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EFFECT OF CASSAVA-LEGUME INTERCROPPING SYSTEMS ON THE POPULATION DYNAMICS OF LEGUMES INSECT PESTS IN THREE MAJOR AGRO-CLIMATIC ZONES OF SIERRA LEONE

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ABSTRACT

Field trials were conducted in three agro-climatic zones of the country to evaluate the effect of cassava-legume-based intercropping systems on the population dynamics of legumes insect pests. The experiment consisted of a factorial treatment combination of seven cropping systems, two cassava architectures, and two spatial arrangements. The study reveals that a higher percentage incidence and severity scores of the legumes insect pests were recorded on the sole legumes compared to the intercropping systems. Also, intercropping the grain legumes using the erect cassava variety at a spatial arrangement of 1 m x 1 m recorded the lowest number of pests per plant, incidence and severity of legumes insect pests compared to the branched cassava architecture, and the 2 m x 0.5 m spatial arrangement. In conclusion, it was shown that, cassava-legume intercropping systems could significantly influence reduction in the number of pests per plant, incidence, and severity of legumes insect pests.

Contribution/Originality: This study contributes to the existing literature, as the results of the study agree with the findings of several authors that, intercropping generally influenced the reduction in the incidence and severity of legumes insect pests thus, resulting in an increased in productivity.

1. INTRODUCTION

Cassava, *Manihot esculenta* Grantz (Euphorbiaceae) is an important food security crop for over 800 million people in the World [1]. In Sierra Leone, it is the second most important food crop after rice and such; it has become a strategic commodity for the country's food economy. The production of this crop has now expanded beyond the normal traditional rural production zones into towns and cities of the country. According to Alves, et al. [2], cassava is normally cultivated by small-scale farmers in several forms of cropping associations.

Grain legumes such as cowpea, groundnut, and soybean play an important role in cropping systems, as they contribute to the maintenance of soil fertility by fixing nitrogen into the soil which can be useful to subsequent crops. They are also a major source of protein in human food and animal feed and play an important role in contributing to food security and income generation for many small-scale farmers in sub-Saharan Africa [3].

In general, insect pests are one of the most important constraints that limit the production of grain legumes [4] in addition to declining soil fertility, nutrient deficiency, and other environmental constraints. The management of insect pests using insecticides as a stand-alone tactic has led to serious consequences such as environmental contamination, effect on natural enemies, insect pests, and disease resistance [5]. Due to the problems associated with the use of insecticide as the sole tactic in pest management, there is a need to adopt intercropping as an alternative strategy in the management of these pests.

Intercropping is defined as the cultivation of two or more crop species in the same field for the whole or part of their growing period [6]. It is an ancient agronomic practice and was used worldwide. According to Gurr, et al. [7], this practice in most cases stimulates the presence and effectiveness of natural enemies which enhance pest suppression, thus, potentially reducing the need for costly and ecologically disruptive insecticide application. Even though intercropping does not always lead to insect pest reduction, however, most authors have reported a decrease in insect pest population in intercropping systems Fujita, et al. [8]. In general, strategies involved in reducing pest infestation and damage in intercropping systems include delimiter crop hypothesis, trap crop hypothesis, and natural enemy hypothesis [9].

Spatial arrangements and plant densities of component species generally enhance complementarities and reduce interspecies competition to maximize agronomic and physiological advantages [10] and the spread of insect pests and diseases. It is one important management factor that could determine the sustainability of an intercropping system. Thus, spatial separation of plants can reduce or delay inter-plant contact and thus reduce or delay the spread of insect pests or diseases.

Studies carried out by Ogola, et al. [11] have shown that, intercropping grain legumes with cassava could improve the overall productivity of the system. In addition to increasing productivity, this system in most cases results in a decrease in insect pests, weeds, and disease severity [12] due to increase in biodiversity, alteration of the microclimatic conditions of neighboring plants, and also altering the host plant quality [13]. According to Gabriele [14], considerable evidence has emerged over the past twenty years to suggest that pest problems are much greater in sole cropping systems than in intercropping systems as one of the component crops may serve as a physical barrier resulting in the reduction in the spread of the pests. Furthermore, intercropping enhances the abundance of predators and parasites of insect pests and diseases as the modified environment can delay the spread of pathogens and the introduction of diseases [15].

The objective of this research, therefore, was to investigate the influence of cassava-legume-based cropping systems on the population dynamics of legumes insect pests in three major agro-climatic zones of the country.

2. MATERIALS AND METHODS

2.1. Study Areas

The study was conducted between 2015-2017 under rain-fed conditions in three Agro-climatic zones namely, Sumbuya (N 08.04088^0, W 011.478955^0) in Bo district representing the transitional rain forest, Makeni (N 08.8720^0, W 012.0376^0) in Bombali district representing the savannah woodland and Segbwema (N 07.9930^0, W 010.95224^0) in Kailahun district representing the forest region of the country (Figure 1).

2.2. Land Preparation

For the two years of the research work, land preparation was done manually using cutlass and hoe and the plots were laid out using a measuring tape, garden line, and pegs.

2.3. Planting Material

The cassava varieties used were slicass 6 which is the erect type and slicass 1, which is the branched type. The cowpea, soybean, and groundnut varieties used were IITA573k-1-1, Slibean 2, and Slinut 1 respectively. These planting materials were obtained from Njala Agricultural Research Center.

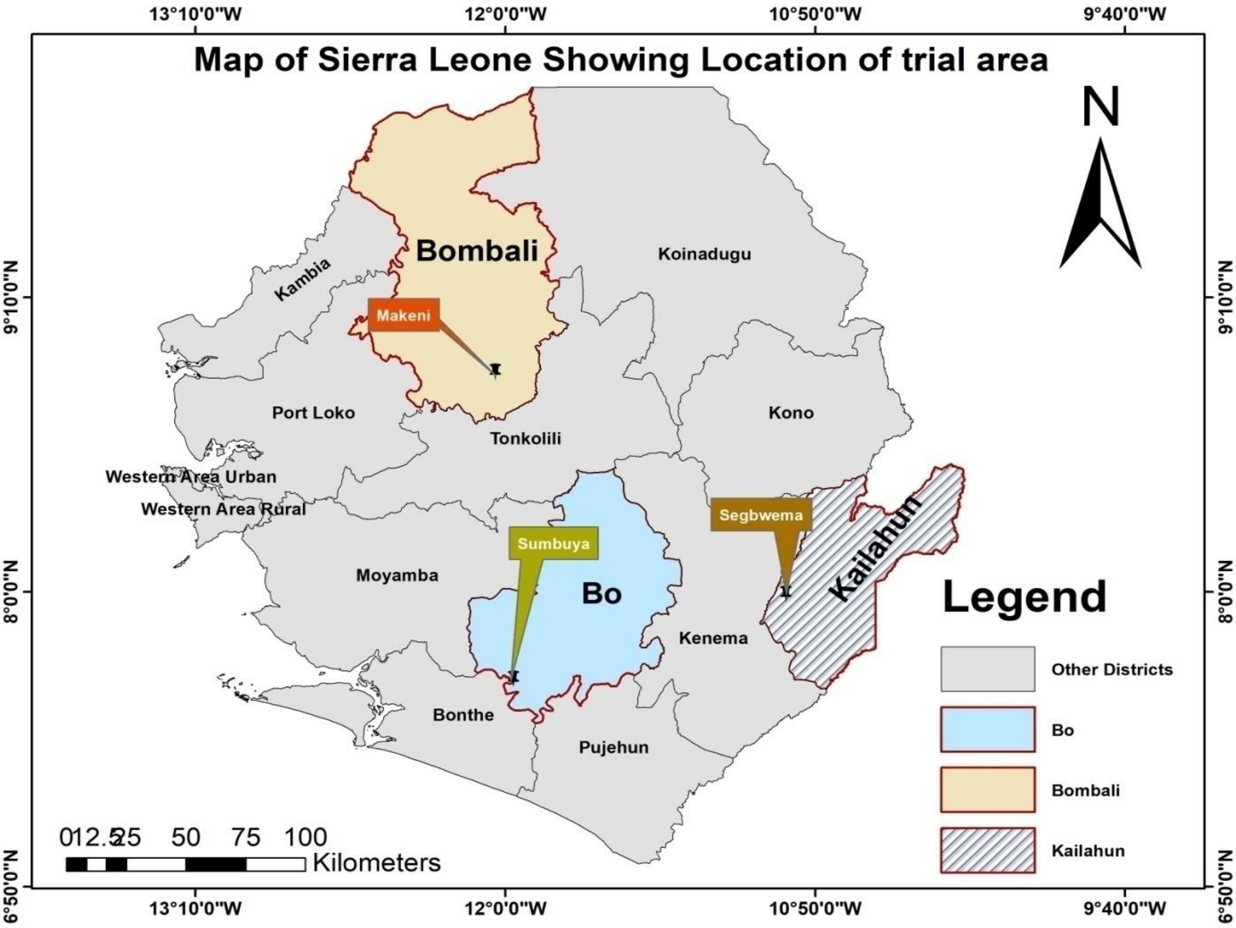

Figure 1. Map of Sierra Leone showing trial sites of the different agro-climatic zones in Sierra Leone.

2.4. Planting and Spacing

The cassava and the three legumes were planted on a flat land in June of each year. Stem cuttings of about 25 cm long with five nodes of each cassava variety were used. Cassava was planted at the spacing of 1 m x 1 m and 2 m x 0.5 m respectively; whilst cowpea and groundnut were planted at the spacing of 50 cm x 20 cm with two seeds per hole for cowpea and one seed per hole for groundnut. On the other hand, soybean was planted at the spacing of 50 cm x 10 cm with two seeds per hole. The legumes were introduced in between the rows of the cassava.

2.5. Experimental Design and Treatments

The experiment was laid out in a randomized complete block design with 28 treatments replicated three times. This gave a total of 84 plots. Each plot measured 6 m x 7 m with a space of 1 m between each plot. The treatments consisted of seven cropping associations (sole cassava, sole groundnut, sole cowpea, sole soybean, cassava + cowpea, cassava + groundnut, and cassava + soybean), two cassava architectures (branched and erect), and two spatial arrangements (1 m x 1 m and 2 m x 0.5 m).

2.6. Data Collection

For cowpea, the following insect pests were assessed: number of thrips (*Megalurothrips sjostedti*) per flower, number of legume pod borer (*Maruca vitrata*) per flower, and percentage incidence and severity of foliage beetle (*Ootheca mutabilis)*.

The number of thrips and legume pod borers were determined using the method of Asante, et al. [16]. Twenty flowers were collected from the border row of each plot in the morning and were placed in vials containing 30% ethanol and brought to the laboratory to determine the number of flower thrips and legume pod borers (*Maruca* *vitrata).* The flowers were dissected and the legume pod borer larvae and thrip nymphs and adults were identified and counted. Insects were counted twice at 10 days intervals, usually between 9 am and 12 noon.

The severity of the foliage leaf beetle was assessed using the visual rating scale of 0-5 (where; 0 = no of plants with signs of damage/symptoms, 1 = 1-5% of plants with signs of damage/symptoms, 2 = 6-25% of plants with signs of damage/symptoms, 3 = 26-50% of plants with signs of damage/symptoms, 4 = 56-75% of plants with signs of damage/symptoms, and 5 = 76-100% of plants with signs of damage/symptoms) [17].

For groundnut, the following insect pests were assessed: incidence and severity of groundnut flower thrips and groundnut leaf miner.Percentage incidence of groundnut flower thrips was recorded on 10 plants at 30, 40, 50, 60 and 70 days after planting. The percentage of damaged leaves was recorded based on the percentage of leaves showing visible scars on the main stems of 10 plants in each plot. In each leaf, a single leaflet or more with a petiole having scars of thrips feeding was considered damaged. Thrips damage ratings of 1-9 were subjected to 10 individual plants in each plot, with 1 = 0-10% damage 3 = 11-30% damage, 5 = 31-50% damage, 7 = 51-70% damage and 9 = 71-100% damage [18].

Assessment for groundnut leaf miner (*Aproaerema modicella*) commences from 40 days after planting and continued at an interval of 14 days for four consecutive times [19] since according to Namara [20], groundnut leaf miner peak infestation could occur during the reproductive stage. The groundnut leaf miner incidence which is expressed as percentage leaf damage was obtained by counting the total number of leaves showing folding and mining symptoms from 10 randomly selected plants per plot [21]. Severity of damage caused by groundnut leaf miner was recorded using a scale of 1-5; where 1 = no damage, 2 = 1-20% leaf damage, 3 = 21-40% leaf damage, 4 = 41-60% leaf damage and 5 = 61-100% leaf damage [22].

For soybean, only the foliage beetle (*Ootheca mutabilis)* was recorded as a pest and was assessed using the same rating scale as on cowpea.

2.7. Data Analysis

All data collected were subjected to analysis of variance (ANOVA) using the SAS statistical package [23] and means were compared using the Student Newman-Keuls Test (SNK) at a 0.05 level of significance. Data for insect counts were square root transformed [24] before analysis.

3. RESULTS

3.1. Cowpea Insect Pests

The number of pod borers per flower was significantly different ($P < 0.05$) with respect to the cropping system; however, the number of pod borers per flower was only significant concerning spatial arrangement and plant architecture of cassava at Sumbuya representing the transitional rain forest zone (Table 1).

For the cropping system, the number of pod borers per flower for the sole cowpea was consistently higher compared to the cassava-cowpea intercrop at the three agro-climatic zones. The number of pod borers per flower was 87%, 82%, and 20% higher in the sole cowpea plots than in the intercropped plots for the agro-climatic zones in Makeni, Segbwema, and Sumbuya respectively. Furthermore, the number of pod borers per flower was significantly ($P < 0.05$) higher in Makeni in the savannah woodland (1.63) compared to Sumbuya in the transitional rain forest (1.10) and Segbwema in the forest zone (0.56). In general, the number of pod borers per flower was low concerning the agro-climatic zones and cropping systems (Table 1).

For the spatial arrangement of cassava, the number of pod borers per flower when cassava was intercropped with cowpea using the 2 m x 0.5 m spatial arrangement was significantly ($P < 0.05$) higher compared to the 1 m x 1 m spatial arrangement. In addition, significant differences were also obtained relating to the agro-climatic zones with Sumbuya in the transitional rain forest (0.94) recording the highest number of legume pod borers per flower followed by Makeni in the savannah woodland (0.37) whilst Segbwema in the forest zone registered the least (0.16)

(Table 1). Concerning plant architecture, intercropping cowpea with the branched cassava architecture was observed to have recorded a slightly higher number of pod borers per flower compared to the erect type (Table 1). Furthermore, the three-way interactions among cropping systems x spatial arrangement x plant architecture with respect to the number of pod borers per flower across the agro-climatic zones were not significant (P > 0.05).

The number of thrips per flower with respect to the cropping system was significantly different (P < 0.05) for the agro-climatic zones in Segbwema and Sumbuya but was not significantly different (P > 0.05) in Makeni (Table 1). The number of thrips per flower was generally low at the three agro-climatic zones with the sole cowpea recording higher values compared to the cassava-cowpea intercrop. The number of thrips per flower recorded by the sole cowpea was 23%, 53%, and 56% higher compared to the cassava-cowpea intercropping system in Makeni in the savannah woodland zone, Sumbuya in the transitional rain forest zone, and Segbwema in the forest zone respectively (Table 1). Agro-climatic zonal differences in the number of thrips were also observed in which Segbwema representing the forest zone (2.52) was observed to have recorded the highest number of thrips per flower compared to Makeni representing the savannah woodland zone (2.09) whilst, Sumbuya representing the transitional rain forest (1.30) recorded the least (Table 1).

In the case for spatial arrangement and architecture of cassava, the number of thrips per flower was only significant for the agro-climatic zone in Segbwema in which the highest number of thrips per flower was recorded when cowpea was intercropped with cowpea using the 2 m x 0.5 m spatial arrangement for cassava. In addition, the highest number of thrips per flower was recorded when cowpea was intercropped using the branched cassava variety.

Also, the three-way interactions among cropping systems x spatial arrangement x plant architecture with respect to the number of thrips per flower in all the zones were not significant (P > 0.05).

Relating to the foliage beetle, percentage incidence was not significantly different (P > 0.05) across cropping system, spatial arrangement, and plant architecture. Incidences across the three agro-climatic zones were high. In addition, on average, higher values of foliage beetle incidences were recorded in Makeni in the savannah woodland followed by Segbwema in the rain forest zone and Sumbuya in the transitional rain forest zone (Table 1).

Concerning foliage beetle severity score, significant differences were recorded with respect to the cropping system for the agro-climatic zones in Makeni and Sumbuya with the sole cowpea recording significantly (P < 0.05) higher values in the two agro-climatic zones compared to the intercrop (Table 1). The foliage beetle severity score was 13% and 19% higher in the sole cowpea system compared to the cassava-cowpea intercropping system in Makeni representing the savannah woodland and Sumbuya representing the transitional rain forest respectively. In general, the foliage beetle severity score with respect to the cropping system, spatial arrangement, and plant architecture was moderately high across the three zones. Furthermore, on average, the foliage beetle severity scores were higher for the agro-climatic zones in Makeni followed by Segbwema whilst Sumbuya recorded the least (Table 1).

Table 1. Effect of cropping systems (CS), spatial arrangement of cassava (SA), and plant architecture of cassava (PA) on cowpea insect pests with respect to Agro-climatic zone over a two year cropping season.

Agro-climatic zones												
	Savannah woodland (Makeni)				**Rain forest (Segbwema)**				**Transitional rain forest (Sumbuya)**			
Parameter	**Cowpea insect pests**				**Cowpea insect pests**				**Cowpea insect pests**			
	No. of maruca per flower	**No. of thrips per flower**	**Foliage beetle incidence (%)**	**Foliage beetle severity**	**No. of maruca per flower**	**No. of thrips per flower**	**Foliage beetle incidence (%)**	**Foliage beetle severity**	**No. of maruca per flower**	**No. of thrips per flower**	**Foliage beetle incidence (%)**	**Foliage beetle severity**
Cropping system												
Sole cowpea	2.88 a	2.36a	100.00a	3.32a	0.95a	3.42a	100.00a	2.69 a	1.22 a	1.80 a	100.00a	2.74 a
Cassava-Cowpea	0.37b	1.82a	99.44a	2.90b	0.17b	1.62 b	99.17 a	2.49 a	0.97b	0.79b	97.34 a	2.22 b
Mean	1.63 a	2.09 b	99.72 a	3.11 a	0.56 c	2.52 a	99.59 a	2.59 b	1.10 b	1.30 c	98.67 a	2.48 b
Spatial arrangement												
1 m x 1 m	0.33a	1.44a	98.75 a	2.89a	0.16a	1.32 b	99.44 a	2.48 a	0.52 b	1.75 a	96.11a	2.16a
2 m x 0.5 m	0.41 a	1.88a	100.00a	2.92a	0.16 a	1.92a	98.89 a	2.49 a	1.35a	1.84a	98.75 a	2.29 a
Mean	0.37 b	1.66 a	99.38 a	2.91 a	0.16 c	1.62 a	99.17 a	2.49 b	0.94 a	1.80 a	97.43 a	2.23 b
Plant architecture												
Erect	0.37	1.77	98.75a	2.90a	0.21a	1.20a	98.83a	2.50 a	0.40b	1.73a	97.14a	2.28 a
Branch	0.39	1.84	100.00a	2.89a	0.19 a	1.88 a	99.55a	2.47 a	1.36 a	1.90 a	97.50a	2.14 a
Mean	0.38 b	1.81 a	99.38 a	2.90 a	0.20 b	1.54 a	99.19 a	2.49 a	0.88 a	1.82 a	97.32 a	2.21 a

Note: Means in column with the same letter are not significantly different at P>0.05 (SNK).
Severity score of cowpea leaf beetle: 1 = 0-20% of foliage consumed, 2 = 21 – 40% of foliage consumed, 3 = 41 – 60% of foliage consumed, 4 = 61 – 80% of foliage consumed and 5 = 81- 100% of foliage.
"a and b" indicates that the means are significantly different at P<0.05

3.2. Groundnut Insect Pests

Groundnut leaf miner incidence was not significantly different (P > 0.05) with respect to the cropping system and cassava plant architecture at Makeni representing the savannah woodland; however, it was significantly different (P < 0.05) concerning the spatial arrangement of cassava. A higher groundnut leaf miner incidence was recorded when groundnut was intercropped using the 2 m x 0.5 m spatial arrangement (37.80%) of cassava relative to the 1 m x 1 m spatial arrangement (31.88%).

Conversely, significant differences (P < 0.05) were recorded in groundnut leaf miner incidence at Segbwema representing the forest zone with respect to the cropping system, spatial arrangement and plant architecture (Table 2). For the cropping system at Segbwema in the forest zone, the sole groundnut (34.00%) was observed to have recorded the highest incidence of groundnut leaf miner compared to the cassava-groundnut system (19.65%). The percentage incidence of leaf miner on the sole groundnut was 73% higher at Segbwema representing the forest zone compared to the cassava-groundnut system.

In the case of the spatial arrangement of cassava, the 2 m x 0.5 m spatial arrangement (27.25%) of cassava recorded significantly higher incidence of leaf miner compared to when groundnut was intercropped using the 1 m x 1 m spatial arrangement (12.89%). Furthermore, intercropping groundnut with the branched cassava variety (24.50%) registered a higher incidence of leaf miner compared to the erect variety (12.71%).

In Sumbuya, the percentage groundnut leaf miner incidence varies significantly (P < 0.05) with respect to the spatial arrangement and architecture of cassava (Table 2). There was no significant difference in leaf miner incidence concerning the cropping system. Intercropping groundnut using the branch cassava architecture at the spatial arrangement of 2 m x 0.5 m recorded the highest leaf miner incidence compared to using the erect cassava variety at the 1 m x 1 m spatial arrangement (Table 2). In addition, the mean leaf miner incidence across the agro- climatic zones with respect to the cropping system, spatial arrangement and plant architecture was different with Makeni in the savannah woodland zone (34.48%) recording the highest followed by Segbwema in the forest zone (21.83%) whilst Sumbuya in the transitional forest zone recorded the least (6.21%). Also, the three-way interactions among cropping system x spatial arrangement x plant architecture with respect to the leaf miner incidence were not significant (P > 0.05).

Concerning the severity of the groundnut leaf miner, significant differences were recorded only at Segbwema representing the rain forest zone with respect to cropping system (Table 3). At Segbwema in the rain forest, the sole groundnut recorded significantly (P < 0.05) a higher severity score compared to the cassava-groundnut system. Similarly, for the spatial arrangement and architecture of cassava, significant differences in leaf miner incidences were recorded only for the agro-climatic zone in Segbwema representing the rain forest zone (Table 3). For both spatial arrangement and plant architecture of cassava, higher leaf miner severity scores were registered when groundnut was intercropped with the branched cassava variety at the spatial arrangement of 2 m x 0.5 m than using the erect cassava variety at the spatial arrangement of 1 m x1 m (Table 3).

Pertaining to the groundnut flower thrips, percentage incidence was significantly different (P < 0.05) at Makeni representing the savannah woodland with respect to the cropping system; but was not significantly different (P > 0.05) concerning architecture and spatial arrangement of cassava (Table 2). The groundnut flower thrips incidence for the sole groundnut system was 27% higher compared to the cassava-groundnut intercropping system.

At Segbwema representing the forest zone, the mean percentage incidence of groundnut flower thrips was significantly different (P < 0.05) with respect to cropping system and plant architecture; however, significant differences (P > 0.05) were not recorded with respect to the spatial arrangement of cassava (Table 2). In the case of the cropping system, the sole groundnut (47.67%) was observed to have attracted a higher incidence of flower thrips compared to the cassava-groundnut intercrop (17.24%). The groundnut flower thrips incidence was 64% higher in the sole groundnut compared to the cassava-groundnut intercropping system. For plant architecture, intercropping groundnut with the branched cassava variety attracted higher incidence (20.50%) of the groundnut flower thrips compared to the erect type (12.57%). The population of groundnut flower thrips was 39% higher for the branch cassava architecture compared to the erect type.

Similarly, for Sumbuya representing the transitional rain forest zone, significant differences in the mean groundnut thrips incidence were observed with respect to cropping system and plant architecture. The groundnut flower thrips incidences were 53% and 55% higher for the sole groundnut and the branched cassava architecture respectively compare to the cassava-groundnut system and the erect cassava architecture.

In general, agro-climatic zonal differences in the flower thrips incidence was also observed with makeni representing the savannah woodland (38.47%) registering significantly ($P < 0.05$) a higher incidence followed by Sumbuya representing the transitional rain forest (24.65%) whilst Segbwema representing the rain forest registered the least (22.06). Furthermore, the three-way interactions among cropping system x spatial arrangement x plant architecture with respect to the groundnut flower thrips incidence were not significant ($P > 0.05$).

Relating to the severity of the groundnut flower thrips, significant differences were recorded for the agro-climatic zones in Segbwema and Sumbuya with respect to the cropping system. There were however no significant differences in flower thrips severity concerning spatial arrangement and architecture of cassava (Table 3).

In both Segbwema, and Sumbuya, the severity scores for the groundnut flower thrips were 40% higher in the sole plots compared to the cassava-groundnut system. Furthermore, the mean severity score for the groundnut flower thrips across the cropping system, spatial arrangement, and plant architecture was also observed to vary significantly with Makeni in the savannah woodland (5.00) recording the highest followed by Segbwema in the forest zone (3.30) and Sumbuya in the transitional rain forest zone (3.30) (Table 3). In addition, the three-way interactions among cropping system x spatial arrangement x plant architecture with respect to severity of groundnut flower thrips were not significant ($P > 0.05$).

3.3. Soybean Insect Pest

Foliage beetle incidence at Makeni representing the savannah woodland was significantly different ($P < 0.05$) with respect to cropping system; but was not significantly different ($P > 0.05$) concerning spatial arrangement and architecture of cassava (Table 4). The sole soybean system recorded the highest incidence (83.99%) of the foliage beetle compared to the cassava-soybean system. In general, the percentage incidence of the foliage beetle across cropping system, spatial arrangement and plant architecture range from moderate (49.42%) to high (83.99%).

For the agro-climatic zone in Segbwema, significant differences in foliage beetle incidences were not recorded with respect to the cropping system, spatial arrangement, and plant architecture. Percentage incidences were generally very high ranging from 94.17%-100%.

In Sumbuya representing the transitional rain forest zone, significant differences in leaf beetle incidence were recorded only with respect to plant architecture with the branch cassava architecture recording the highest incidence (94.58 %) compared to the erect type (80.65 %) (Table 4).

Table 2. Effect of cropping systems (CS), spatial arrangement of cassava (SA), and plant architecture of cassava (PA) on the incidence of groundnut insect pests with respect to agro-climatic zone over a two year cropping season.

Agro-climatic zones						
	Savannah woodland (Makeni)		Rain forest (Segbwema)		Transitional rain forest (Sumbuya)	
Parameter	**Groundnut insect pests**		**Groundnut insect pests**			**Groundnut insect pests**
	Leaf miner incidence (%)	**Groundnut flower thrips incidence (%)**	**Leaf miner incidence (%)**	**Groundnut flower thrips incidence (%)**	**Leaf miner incidence (%)**	**Groundnut flower thrips incidence (%)**
Cropping system						
Sole- groundnut	34.58a	49.84a	34.00a	47.67a	6.21a	44.00 a
Cassava-groundnut	34.15a	36.16b	19.65b	17.24b	6.21a	20.59 b
Mean	34.37a	43.00a	26.83ab	32.46b	6.21b	32.30 b
Spatial arrangement 1 m x 1 m	31.88b	35.79a	12.89b	16.13a	1.33b	20.63 a
2 m x 0.5 m	37.80a	36.24a	27.25a	18.22a	12.87a	20.56 a
Mean	34.84a	36.02a	20.07b	17.18b	7.10c	20.60 b
Plant architecture						
Erect	33.07a	33.29a	12.71b	12.57b	2.52a	13.00 b
Branch	35.42a	39.50a	24.50a	20.50a	10.44b	29.13 a
Mean	34.25a	36.40a	18.61b	16.54b	6.53c	21.07 b

Note: Means in column with the same letter are not significantly different at P>0.05 (SNK).
"a and b" indicates that the means are significantly different at P<0.05

Table 3. Effect of cropping systems (CS), spatial arrangement of cassava (SA), and plant architecture of cassava (PA) on the severity of groundnut insect pests with respect to agro-climatic zone over a two year cropping season.

Agro-climatic zone						
	Savannah woodland (Makeni)		**Rain forest (Segbwema)**			**Transitional rain forest (Sumbuya)**
Parameter	**Groundnut insect pests**		**Groundnut insect pests**			**Groundnut insect pests**
	Leaf miner Severity	**Groundnut flower thrips severity**	**Leaf miner severity**	**Groundnut flower thrips severity**	**Leaf miner incidence (%)**	**Groundnut flower thrips severity**
Cropping system						
Sole- groundnut	3.00 a	5.00 a	3.00 a	5.00 a	2.00 a	5.00 a
Cassava-groundnut	3.00 a	5.00 a	2.00 b	3.00 b	2.00 a	3.00 b
Mean	3.00 a	5.00 a	2.50 a	4.00 b	2.00 b	4.00 b
Spatial arrangement 1 m x 1 m	3.00 a	5.00 a	2.00 b	3.00 a	2.00 a	3.00 a
2 m x 0.5 m	3.00 a	5.00 a	3.00 a	3.00 a	2.00 a	3.00 a
Mean	3.00	5.00	2.50	3.00	2.00	3.00
Plant architecture						
Erect	3.00 a	5.00 a	2.00 b	3.00 a	2.00 a	3.00 a
Branch	3.00 a	5.00 a	3.00 a	3.00 a	2.00 a	3.00 a
Mean	3.00	5.00	2.50	3.00	2.00	3.00

Note: Means in column with the same letter are not significantly different at P>0.05 (SNK).
Severity of damage score of groundnut leaf miner: 1 = no damage, 2 = 1-20% leaf damage, 3 =21-40% leaf damage, 4 = 41-60% leaf damage and 5= 61-100% leaf damage [22].
Severity damage score of groundnut flower thrip:1-10% = no damage to damage , 3 = 11-30% damage, 5 = 31-50% damage, 7 = 51-70% damage and 9= 71-100% damage [25].
"a and b" indicates that the means are significantly different at P<0.05

Table 4. Effect of cropping systems (CS), spatial arrangement of cassava (SA), and plant architecture of cassava (PA) on soybean insect pest with respect to agro-climatic zone over a two year cropping season.

Parameter	Agro-climatic zones					
	Makeni		Segbwema		Sumbuya	
	Soybean insect pests		Soybean insect pests		Soybean insect pests	
	Foliage beetle incidence (%)	Foliage beetle severity	Foliage beetle incidence (%)	Foliage beetle severity	Foliage beetle incidence (%)	Foliage beetle severity
Cropping system						
Sole- soybean	83.99 a	3.10a	100.00a	2.63a	85.98a	2.21a
Cassava-soybean	51.15 b	1.90b	94.17a	2.46a	84.31a	2.14a
Mean	67.57 c	2.50a	97.09a	2.55a	85.15b	2.18 b
Spatial arrangement 1 m x 1 m	52.07 a	1.94a	100.00a	2.53a	86.11a	2.34a
2 m x 0.5 m	51.96 a	1.87a	100.00a	2.39 a	85.57a	2.12a
Mean	52.05 c	1.91b	100.00a	2.46 a	85.84b	2.23 a
Plant architecture						
Erect	52.64 a	1.95 a	100.00a	2.60 a	80.65b	2.23 a
Branch	49.42 a	1.89 a	100.00a	2.34 a	94.58a	2.15 a
Mean	51.03 c	1.92 b	100.00a	2.47 a	87.62b	2.19 a

Note: Means in column with the same letter are not significantly different at $P>0.05$ (SNK).
Severity score of foliage beetle 1 = 0-20% of foliage consumed, 2 = 21 – 40% of foliage consumed, 3 = 41 – 60% of foliage consumed, 4 = 61 – 80% of foliage consumed and 5 = 81- 100% of foliage.
"a and b" indicates that the means are significantly different at $P<0.05$

Concerning the severity score, significant differences were not observed across cropping system, spatial arrangement, and plant architecture for the agro-climatic zones in Segbwema and Sumbuya. However, significant differences ($P < 0.05$) were observed in the severity of the foliage beetle concerning the cropping system at Makeni representing the savannah woodland where in the sole-soybean (3.10) system registered higher severity score compared to the cassava-soybean system (1.90) (Table 4).

4. DISCUSSION

Significantly lower insect pest populations were recorded when legumes were intercropped with cassava compared to the sole legumes. This result conforms to the findings of Olufemi and Odebiyi [26] for the cowpea-maize intercropping system. Schulthess, et al. [27] also reported a significantly low level of infestation by insect pests when maize was intercropped with cassava. In addition, Epidi, et al. [28] also reported low pest incidence when rice was intercropped with groundnut. Furthermore, Kennedy and Raveendran [29] reported reduced incidence and severity of leaf miner, leafhopper, and thrips, when groundnut was intercropped with peral millet. In addition, Legese and Gobeze [30] reported a 12% decrease in the incidence of pests and diseases and an 8% increase in production when bean was intercropped with cassava. Furthermore, Up to 30% crop pest reduction was reported by Baliddawa [31] due to the effect of natural enemies in intercropping systems. Also, work done by Risch, et al. [32] and Theis and Tscharntke [33] reported lower crop pest densities in intercropping systems compared to monoculture.

Several research findings have reported a considerable reduction in insect pest population in intercropping systems compared to sole cropping [9]. Also, a review by Andow [34] involving 209 studies of intercropping systems shows that, insect pest incidences were 52% lower in intercropping systems compared to monocultures.

Various reasons have been adduced for the decrease in pest populations under different intercropping systems. One such reasons for the decrease of pest populations in intercropping systems could be attributed to the disruption of the insect's visual and olfactory responses [35, 36] because of the introduction of a second crop into the cropping system. Research conducted by Root [37] and Andow [34] have shown that insect pests are more likely to find and spend more time in monocultures compare to polycultures. Furthermore, Vandermeer [9] opined that, the presence of a second host crop may disrupt the host selection behavior of insect pests. Another possible reason is that intercropping contributes to the diversity of the agro-ecosystem, which results in the modification of the habitat, which can influence the population build-up of insect pests [38]. Also, Jankowska [39] reported that diverse agro-ecosystem created by multiple cropping tends to increase the number of natural enemies. Herrera [40] also showed that intercropping systems could increase the level of insect diversity which helps in stabilizing the buildup of pests of certain crops. For example, Dhaliwal and Arora [41] reported an increased in population of *Gonizous* sp., a parasitoid that effectively controls the population of groundnut leaf miner when groundnut was intercropped with pearl millet. Also, work done by Chabi-Olaye, et al. [42] reported a drastic reduction in the number of eggs produced by *Sesamia calamistis* and *Busseola fusca* as a result of the difficulty in locating the host by the ovipositing adult moths when maize was intercropped with grain legumes or cassava. Furthermore, Perfect, et al. [43] in Nigeria and Karel, et al. [44] in Tanzania reported a considerable reduction in populations of *Empoasca olichi*, and *Ootheca mutabilis* when cowpea was intercropped with maize. Also, Nigussie and M. S. Reddy [45] reported a significantly higher incidence of stem borers and earworms in sole maize compared to the maize-bean intercropping in Ethiopia.

With respect to spatial arrangement and architecture of cassava, significant differences were not recorded in the number of insect pests and the incidences and severity of the assessed insect pest of the grain legumes. However, slightly higher incidences and severity scores were recorded with respect to the 2 m x 0.5 m spatial arrangement of cassava than the 1 m x 1 m spatial arrangement. The possible reason for this could be the high population density of legumes in the 2 m x 0.5 m spatial arrangement compared to the 1 m x1 m arrangement. This shows that the more the plants are clustered together, the more the spread and establishment of the pest. The above observation conforms to the findings of [46].

For plant architecture, the high humidity created by the broad canopy of the branch cassava variety may have provided a conducive environment for the development of the assessed pests.

5. CONCLUSIONS

The study has revealed that intercropping cassava with grain legumes decreased the number of pests per flower, percentage incidence, and severity of legume insect pests compared to the sole legumes. Also, the number of pests per flower, percentage incidence, and severity of legumes pests were on average lower when the legumes were intercropped with the erect cassava variety using the 1 m x 1m spatial arrangement of cassava. Furthermore, with the exception of the number of cowpea flower thrips per flower that was higher in Segbwema representing the forest zone, the number of insect pests per flower and the percentage incidences of the remaining legumes insect pests were all higher in Makeni representing the savannah woodland.

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