World Journal of Agricultural Research, 2023, Vol. 11, No. 1, 1-7
Available online at http://pubs.sciepub.com/wjar/11/1/1
Published by Science and Education Publishing
DOI:10.12691/wjar-11-1-1

Demography and Feeding Damage of Two Pest Insects on Tolerant and Susceptible Genotypes of the Bottle Gourd *Lagenaria siceraria* (Molina) Standley (Cucurbitaceae)

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Received January 02, 2023; Revised February 05, 2023; Accepted February 15, 2023

Abstract The demographical traits and damage from two pest insects (*Asbecesta cyanipennis* and *Lamprocopa occidentalis*) feeding on the bottle gourd (*Lagenaria siceraria*) were assessed on farm in Manfla (Center Ivory Coast). Two accessions (tolerant and susceptible) were observed in monoculture and in intercropping, during the first cropping season of 2018. The insect main development stages, the extent of plant organ attacks, and yield components of the cucurbit were assessed. Results indicated that *L. occidentalis* accomplishes its life cycle on bottle gourd, suggesting that the insect satisfies both its reproductive and food needs on this plant. *A. cyanipennis* whose eggs and larvae have not been observed on bottle gourd, appeared as an opportunistic herbivorous on this plant. Both insects feed on all parts of the bottle gourd (leaf, flower, and fruit), with up to 50% damaged leaves, depending on accession type, plant growth stage, and cropping system. Foliar damage caused by the studied insects was greater on the susceptible accession, particularly at the tendril stage and in monoculture. The control of *L. occidentalis* is thus a challenge for sustainable protection of bottle gourd against pest insects. To address this challenge, intercropping could give satisfactory results in terms of leaf damage reduction and yield gain.

Keywords: *Asbecesta cyanipennis, bottle gourd, feeding damage, live cycle, Lagenaria siceraria, Lamprocopa occidentalis, yield loss*

Cite This Article: Bi Nady Delphin Fouha, and Bi Irié Arsène Zoro, "Demography and Feeding Damage of Two Pest Insects on Tolerant and Susceptible Genotypes of the Bottle Gourd *Lagenaria siceraria* (Molina) Standley (Cucurbitaceae)." *World Journal of Agricultural Research*, vol. 11, no. 1 (2023): 1-7. doi: 10.12691/wjar-11-1-1.

1. Introduction

Food security in Sub-Saharan countries depends on the development and promotion of local food crops. In West Africa, oilseed cucurbits are among the most indigenous locally utilized plants, commonly called minor crops. The agronomical, food, pharmacological and economic importance of these crops demonstrate their interest for rural people [1-5]. However, the development of their cropping systems is still constrained by several production factors, among which phytosanitary problems are challenges in terms of yield losses. Pest insects are among the most damaging enemies of cultivated cucurbits [6-9]. They attack all parts of the plant [10] and can also transmit viruses, induce the attack of plants by other harmful organisms, often resulting in significant yield losses.

From the cucurbit species occurring in Africa, *Lagenaria siceraria* (Molina) Standley, commonly called bottle gourd, is one of the most important in terms of food and pharmaceutical values. Indeed, this species has a good yield potential, because it produces large fruits containing several seeds [11], compared to the other minor cucurbit landraces. In addition, according to Loukou *et al*. [2] the kernels of this species have high contents of lipids (56.67% ± 4.90) and proteins (29.83% ± 1.74). Increasing number of studies highlight the effectiveness of extracts from *L. siceraria* in the treatment of several human diseases [3,4,12].

It is therefore important to develop bottle gourd pest insects effective control strategies at reasonable costs to prevent yield losses, while considering the interests of farmers and the environment [13,14]. To develop an effective pest control strategy, a comprehensible study aimed at their biology, ecology, damage, and various interactions with host plants is a prerequisite [15,16,17]. Studies carried out in Ivory Coast [18,19] identified two major pest insects of bottle gourd: *Asbecesta cyanipennis* (Weise) and *Lamprocopa occidentalis* (Harold). However, the biology, ecology, and population dynamics of these insects on *L. siceraria* in their natural area are insufficiently known. For example, it is not known if these insects are strictly dependent on the bottle gourd, or they attack the plant by opportunistic herbivory. The response to such a question is useful to implement sustainable strategy to control these insects. The present study on the demography and feeding damages of the two insects was conducted as a part of a research program aimed at optimising a pest insects management technique to increase the yield of *L. siceraria*.

2. Materials and Methods

2.1. Study Site

The experiment took place in Manfla, a village located between 7°00'N - 7°26' N and longitudes 6°00'W - 6°30'W, and 400 km North Abidjan (Ivory Coast). The rainfall distribution in Manfla is bimodal with a long rainy season from March to July and a short rainy season from September to November. In the ecological zone where Manfla is located, the rainy seasons are separated by a short dry period (July-August) and a long dry season (December-February). Annual rainfall varies from 800 to 1400 mm with a long-term mean of 1200 mm, the annual mean temperature arounding 27°C. The experiments were established in a sandy loam soil with pH= 6.45, sandy (57%), loam (36%), clay (7%), organic matter content (6%), N-NO_3 (3.5 ppm), available P (24.4 ppm), 0.45 ppm of K, and 0-20 cm depth [20]. The vegetation is a woodland savanna.

2.2. Biological Materials

Two edible-seeded *Lagenaria siceraria* (Molina) Stadley accessions identified as resistant (NI42) and susceptible (NI76) by Anzara *et al*. [19] were used as plant materials. Genotypes analyzed in this study were obtained from four self-pollination cycles, resulting in sufficiently homogenous genetic resources.

Two insect species, *Asbecesta cyanipennis* (Weise) and *Lamprocopa occidentalis* (Harold) were examined. Their choice was due to the level and extent of their nuisance on bottle gourd (*L. siceraria*) in the target village. The experiments were carried out under field conditions during the first cropping season of 2018, and sowings were done the first day of a significant fall of rain (06 June 2018). The two target pest insect species were examined in natural infestation conditions.

2.3. Experimental Design

Three plots of 20 m x 20 m (0.4 ha) each, distanced by at least 1 km were set up. A border of 50 m without any other cultivated crop was managed around each plot. One of the plots was sown with the two accessions (the tolerant NI42, and the susceptible NI76) in an intercropping system. On this plot, sowing of the two accessions was done in a regular lattice design, to compare variations in feeding damage and yield components on the rational basis. The second plot was sown only with the susceptible accession (NI76), while the third plot received only the tolerant accession (NI42).

The seed samples were sown at 3 cm depth and a spacing of 3 m was arranged between and within rows. In each plot, sowing was done following 6 rows of 6 holes, resulting in 36 holes per plot. Four seeds per hole were sown directly and thinned out to one plant per hole at first tendril appearance stage. The plots were hoe weeded regularly to prevent interaction between plants, pest insects, and weed load. No insecticide treatment was applied to the plots.

2.4. Data Collection and Statistical Analyses

Carefully monitoring of individuals of each insect species was done on each plot. Each of the 36 plants on each plot were examined both for insect feeding damage and production. Eggs were searched both in the plots and in the surrounding area. The observations focused on the different stages of the development cycle, from egg to adult insect. The feeding and reproductive behaviors of the target insects were also examined. Variables characterizing the life cycle and the dynamics of insect populations were measured or observed at three phenological stages of the plant (seedling, tendril, fruit maturation). Observations and measurements made on insects concerned number of eggs, hatching rate, average duration of the different phases of life cycle, egg-laying niches, different activities (mating, feeding, and resting) and abundance of adults (number of individuals per plant).

The type and extent of damage caused by each of the pest insects observed in this study are specific and can be easily differentiated, even in their absence. *A. cyanipennis* shreds the leaves while *A. cyanipennis* gnaws them entirely (Figure 1).

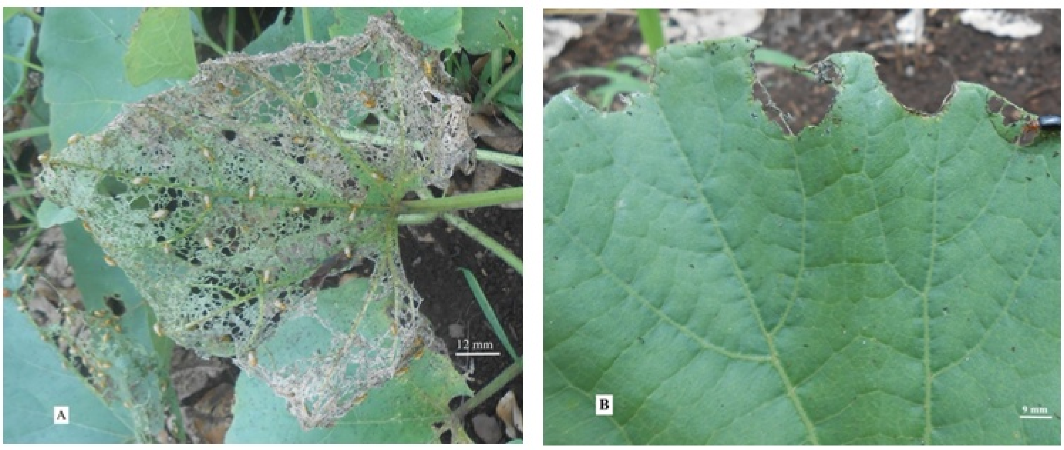

Figure 1. Type of feeding damage caused by adult individuals of (A) *Lamprocopa occidentalis* and (B) *Asbecesta cyanipennis*

All plants in each plot were observed for feeding damage and the percent of leaf damaged was estimated. Thus, for each plant and each plot, the total number of leaves (nLt) and the number of leaves damaged by insects (nLD) were noted, allowing the calculation of the percentage of damaged leaves (PDL) using the following formula:

$$PDL = \frac{\text{nLD}}{\text{nLt}} \text{x10}$$

Five traits considered as yield components in cucurbits [21], and characterizing the plant, fruit, and seed were measured in this study. The measured traits were plant length (PL), number of fruits per plant (NF), seed weight per fruit (SW), and 100-seed weight (100-SW). The measurement approaches of the selected traits followed Koffi *et al*. [22].

Mean values and standard deviations were calculated for each parameter. Multivariate analysis of variance (MANOVA) which is appropriate for two-way mixed model was performed to check significant difference between damage level according to: i) accession, ii) cropping system, and iii) plant growth stage. ANOVA procedure of R Development Core Team [23] was used to identify parameters contributing to differences when MANOVA revealed significant difference for a factor. The LSD were used to identify differences among mean values ($P < 0.05$).

3. Results

3.1. Description of Pest Insect's Live Cycles, Demography, and Feeding Damage

3.1.1. Lamprocopa Occidentalis (Weise)

Adult individuals of *Lamprocopa occidentalis* (Weise) mate on bottle gourd and females lay their eggs on the underside of leaves, usually at one end (Figure 2). The eggs are arranged in a grouped fashion, thus forming a cluster. A female can lay 30 to 60 eggs, pale yellow in color and ovoid or elongated in shape. After four to six days, their color changes to white, indicating that hatching is going to take place.

The small larvae, very mobile, immediately attack the leaves, avoiding the primary and secondary veins. Their development takes about a month, during which time they undergo changes. The color of these larvae changes from bright yellow to pale yellow. Five rows of pairs of hairs appear along the body. Two rows of two pairs are on each side and one row is in the center.

The adults reaching up to 9 mm, are grayish in color and shiny. They spend their entire life cycle on plants with feeding and reproduction as their main activities. Adults of this species are devastating to plants like their larvae. They completely or partially destroy the leaf. When they are in colonies, as shown in Figure 2 D, the entire leaf is destroyed.

Individuals of all phases of the life cycle of *L. occidentalis* are observed on all organs of the bottle gourd, at all phenological stages of the plant. However, the seedling and fruiting stages are the most devastated by the pest insect. This insect pest is the most important destroyer of *Lagenaria siceraria* observed during this study. It damages leaves, flowers, and fruits.

3.1.2. *Asbecesta cyanipennis* (Harold)

Individuals of *A. cyanipennis* are small beetles usually measuring 3 to 6 mm length. Only adult individuals of this species have been observed on *L. siceraria*. They are often blue in color. The elytra are punctuated with blue or blue verging on green. The pronotum, head and ventral surface are yellowish-brown to orange in color. The eyes are black. The first segments of the antennae are reddish, the others blackish. The adults attack flowers, fruits, and leaves on which they make multiple small holes. This insect is more present on the seedlings on which the damage is the most important (Figure 3).

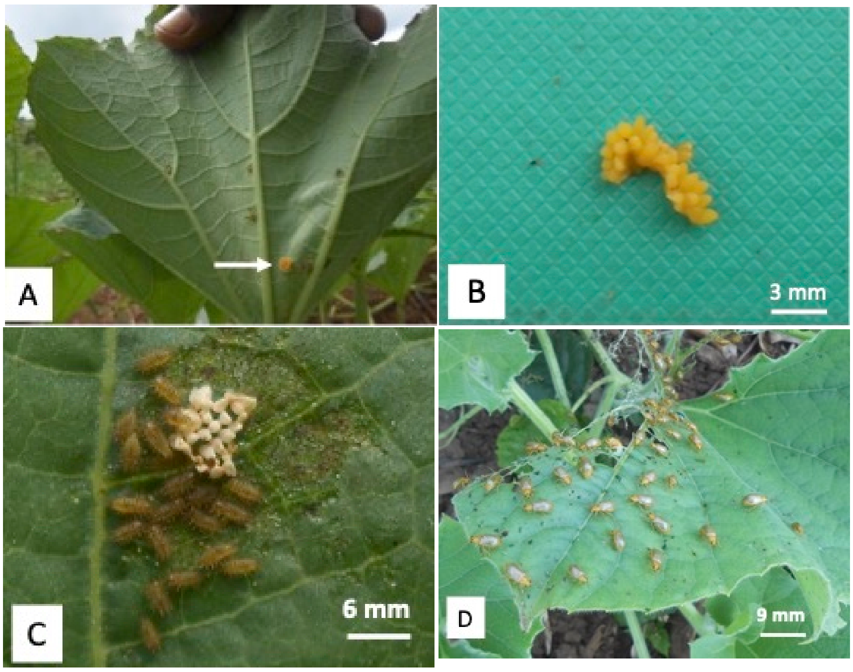

Figure 2. Main stages in the live cycle of *Lamprocopa occidentalis*: A and B: clustered eggs; C: larvae; D: adult individuals

Figure 3. Adult individuals of *Asbecesta cyanipennis* feeding on leaves of the bottle gourd

3.2. Pest Insect's Demography Traits

The number of adult individuals per plant of the two insect species studied varied significantly according to accession type (Table 1). The number of adult individuals were significantly higher on plants of the susceptible accession (NI76). The average number of eggs per plant did not vary significantly between the accessions. But whatever the accession, the number of eggs per plant of *L. occidentalis* was significantly higher than those of larvae and adults. No significant difference was observed between the mean numbers of larvae and adults of *L. occidentalis*, estimated on per plant basis.

Multivariate analysis of variance (MANOVA) showed that accession type, cropping system, plant phenological stage, and their various interactions had significant effects on the demography traits of the two pest insect species studied (Table 2). Consequently, three-ways analysis of variance (ANOVA 3) was performed using each demography parameter and data from the triple interaction were considered for interpretations (Table 3).

Table 1. Mean number of individuals of different live cycle stages in two pest insect species observed on plots sown with tolerant (NI42) and susceptible (NI76) accession of the bottle gourd

Accession	*Lamprocopa occidentalis*[1]			*Asbecesta cyanipennis*
	Egg	Larvae	Adult	
Tolerant NI42	13.58±14.01	4.92±6.24^{b}	4.75±5.12^{b}	1.5±1.74^{b}
Susceptible NI76	14.84±15.98	7.79±7.64^{a}	6.39±6.42^{a}	2.14±3.20^{a}
F	1.14	25.99	15.11	5.15
P	0.286	<0.001	<0.001	<0.001

[1] For each species and live cycle stage, values followed by different letter in a colon are significantly different (P<0.05) using LSD.

Table 2. Results of MANOVA related to demography traits of two pest insects analyzed according to accession type, cropping system, and plant phenological stages of the bottle gourd

Factors and their interactions	Statistical tests parameters	
	Wilks's lambda	*F*
Accession (A)	18.17	<0.001
Cropping system (B)	51.46	<0.001
Plant phenological stage (C)	170.90	<0.001
A x B	19.66	<0.001
A x C	3.62	<0.001
B x C	52.95	<0.001
A x B x C	8.8	<0.001

Results of the statistical tests presented in Table 3 show that the greatest spawning of *L. occidentalis* was observed on the susceptible accession (NI76), at the tendril stage and in monoculture. The larvae and adults of this species had significantly high numbers, regardless of the cropping system. However, the adults were abundant when the accessions were in intercropping. In the tolerant accession (NI42), adult individuals of *A. cyanipennis* (the life cycle stage observed in this study) were significantly higher on seedlings in monoculture, compared to intercropping. Overall, the statistical analyses showed that whatever the accession and the cropping system, *A. cyanipennis* was abundant at the seedling stage and *L. occidentalis* (larvae and adults) at the fruiting stage.

Table 3. Interaction Effect of Accession, Cropping System, and Plant Growth Stage on Demography Traits of Two Pest Insects Feeding Leaves of the Bottle Gourd

Accession	Cropping system	Growth stage	*Asbecesta cyanipennis*[1]			*Lamprocopa occidentalis*
			Egg	Larvae	Adult	
Tolerant NI42	Monocrop	Tendril	0.00±0.00^{d}	0.00±0.00^{e}	0.19±0.52^{f}	3.69±1.75^{b}
		Seedling	29.56±13.09^{b}	3.97±4.55^{d}	4.44±2.34^{f}	0.69±0.98^{de}
		Fruit maturation	20.61±7.91^{c}	11.22±7.22^{b}	9.44±2.26^{c}	0.83±0.77^{cde}
	Intercrop	Tendril	0.00±0.00^{d}	0.00±0.00^{e}	0.33±0.59^{f}	1.06±1.35^{cde}
		Seedling	3.72±1.90^{d}	3.44±1.98^{d}	0.39±0.78^{e}	0.5±1.2^{de}
		Fruit maturation	18.17±4.15^{c}	10.44±4.22^{c}	13.89±2.25^{a}	1.5±1.42^{cd}
Susceptible NI76	Monocrop	Tendril	0.00±0.00^{d}	0.00±0.00^{e}	0.25±0.55^{f}	6.92±3.31^{a}
		Seedling	36.58±11.87^{a}	9.58±5.31^{c}	8.06±2.77^{d}	0.67±1.29^{de}
		Fruit maturation	19.56±6.54^{c}	16.28±6.31^{a}	14.69±3.48^{a}	0.75±1.57^{de}
	Intercrop	Tendril	0.00±0.00^{d}	0.00±0.00^{e}	0.11±0.47^{f}	0.39±0.70^{e}
		Seedling	0.67±1.03^{d}	4.67±2.25^{d}	0.39±0.85^{f}	0.44±0.92^{de}
		Fruit maturation	20.61±6.53^{c}	13.72±2.87^{b}	11.06±3.59^{b}	1.72±1.13^{c}
Statistics		*F*	5.92	1.65	20.24	12.32
		P	<0.001	<0.001	<0.001	<0.001

[1] For each species and live cycle stage, values followed by different letter in a colon are significantly different (*P*<0.05) using LSD.

Table 4. Pest Insects Feeding Damage Effect on Leaves and Yield Components as Influenced by Accession, Cropping System, and Plant Growth Stage in the Bottle Gourd[1]

Accession	Cropping system	Growth stage	PDL (%)[2]	Yield components			
				PL	NF	SW (g)	100-SW (g)
Tolerant NI42	Monocrop	Tendril	29.76±20.6^{de}				
		Seedling	18.52±16.95^{gh}				
		Fruit maturation	25.97±12.62^{def}	11.53±2.51	4.1±1.38^{a}	78.91±33.21^{a}	24.54±3.93^{a}
	Intercrop	Tendril	13.77±3.65^{gh}				
		Seedling	20.89±5.01^{f}				
		Fruit maturation	34.06±9.75^{cd}	10.34±1.71	2.42±0.91^{b}	72.73±43.22^{b}	21.19±5.42^{b}
Susceptible NI76	Monocrop	Tendril	50.40±19.46^{a}				
		Seedling	41.67±17.34^{bc}				
		Fruit maturation	38.47±13.75^{c}	6.28±1.2	1.19±0.62^{c}	34.61±18.24^{d}	19.67±3.48^{bc}
	Intercrop	Tendril	10.39±3.54^{g}				
		Seedling	22.83±6.51^{ef}				
		Fruit maturation	48.55±11.03^{ab}	5.90±1.32	0.89±0.57^{c}	52.97±28.02^{c}	18.94±3.98^{c}
Statistics		*F*	5.768	1.92	21.03	5.96	3.9
		P	<0.001	0.167	<0.001	<0.001	<0.001

[1] For each species and live cycle stage, values followed by different letter in a colon are significantly different (P<0.05) using LSD.
[2] PDL: percentage of damaged leaves; PL: plant length; NF: number of fruits per plant; SW: seed weight per fruit; 100-SW: 100-seed weigh.

3.3. Influence of Pest Insects on Leave Damage and Yield Components

3.3.1. Influence of Insect Feeding on Leaves

The damage caused by pest insects on the leaves of bottle gourd, expressed in terms of percentage of damaged leaves (PDL), varied significantly (P < 0.001) according to accession, cropping system, plant growth stage, and their interactions. The triple interaction was therefore considered to interpret the results (Table 4). These results indicated that the leaves were more damaged in intercropping compared to monoculture. In this cropping system, the leaves of the susceptible accession NI76 suffered more damage. The cropping system therefore had a significant impact on the intensity of leave destruction. The presence of susceptible and tolerant accessions on the same plot was less beneficial for the tolerant accession in terms of the damage extent on leaves. Both accessions were more damaged by insects at the fruiting stage, but the damage intensity in the susceptible accession NI76 was significantly higher than that of the tolerant accession NI42. The results showed that overall, the fruiting stage was the most vulnerable, regardless of the cropping system applied.

3.3.2. Influence of Pest Insects on Yield Components

The results in Table 4 indicate that plant length did not vary significatively between treatments. However, the tolerant accession NI42 presented the greatest number of fruits, with heavier seeds whatever de cropping system implemented. Nevertheless, the highest values were observed in monoculture. In the susceptible accession NI76, the best values were rather observed in intercropping. Thus, the tolerant accession showed good productivity when produced in monoculture, unlike the sensitive accession.

4. Discussion

Appropriate management of crop production factors ensures yield sustainability [24,25]. Sustainable management of pest insects in oilseed cucurbits, especially by smallholders, is a real challenge [19,26,27,28]. Several investigations on innovative strategies for sustainable protection of cucurbits against pest insects are being carried out [9,29,30], but the consolidation of the results requires a deep knowledge of biology, demography, and population dynamics [31,32].

This study showed that *L. occidentalis* accomplishes the main stages of its live cycle on the bottle gourd and stays there all day. Adja *et al*. [18] had also observed this insect species on two cucurbit species including the bottle gourd (*Lagenaria siceraria* and *Citrullus lanatus*), during three consecutive cropping seasons.

A female of this insect lays 30-60 eggs, which give numerous larvae. The resulting larvae and adult individuals colonize all plants, averaging 5-6 individuals per plant. Results indicated also that this insect species had not preference between accession types for egg laying, because similar numbers were observed on both tolerant and susceptible accessions. On the other hand, the numbers of larvae and adults were significantly higher on the susceptible accession. This behavior is a survival instinct because it provides better chances for the development of individuals. Jenkins *et al*. [33] observed in cotton that *Alabama argillacea* (Hübner) moths preferred to oviposit on glandless lines, but the resulting larval feeding caused considerably more damage to all glandless than to glanded lines. Larvae and adult individuals on *L. occidentalis* fed on leaves with similar rates. Altermatt and Pearse [34] showed that despite nutritional differences between plant tissue and nectar, there are similarities between adult and larval feeding in Lepidoptera.

From the examination of 36 plants per plot i.e., a total of 108 plants during the entire cropping season, we did not observe any eggs or larvae of *A. cyanipennis* in the fields. Furthermore, we noted that the average number of adult individuals of *L. occidentalis* was twice higher than that of *A. cyanipennis*, regardless of the type of accession considered (tolerant or susceptible). These results suggested that *L. occidentalis* could be a cucurbit-host-specific species, contrarily to *A. cyanipennis* which is probably an opportunistic herbivorous insect on the target crop. The hypothesis concerning *A. cyanipennis* is supported by the work of Anzara *et al.* [19] who reported very low proportions (8.70-11.72%) of this species in gourd fields, with a total absence during certain cropping seasons. However, this hypothesis must be tested using screen house trials.

Leave damage was greater in monoculture and on plants at the tendril stage, compared to seedlings. The extent of attacks on developed plants may be related to the availability of leaf biomass at this stage.

Overall, the highest values of yield components analyzed were observed in monoculture particularly in the tolerant accession. However, for the susceptible accession, the yield components reduction between the two cropping systems tested was low for plant length and number of fruits per plant. The value of seed weight was about 1.5 higher in intercropping. Several on-farm studies demonstrate the beneficial effects of intercropping on crop growth and yield through the reduction of disease and pest damage [35,36,37].

Thus, to intensify the production of *L. siceraria* in low input cropping systems, special attention must be given to the control of *L. occidentalis*. Intercropping systems involving the tolerant accession (NI42) examined in this research could be satisfactory in terms of pest insects feeding damage reduction and yield gain.

Funding

This research received no external funding.

Data Availability Statement

Data are contained within the article.

Acknowledgments

We thank the chiefdom of the village of Manfla (Centre-Western Ivory Coast) for having lent us a plot for the implementation of our research.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Achigan-Dako, G.E., Fanou, N., Kouke, A., Avohou, H., Vodouhe, R.S., Ahanchede, A.. Évaluation Agronomique de Trois Espèces de Egusi (Cucurbitaceae) Utilisées Dans l'alimentation Au Bénin et Élaboration d'un Modèle de Prédiction Du Rendement. *Biotechnologie, Agronomie, Société et Environnement* 2006, *10*: 121-129.

[2] Loukou, A.L., Gnakri, D., Djè, Y., Kippré, A.V., Malice, M., Baudoin, J.P., Zoro Bi, I.A. Macronutrient Composition of Three Cucurbit Species Cultivated for Seed Consumption in Côte d'Ivoire. *African Journal of Biotechnology* 2007, *6*: 529-533.

[3] Prajapati, R.P., Kalariya, M., Parmar, S.K., Sheth, N.R.. Phytochemical and Pharmacological Review of *Lagenaria sicereria*. *Journal of Ayurveda and Integrative Medicine* 2010, *1*: 266-272.

[4] Zahoor, M., Ikram, M., Nazir, N., Naz, S., Batiha, G.E.-S., Kamran, A.W., Tomczyk, M., Kabrah, A. A Comprehensive Review on the Medicinal Importance; Biological and Therapeutic Efficacy of *Lagenaria siceraria* (Mol.) (Bottle Gourd) Standley Fruit. *Current Topics in Medicinal Chemistry* 2021, *21*, 1788-1803.

[5] Zoro Bi, I.A., Koffi, K.K., Djé, Y. Caracterisation Botanique et Agronomique de Trois Espèces de Curcubites Consommées En Sauce En Afrique de l'Ouest: *Citrullus* Sp., *Cucumeropsis mannii* Naudin et *Lagenaria siceraria* (Molina) Standley. *Biotechnologie, Agronomie, Société et Environnement.* 2003, *7*, 189-199.

[6] Athey, K.J., Peterson, J.A., Dreyer, J., Harwood, J.D., Williams, M.A. Effect of Breathable Row Covers and Ground Cover on Pest Insect Levels and Cucurbit Yield. *Journal of Economic Entomology*, 2022, *115*, 193-200.

[7] Egerer, M., Liere, H., Lucatero, A., Philpott, S.M. Plant Damage in Urban Agroecosystems Varies with Local and Landscape Factors. *Ecosphere* 2020, *11*, e03074.

[8] Fomekong, A., Messi, J., Kekeunou, S., Tchuenguem- Fohouo, F.N. Entomofauna of *Cucumeropsis mannii* Naudin, Its Impact on Plant Yield and Some Aspects of the Biology of *Dacus bivitattus* (Diptera: Tephritidae). *African Journal of Agricultural Research.* 2008, *3*, 363-370.

[9] Ingwell, L.L., Kaplan, I. Insect Exclusion Screens Reduce Cucumber Beetle Infestations in High Tunnels, Increasing Cucurbit Yield. *Journal of Economic Entomology* 2019, *112*, 1765-1773.

[10] Edelson, J.V., Duthie, J., Roberts, W. Watermelon Seedling Growth and Mortality as Affected by *Anasa tristis* (Heteroptera: Coreidae). *Journal of Economic Entomology*, 2002, *95*, 595-597.

[11] Morimoto, Y., Maundu, P., Fujimaki, H., Morishima, H. Diversity of Landraces of the White-Flowered Gourd (*Lagenaria siceraria*) and Its Wild Relatives in Kenya: Fruit and Seed Morphology. *Genetic Resources and Crop Evolution*, 2005, *52*, 737-747.

[12] Saeed, M., Khan, M.S., Amir, K., Bi, J.B., Asif, M., Madni, A., Kamboh, A.A., Manzoor, Z., Younas, U., Chao, S. *Lagenaria siceraria* Fruit: A Review of Its Phytochemistry, Pharmacology, and Promising Traditional Uses. *Frontiers in Nutrition,.* 2022, *9*, 927361.

[13] Kaiser, A., Burger, P. Understanding Diversity in Farmers' Routinized Crop Protection Practices. *Journal of Rural Studies*, 2022, *89*, 149-160.

[14] Marliac, G., Penvern, S., Barbier, J.-M., Lescourret, F., Capowiez, Y. Impact of Crop Protection Strategies on Natural Enemies in Organic Apple Production. *Agronomy for Sustainable Development*, 2015, *35*, 803-813.

[15] Furlan, L., Milosavljević, I., Chiarini, F., Benvegnù, I. Effects of Conventional versus No-Tillage Systems on the Population Dynamics of Elaterid Pests and the Associated Damage at Establishment of Maize Crops. *Crop Protection*, 2021, *149*, 105751.

[16] Hooks, C.R., Johnson, M.W. Impact of Agricultural Diversification on the Insect Community of Cruciferous Crops. *Crop Prot.* 2003, *22*, 223-238.

[17] Karungi, J., Nampala, M.P., Adipala, E., Kyamanywa, S., Ogenga-Latigo, M.W. Population Dynamics of Selected Cowpea Insect Pests as Influenced by Different Management Practices in Eastern Uganda. *African Crop Science Journal*, 1999, *7*, 487-495.

[18] Adja, N.A., Danho, M., Alabi, T.A.F., Gnago, A.J., Zimmer, J.-Y., Francis, F., Kouassi, K.P., Baudoin, J.-P., Zoro, B.I.A. Entomofauna Associated with African Oleaginous Cucurbits (*Lagenaria siceraria* Molina (Standl.1930) and *Citrullus lanatus* Thumb (Matsum & Nakai 1916)) and Impact of Pests on Production. *Annales de la Société entomologique de France NS* 2014, *50*, 301-310.

[19] Anzara, G.K.G.R., Koffi, K.K., Coulibally, S.S., Fouha, B.N.D., Baudoin, J.-P., Campa, C., Zoro, B.I.A. Influence of Herbivorous Insects on the Production of *Lagenaria siceraria* (Molina) Standley (Cucurbitaceae). *African Journal of Plant Science*, 2015, *9*, 449-456.

[20] Kouassi, N.J., Zoro Bi, I.A. Effect of Sowing Density and Seedbed Type on Yield and Yield Components in Bambara Groundnut (*Vigna subterranea*) in Woodland Savannas of Cote D'ivoire. *Experimental Agriculture*, 2010, *46*, 99-110.

[21] Yao, K.A., Koffi, K.K., Ondo-Azi, S.A., Baudoin, J.-P., Zoro, B.I. Seed Yield Component Identification and Analysis for Exploiting Recombinative Heterosis in Bottle Gourd. *International Journal of Vegetable Science*,. 2015, *21*, 441-453.

[22] Koffi, K.K., Gbotto, A.A., Malice, M., Dje, Y., Bertin, P., Baudoin, J.-P., Zoro Bi, I.A. Morphological and Allozyme Variation in a Collection of *Cucumeropsis mannii* Naudin (Cucurbitaceae) from Côte d'Ivoire. *Biotechnologie, Agronomie, Société et Environnement.* 2008, *36*, 777-789.

[23] R Development Core Team R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing 2011.

[24] Anantha, K.H., Garg, K.K., Barron, J., Dixit, S., Venkataradha, A., Singh, R., Whitbread, A.M. Impact of Best Management Practices on Sustainable Crop Production and Climate Resilience in Smallholder Farming Systems of South Asia. *Agricultural Systems,* 2021, *194*, 103276.

[25] Reddy, B.V.S., Reddy, P.S., Bidinger, F., Blümmel, M. Crop Management Factors Influencing Yield and Quality of Crop Residues. *Field Crops Research,* 2003, *84*, 57-77.

[26] Goré, B.B., Baudoin, J.-P., Zoro, B.I. Effects of the Numbers of Foliar Insecticide Applications on the Production of the Oilseed Watermelon *Citrullus lanatus*. *Sciences & Nature,* 2011, *8,* 53-62.

[27] Patel, S., Rauf, A. Edible Seeds from Cucurbitaceae Family as Potential Functional Foods: Immense Promises, Few Concerns. *Biomedicine & Pharmacotherapy,* 2017, *91*, 330-337.

[28] Sharma, A., Rana, C., Chiwani, K. Important Insect Pests of Cucurbits and Their Management. In *Handbook of cucurbits: Growth, cultural practices and physiology*; Pessarakli, M., Ed.; CRC Press: Boca Raton, Florida (USA), 2016; pp. 327-359.

[29] Cave, G.L., West, A.J., McCord, M.G., Koene, B., Beck, J.B., Deguenon, J.M., Luan, K., Roe, R.M. Novel 3-D Spacer Textiles to Protect Crops from Insect Infestation and That Enhance Plant Growth. *Agriculture* 2022, *12*.

[30] Nordey, T., Deletre, E., Mlowe, N., Martin, T. Nethouses Protect Cucumber Plants from Insect Pests and Increase Yields in Eastern Africa. *Journal of Horticultural Science and Biotechnology,* 2020, *95*, 673-678.

[31] Chidawanyika, F., Mudavanhu, P., Nyamukondiwa, C. Biologically Based Methods for Pest Management in Agriculture under Changing Climates: Challenges and Future Directions. *Insects* 2012, *3*, 1171-1189.

[32] Nawaz, A., Sufyan, M., Gogi, M.D., Javed, M.W. Sustainable Management of Insect-Pests. In *Innovations in sustainable agriculture*; Farooq, M., Pisante, M., Eds.; Springer International Publishing: Cham, 2019; pp. 287-335.

[33] Jenkins, J.N., Maxwell, F.G., Lafever, H.N. The Comparative Preference of Insects for Glanded and Glandless Cottons. *Journal of Economic Entomology,* 1966, *59*, 352-356.

[34] Altermatt, F., Pearse, I.S. Similarity and Specialization of the Larval versus Adult Diet of European Butterflies and Moths. *The American Naturalist,* 2011, *178*, 372-382.

[35] Madembo, C., Mhlanga, B., Thierfelder, C. Productivity or Stability? Exploring Maize-Legume Intercropping Strategies for Smallholder Conservation Agriculture Farmers in Zimbabwe. *Agricultural Systems,* 2020, *185*, 102921.

[36] Mthembu, B.E.; Everson, T.M.; Everson, C.S. Intercropping Maize (*Zea mays* L.) with Lablab (*Lablab purpureus* L.) for Sustainable Fodder Production and Quality in Smallholder Rural Farming Systems in South Africa. *Agroecol. Sustainable Food Systems,* 2018, *42*, 362-382.

[37] Tripathi, S.C., Venkatesh, K., Meena, R.P., Chander, S., Singh, G.P. (2021). Sustainable Intensification of Maize and Wheat Cropping System through Pulse Intercropping. *Scientific Reports*, *11*: 1-10.