops planted with plant spacing 60 cm x 30 cm, 60 cm x 40 cm and 70 cm x 30 cm at 8 WAP during 2017 cropping season. Similar trend occurred in 2018 cropping season, where plant spacing with 60 cm x 30 cm, 60 cm x 40cm, 70cm x 30 cm and 70 cm x 40 cm recorded statistically no significant difference on abundance of insect pests at 4 WAP. Also, plant spacing with 60 cm x 30 cm, 70 cm x 30 cm and 70 cm x 40 cm respectively did not show significant difference at 8 WAP in 2018 cropping season.

Table 2. *Mean insect population $plant^{-1}$ as influenced by plant spacing during 2017 and 2018 main cropping season.*

Plant Spacing (cm)	Insect Population $Plant^{-1}$			
	2017		2018	
	4 WAP	8 WAP	4 WAP	8 WAP
50x40	12.33^a	16.33^a	15.00^a	18.33^a
60x30	8.33^c	13.00^{ab}	11.00^b	14.33^b
60x40	10.00^b	14.33^{ab}	12.00^b	15.66^{ab}
70x30	5.33^d	12.00^{ab}	9.00^b	14.66^b
70x40	5.66^d	10.00^b	9.00^b	13.00^b
Pr > F	<.0001	0.0357	0.0079	0.0215

Means sharing the same letters are not significantly different at 5% level of significance.

The damage of okra leaves by insects was significantly different among various plant spacing treatments in the 2017 and 2018 main cropping seasons (Table 3). The recommended planting space (50 cm x 40 cm) significantly recorded the highest number of damaged leaves than all other treatments for both cropping years. In 2018 main cropping season, damage caused by insects on the leaves of okra statistically had no significant difference on plant spacing 60 cm x 30 cm, 60 cm x 40 cm, 70 cm x 30 cm and 70 cm x 40 cm at 4 and 8 WAP, similar trend was observed in 2017 cropping season at 8 WAP. In addition, at 4 WAP, plant spacing 50 cm x 40 cm (Recommended rate), 60 cm x 30 cm and 60 cm x 40 cm, and 70 cm x 30 cm and 70 cm x 40 cm did not showed significant difference on damaged leaves of okra during 2017 cropping season.

Table 3. *Mean number of damages leaves plant^{-1} as influenced by okra insect pests during 2017 and 2018 main cropping season.*

Plant spacing (cm)	Number of damaged leaves plant^{-1}			
	2017		2018	
	4 WAP	8 WAP	4 WAP	8 WAP
50x40	13.66^{a}	26.33^{a}	19.66^{a}	20.00^{a}
60x30	11.00^{a}	12.33^{b}	11.00^{b}	7.66^{b}
60x40	10.00^{a}	13.00^{b}	10.66^{b}	10.00^{b}
70x30	3.66^{b}	6.33^{b}	5.33^{b}	4.00^{b}
70x40	3.66^{b}	9.33^{b}	6.00^{b}	5.33^{b}
Pr > F	0.0030	0.0124	0.0057	0.0006

Means sharing the same letters are not significantly different at 5% level of significance.

3.2. Plant Height

The tallest height of okra was obtained from plots treated with 50 cm x 40 cm plant spacing (Recommended rate) and was significantly ($P < 0.05$) taller than all other plant spacing treatments in both 2017 and 2018 main cropping seasons (Table 4). The result of the present study was in conformity with the report of [6] that plant height increased with increasing plant density. This might have attributed to elongation of internodes, strong rivalry between and within plants and their desire to reach the available growth factors such as sunlight. On the other hand, the shortest plant heights were obtained from wider plant spacing (70 cm x 40 cm) during 2017 and 2018 cropping seasons. However, the values for okra height did not differ statistically from plant spacing 60 cm x 30 cm, 60 cm x 40 cm, 70 cm x 30 cm and 70cm x 40cm at 4 WAP in 2017 cropping season.

Table 4. *Effect of plant spacing on okra height (cm) during 2017/2018 cropping season.*

Plant spacing (cm)	Plant height plant^{-1} (cm)			
	2017		2018	
	4 WAP	8 WAP	4 WAP	8 WAP
50x40	39.00^{a}	66.00^{a}	48.66^{a}	74.66^{a}
60x30	28.60^{b}	63.46^{a}	42.00^{b}	68.63^{ab}
60x40	22.13^{b}	58.83^{a}	38.00^{b}	64.00^{ab}
70x30	21.50^{b}	45.33^{b}	31.33^{c}	54.83^{bc}
70x40	18.83^{b}	43.66^{b}	29.83^{c}	46.33^{c}
Pr > F	0.0123	0.0030	0.0005	0.0045

Means sharing the same letters are not significantly different at 5% level of significance.

3.3. Leaf Area

The results of analysis of variance from this study showed that leaf area increased significantly ($P < 0.05$) with closest plant spacing (Table 5). The widest leaf area values was obtained from the closest plant spacing of 50 cm x 40 cm (Recommended rate), being significantly ($P < 0.05$) different from all other plant spacing treatments in both 2017 and 2018 cropping seasons. Hence, findings are in accordance with [7], who reported that increasing plant density per m^2 was accompanied with progressive and significant reductions in number of branches, number of leaves and leaf area per plant. Plant spacing of 70 cm x 40 cm produced the narrowest leaf area at 4 and 8 weeks after planting (WAP) during 2017 and 2018 okra cropping seasons. Additionally, there was no significant difference between plant spacing 70 cm x 40 cm, 70 cm x 30 cm and 60 cm x 40 cm on leaf area of okra at 8 weeks after planting in 2018 cropping season. In general, at 4 and 8 WAP, wider leaf area was recorded at closer spacing of okra crop than wider spacing. Thus, in wider plant spacing, there was less light interception and more weeds germinate and grow rapidly which also result in lower yield [8].

Table 5. *Effect of plant spacing on leaf area (cm) of okra during 2017/2018 cropping season.*

Plant spacing (cm)	Leaf area plant^{-1} (cm)			
	2017		2018	
	4 WAP	8 WAP	4 WAP	8 WAP
50x40	346.67^{a}	472.00^{a}	404.00^{a}	545.33^{a}
60x30	303.50^{ab}	359.33^{b}	323.17^{ab}	381.33^{b}
60x40	271.83^{abc}	275.17^{c}	259.50^{bc}	258.67^{c}
70x30	214.33^{bc}	235.33^{cd}	171.83^{cd}	233.00^{c}
70x40	191.00^{c}	205.00^{d}	139.83^{d}	158.50^{c}
Pr > F	0.0080	<.0001	0.0008	<.0001

Means sharing the same letters are not significantly different at 5% level of significance.

3.4. Number of Pods and Pod Weight Plant^{-1}

The results of analysis of variance depicted that the maximum number of matured pods plant^{-1} was obtained from plant spacing 70 cm x 40 cm which was statistically at par with 70 cm x 30 cm, and 60 cm x 40 cm plant spacing in both 2017 and 2018 cropping seasons (Table 6). The plots cropped with 70 cm x 40x cm Plant spacing significantly increased number of pods by 108% in 2017 and 113% in 2018 as compared to 50 cm x 40 cm (Recommended rate) plant spacing in both cropping years. This result confirms the findings of [9], who reported that decreasing the plant population by increasing the spacing between plants significantly increased the yield and also the number of pods of okra. However, minimum number of matured okra pods was recorded from plant spacing 50 cm x 40 cm in both 2017 and 2018 cropping seasons. This result is in conformity with the study [10], who reported that fruit number of okra significantly increased with decrease in population density. This could be attributed that plants grown under low population density have good growth performance since rivalry for available growth resources are inadequate as compared to plants grown under high plant population density.

Conversely, statistical analysis revealed significant differences ($P < 0.05$) among the different plant spacing for mean weight of okra pods plant^{-1} (Table 6). Maximum pod weight of matured okra crop was recorded in 70 cm x 40 cm plant spacing and was significantly ($P< 0.05$) different from the pod weights of all other plant spacing treatments. Nevertheless, minimum pod weight was recorded from plant spacing with 50 cm x 40 cm in both years. The results of this study was in agreement with the findings [11], who showed that wider spacing leads to heavier individual pod weight of okra. The maximum matured pods weight plant^{-1} at lowest plant population may be attributed to the availability of more nutrients and moisture favouring optimum vegetative growth in widest plant spacing, providing adequate assimilate for the development of pods, hence resulting in higher pods weight.

Table 6. *Effect of plant spacing on number of okra pods weight plant^{-1} during 2017 - 2018 cropping season.*

Plant spacing (cm)	Average number of pods and pods weight plant^{-1}			
	2017		2018	
	NPP	PW	NPP	PW
50x40	4.80^{c}	60.75^{c}	5.00^{c}	63.77^{c}
60x30	6.46^{b}	84.84^{bc}	6.66^{b}	87.21^{bc}
60x40	9.03^{a}	100.31^{ab}	9.33^{a}	102.35^{ab}
70x30	9.20^{a}	113.04^{ab}	9.66^{a}	115.71^{ab}
70x40	10.00^{a}	128.25^{a}	10.66^{a}	132.26^{a}
Pr > F	0.0002	0.0022	0.0001	0.0021

Means sharing the same letters are not significantly different at 5% level of significance.
NPP = number of pods plant^{-1}; PW = Pod weight.

3.5. Pod Yield Ha^{-1}

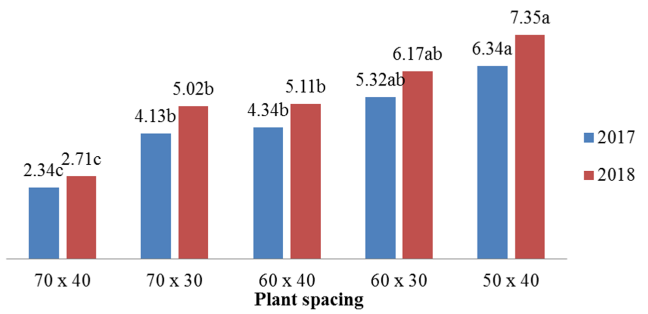

Figure 1. *Effect of plant spacing on pod yield of matured okra during 2017 and 2018 main cropping seasons.*

The results of analysis of variance indicated that pod yield of okra was significantly ($P<0.05$) affected by plant spacing (Figure 1). The highest pod yield ha^{-1} was recorded from plots treated with plant spacing 50 cm x 40 cm and was significantly ($P < 0.05$) different from all other plant spacing treatments in both 2017 and 2018 cropping seasons. The result also affirmed report [12] that the highest yield of okra was recorded from close spacing, which was statistically different from other two spacing and the widest spacing produced the lowest yield. The pod yield of matured okra ha^{-1} with plant spacing 60 cm x 40 cm was statistically at par with 70 cm x 30 cm plant spacing during 2017 and 2018 cropping seasons. However, the lowest matured pod yield of okra ha^{-1} was obtained from plant spacing 70cm x 40cm in both years. The highest pod yield of okra ha^{-1} in closed spacing may be attributed to higher number of plants per unit area and enhanced utilization of accessible natural growth resources than wider spacing [13].

3.6. Partial Budget Analysis

3.6.1. Revenue Generated

The revenue generated ha^{-1} from the sale of fresh okra pods differed considerably among the plant spacing for both 2017 and 2018 main cropping seasons (Table 7). The recommended plant spacing (50 cm x 40 cm) generated the highest revenue (Le 19,020,000 ha^{-1}) in 2017 and 2018 (22,050,000). In comparison to the recommended plant spacing (50 cm x 40 cm) of okra in 2017 cropping season, the revenue generated decreased by 16.1% in the 60 cm x 30 cm plant spacing, 31.5 in the 60 cm x 40 cm plant spacing, 34.9% in the 70 cm x 30 cm plant spacing and 63.1% in the 70cm x 40cm plant spacing (Table 7). Similar trend was observed in 2018 cropping season, where revenue generated decreased by 16.1% with plant spacing 60cm x 30cm, 31.7% (60 cm x40 cm), 30.5% (70 cm x 30 cm) and 63.1% (70 cm x 40 cm) respectively. The decrease in the revenue generated could be associated with the lower fresh pod yield produced by the various plants spacing in 2017 and 2018 cropping seasons.

3.6.2. Variable Cost of Production

The total variable cost of producing 1 ha of okra differed among the plant spacing of okra. The costs that vary based on the plant spacing were cost of okra seeds and labour for planting okra seeds in both 2017 and 2018 cropping seasons (Table 7). The least variable cost was incurred by the 70cm x 40cm plant spacing (Le 483,000.00) in 2017 and 2018 cropping seasons. In comparison to the recommended plant spacing (50 cm x 40 cm), the total variable cost for both year's cropping seasons increased by 10.3% in the 60 cm x 30 cm plant spacing and decreased by 17.2% in the 60 cm x 40 cm, 5% in the 70 cm x 30 cm plant spacing 29.7% in the 70 cm x 40 cm plant spacing respectively (Table 7). The increase in the variable cost in 60 cm x 30 cm in 2017 and 2018 cropping seasons was due to the high cost of seeds and labour for planting the seeds.

3.6.3. Gross Margin

The economic analysis revealed that the recommended plant spacing of okra (50 cm x 40 cm) produced the highest gross margin of Le 18,333,000.00 ha^{-1} in 2017 and Le 21,363,000 ha^{-1} in 2018 (Table 8). In comparison to the other plants spacing, the gross margin in 2017 cropping season decreased by 17.1% in the 60 cm x 30 cm, 32.1% in the 60 cm x 40 cm plant spacing, 36.0% in the 70 cm x 30 cm plant spacing and 64.3% in the 70 cm x 40 cm plant spacing (Table 8). While in 2018, the gross margin decreased by 16.9% in the 60cm x 30cm, 31.0% in the 60 cm x 40 cm plant spacing, 32.6% in the 70cm x 30cm plant spacing and 64.2% in the 70 cm x 40 cm plant spacing. Variation in gross margins due to plant spacing in okra has also been reported by the study [14]. The higher gross margin from the 50 cm x 40 cm plant spacing could be associated to the higher pod yield which contributed to higher revenue generated. Reducing the plant density to manage insect pest of okra is not a profitability venture, because it could lead to lower pod yield.

Table 7. *Partial budget analysis of okra production under different plant spacing during 2017 and 2018 main cropping seasons.*

Year	Items	Plant spacing (cm)				
		50 x40	60 x 30	60 x 40	70 x 30	70 x 40
2017	Revenue					
	Yield (t ha^{-1})	6.34	5.32	4.34	4.13	2.34
	Unit price	3,000	3,000	3,000	3,000	3,000
	Total revenue (Le ha^{-1})	19,020,000	15,960,000	13,020,000	12,390,000	7,020,000
	Variable costs					
	Quantity of seeds (kg ha^{-1})	13.8	15.3	11.5	13.1	9.8
	Unit cost of seeds (Le kg^{-1})	15,000	15,000	15,000	15,000	15,000
	Subtotal (Le ha^{-1})	207,000	229,500	172,500	196,500	147,000
	Labour for planting					
	Number of man-days ha^{-1}	40	44	33	38	28
	Unit cost (Le man-day^{-1})	12000	12000	12000	12000	12000
	Subtotal (Le ha^{-1})	480,000	528,000	396,000	456,000	336,000
	Total variable cost (Le ha^{-1})	687,000	757,500	568,500	652,500	483,000
	Gross margin (Le ha^{-1})	18,333,000	15,202,500	12,451,500	11,737,500	6,537,000
2018	Revenue					
	Yield (t ha^{-1})	7.35	6.17	5.11	5.02	2.71
	Unit price	3,000	3,000	3,000	3,000	3,000
	Total revenue (Le ha^{-1})	22,050,000	18,510,000	15,330,000	15,060,000	8,130,000
	Variable costs					
	Cost of okra seeds					
	Quantity (kg ha^{-1})	13.8	15.3	11.5	13.1	9.8
	Unit cost (Le kg^{-1})	15,000	15,000	15,000	15,000	15,000
	Subtotal (Le ha^{-1})	207,000	229,500	172,500	196,500	147,000
	Labour for planting					
	Number of man-days ha^{-1}	40	44	33	38	28
	Unit cost (Le man-day^{-1})	12000	12000	12000	12000	12000
	Subtotal (Le ha^{-1})	480,000	528,000	396,000	456,000	336,000
	Total variable cost (Le ha^{-1})	687,000	757,500	568,500	652,500	483,000
	Gross margin (Le ha^{-1})	21,363,000	17,752,500	14,761,500	14,407,500	7,647,000

4. Conclusion

The effect of insect pests' population on growth performance such as number of damaged leaves, plant height and leaf area of okra as influenced by plant spacing revealed that okra cropped in plant spacing 50 cm x 40 cm inclined the highest number of insects, damaged leaves, plant height, leaf area per plant at 4 and 8 WAP in 2017 and 2018 main cropping seasons. The influence of plant spacing on number of matured okra pods and pod weight $plant^{-1}$ revealed that okra cropped under plant spacing 70 cm x 40 cm inclined maximum pod number and weight $plant^{-1}$. On the contrary, highest pod yield ha^{-1} was recorded from plots treated with plant spacing 50 cm x 40 cm in both 2017 and 2018 cropping seasons. In general, the study revealed that 50 cm x 40 cm plant spacing could be regarded as the appropriate for optimum yield of okra. The profitability analysis revealed that the recommended plant spacing of okra (50 cm x 40 cm) produced the highest gross margin of Le 18,333,000.00 ha^{-1} and Le 21,363,000 ha^{-1} respectively during 2017 and 2018 main cropping seasons of okra production. It is recommended integrating plant spacing with other cultural methods of controlling insect pests of okra should be investigated in order to determine a sustainable and cost-effective method of controlling insect pests of okra.

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