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ASSESSMENT OF FRUIT YIELD LOSS IN CUCUMBER DUE TO LEAF FEEDING BY *Epilachna chrysomelina* FABRICIUS (COLEOPTERA: COCCINELLIDAE)

***AKINKUNMI, O.Y.,[1] PITAN, O.R.[2] AND ADEOYE, O.T.[3]**
[1]National Horticultural Research Institute, PMB 5432 Jericho, Idi-Ishin Ibadan, Nigeria
[2]Department of Crop Protection, Federal University of Agriculture, Abeokuta, Nigeria
[3]Department of Forest Conservation and Protection, Forestry Research Institute of Nigeria
*Corresponding author: akinkunmikemi1@gmail.com

Abstract
Fruit yield loss in cucumber (Cucumis sativus L.) to leaf feeding by Epilachna chrysomelina Fabricius (Coleoptera: Coccinellidae) at six population densities (0, 1-,2-,3-,4- and 5-pairs per cage) was studied in screen house and field experiments. Increased beetle density, resulted into a significant reduction (P < 0.05) in the number of fruit, fruit length, fruit width and fresh fruit yield produced in both experiments. At 1-pair and 2-pairs infestation level yield reduction was not statistically different from the control. However, over 54% fruit yield reduction was recorded when beetle density was increased beyond 3-pairs infestation level. The damage threshold of the beetle at which significant reduction (P < 0.05) occurred in fresh fruit yield per cage, when compared with the control, was 3-pair level. At this infestation level, initiation of control measures is justified. Regression analysis in both experiments indicated that Epilachna chrysomelina density was positively related to fruit damage and negatively associated with fresh fruit yield. Results of the chi-squared analysis further revealed that the screen cage and field cage experiment models were similar and either model could be used for predicting damage and yield with respect infestation by the beetle.

Key Words: *Epilachna chrysomelina, Yield response, Infestation level, Cucumber, Damage*

Introduction

The African melon Ladybird beetle *Epilachna chrysomelina* Fabr (Coleoptera: Coccinellidae) is a destructive pest of economic importance inhabiting tropical and subtropical regions (Katoh *et al*., 2014). It attacks cultivated crops belonging to Cucurbitaceae and Solanaceae families such as cucumber, pumpkin, melon, garden egg, potato, melon and gourds (Ahmad *et al*., 2001; Das *et al*., 2012; Pitan and Filani, 2013). Both the larvae and adults feeding activity cause damage by scrapping the epidermal tissues of the leaves reducing the leaf area available for photosynthetic activities which is injurious to the host plant (Endo *et al*., 2004; Mondal and Ghatak, 2009). The beetle is also a vector ofsquash and cucumber mosaic virus. These diseases manifested by misshapen fruits, leaf blistering, yellowing and distortions (Al-Digail *et al*., 2012). Yield losses up to 80% on cucurbits (Wioletta and Karol,

2016) and 60% on solanaceous plants (Mall *et al*., 1992) and 70 - 90% yield reduction on cucumber (Akinkunmi, 2020) have been reported to be caused by the beetle which adversely affects both quality and quantity of crop output, therebythreatening food security and nutritional quality.

Several management measures employed in reducing the density of *Epilachna chrysomelina* include, intercropping cucumber with amaranth (Pitan and Esan, 2013) and maize (Pitan and Filani, 2014), manipulation of sowing dates to avoid severe beetle infestation on the field, the use of entomopathogenic fungus, nematode, bacteria and viruses as bio-control agents (Abdel *et al*., 2001), use of essential oils from neem, ginger, lime, lemon, orange and basil (*Ocimum basilicum* L) on hosts served as antifeedants against the fourth instar grub of *Epilachna vigintioctopunctata* (Ponnuvel*et al*., 2013) as well as the applications of chlorophos (trichlorfon), carbophos (malathion) or phosphamide (dimethoate) Tilavov (1985) and lambdacyhalothrin (Pitan and Filani, 2013) which resulted into eradicating adults and larvae of all ages and higher number and heavier fruits produced.

Quantitative data on crop losses due to *Epilachna* beetle infestation and damage are still very scanty. This information, is however of importance for easy establishment of the pest's economic status, aids identifying the infestation level that justifies control (action threshold) and gives basis for future research planning which thereby facilitates decision making in the adoption of suitable sustainable pest management strategies to bring yield loss to a minimal level. The objective of this study therefore, is to determine the population density of *Epilachna chrysomelina* capable of causing economic yield loss and damage in cucumber.

Materials and Methods

Study Area

Studies were carried out in the screen house and field at the National Horticultural Research Institute (NIHORT), Ibadan, Nigeria (Latitude 7°54′ N and Longitude 3° 54′ E, 213 m above the sea level) under laboratory condition with temperature 25° ± 2° C and relative humidity 75 - 90% under natural tropical lighting condition according to Hossain *et al*. (2009). Cucumber seeds were planted in pots and were used in a screen cage study, while in the field; cucumber was seeded and afterward covered with wire mesh screen cages measuring 1.2 m x 1.2 m x 2.0 m.

Laboratory Culture of Epilachna chrysomelina

Initial stock of adult *Epilachna chrysomelina* used in the study were collected from field populations infesting cucumber plants at the experimental fields of NIHORT, Ibadan. Ten unsexed adult beetles from the collection were later released into three weeks old potted cucumber plants covered with wire mesh cages measuring (65 cm × 65 cm × 70 cm) for oviposition. The beetles were removed 10 days after introduction to the plants, (when they must have mated and laid eggs). Insect culture was maintained under ambient temperature 25° C - 28° C and relative humidity 75 - 90% using thermo-hygrometer under natural tropical lighting condition.Eggs laid on the plants were observed until adult emergence. Emerged adults of similar ages (< 24 hrs old) were used for the studies according to the method described by Pitan and Ekoja (2011).

Screen House Experiment

Ninety 10-litre plastic pots filled with sterilised top soil were planted with three

cucumber seeds each. The seedlings were later thinned to one seedling per pot a week after sowing (1WAS). The potted plants were raised in wire mesh screen cages measuring 1.0 m x 1.0 m x 1.2 m and provided with a door for easy access. The pots containing the seedlings were distributed into 18 cages at five pots per cage, making five plants per cage. At 3 weeks after sowing (3WAS), the caged cucumber seedlings were infested with newly emerged (< 24 hrs) adults (male and female) collected from the laboratory culture at 0 (control), 1, 2, 3, 4 and 5 pairs per cage, representing six treatments. The cages were later arranged in a completely randomized design and replicated three times. The number of insects in each cage was kept constant by replacing dead beetles with newly emerged ones from the laboratory culture until crop harvest. Watering of the plants (with 60cl of water) was done every two days while weeding was carried out at four weeks interval. The caged cucumber plants were examined daily between 7 and 8 am when the insects were relatively inactive. Data were taken on the number of fruits produced per plant while the number of fruits damaged by the beetles per plant was taken weekly. Harvesting of the fruits was done twice per week at maturity (65-80 DAS) when the fruits became shiny green by using a sharp scissors to detach the fruits from the mother plants. The fruits were then measured in length and diameter with tape measure and weighed and later sorted out into damaged and undamaged categories. A fruit was considered damaged when one or more incisions, grooves or scars characteristic of fruit-tissue consumption by *E. chrysomelina* were found on the skin.

Field Experiment using Screen Cages

Three seeds of cucumber were planted per hole on a field size 11 m x 5 m that was used for the experiment. The seeds were spaced 50 cm x 50 cm and were later thinned to one seedling per hole at 1 WAS. At 2 WAS, cages earlier used for the screen house pot experiment were moved to the field and placed over 5 young seedlings plants in order to prevent other insects from inflicting damage before the introduction of the beetle. At 3 WAS, the caged plants were infested with newly emerged adult beetle, collected from the laboratory culture, at 0 (control), 1, 2, 3, 4 and 5 pairs per cage representing six treatments arranged in a randomized Complete Block Design (RCBD) with three replicates. The beetle population level was kept constant as in the screen house pot experiment by releasing newly emerged beetles from the culture into the field plants. The same experimental protocol and harvesting procedures used were as described in the screen house experiment.

Statistical Analysis

Collected data were subjected to analysis of variance procedure SAS (2000) and significant means were separated using Studentised Newman Keuls (SNK) at ($P < 0.05$). Linear regression analysis was used to determine the relationships between beetle density, cucumber damage and yield. Chi-square analysis was used to assess data generated from crop damage relationships obtained from the screen house and field experiments.

Results

Increase in beetle density in the cages, resulted into a significant reduction in the number of fruits produced and increase in fruit damage compared with the control cages which produced significantly highest number of fruits per plants in both experiments. Number of fruit produced in cages with 1-pair infestation level was not significantly different from what was

obtained from cages with 2-pairs infestation level (Table 1). Significant reduction in the number of fruits produced per plant occurred at the 3-pairs level of infestation in both experiments. In addition, 4-pairs and 5-pairs infestation levels produced significantly lowest numbers of fruits relative to the controls; however, they were not statistically different from one other. Percentage reduction in number of fruits produced over the control cages ranged between 21.47% and 81.46% in potted cucumber in screen cages and 18.46% and 71.54% in field caged cucumber with percentage fruit damage ranged between 5.84% and 85.50 in potted cucumber in screen cage and 16.04% and 89.19% in field caged cucumber respectively. Damage as a result of feeding activities of *E. chrysomelina* on the fruits was characterised by the presence of scars, patches and grooves thereby reducing the marketable fruit yield. However, no damage was recorded in the control cages.

A significant reduction in fruit length and fruit width per plant was observed at the 3-pairs level of infestation in both the screen house and in the field experiments (Table 2). Inhibition in fruit length ranged from 2.52-37% and 3-43% in the screen cage and field cage respectively, while fruit width inhibition ranged from 4.11-44.82% and 4.13-46.9%. Fruit length was 37% (in screen cage) and 43% (field cage) shorter compared to those in the control. In both experiments, fruits length and width in cages infested with 4-pairs and 5-pairs were the smallest and were not statistically different from one another.

The number of fruits produced per cage varied from 2.55 - 16.34 in the screen cage plants and 4.86 - 19.80 in field cage cucumber plants, with 5-pairs infestation level recorded the lowest number of fruit per cage. At 3-pairs infestation level, decline in the number of fruit produced per cage was observed in both experiments and this continued in the 4-pairs and 5-pairs infestation levels. The infestation level of *E. chrysomelina* at which significant reduction in fresh fruit yield occurred per cage was 3-pairs in both experiments. Also, over 50% yield inhibition occurred at the 3-pairs infestation level, while inhibition in yield exceed 80% at the 5-pairs infestation level in both experiments (Table 3). Regression analysis in both experiments showed that *E. chrysomelina* population and fruit damage was a linear function. (Screen cage, $Y = 20.402X - 7.549$; $F = 126.33$; $n = 6$; $P < 0.0001$; $R^2 = 0.8944$; field, $Y = 20.316X - 4.394$; $F = 158.52$; $n = 6$; $P = 0.001$; $R^2 = 0.8936$) and fresh fruit yield (Screen cage, $Y= -1.0046X + 5.9748$; $F = 118.45$; $P < 0.0001$; $R^2 = 0.9599$; field, $Y= -0.9670X + 5.4962$; $F = 162.90$; $P = 0.0001$; $R2 = 0.9484$. Chi-square ($\chi 2$) analysis conducted revealed that the screen cage and field cage experiments models obtained were similar (Fruit damage: $\chi 2 = 1.26$ degrees of freedom (df) = 5, $P = 0.9635$, fresh fruit yield: $\chi 2 = 0.82$, degrees of freedom (df) = 5, $P = 0.9556$; number of fruit produced: $\chi 2 = 0.82$ degrees of freedom (df) = 5, $P = 0.98885$).

Discussion

Yield losses by *Epilachna chrysomelina* can be enormous in the absence of proper management. Reduced number of cucumber fruits produced, inhibition in fruit length and width as well as increased fruit damage obtained in this study were indications that *Epilachna chrysomelina* is a major biotic stressor of the crop (Ahmad *et al*., 2001; Rath, 2005; Pitan and Esan 2013 and Pitan and Filani (2013). Biotic stress inflicted on the crop resulted into distortion in the crop physiology which brought about negative implications on the yield. According to Marsh *et al*. (1990), the number of fruit

produced and yield obtained in a crop are related to the physiology of such crop. In both the screen cage and field cage experiments, variations in fruit production observed could be attributed to changes in the crop physiology as a result of the introduced biotic factor. This variation in number of fruit and yield is an adjustment to the potential in the crop to maintain new fruits. *E. chrysomelina* as a leaf feeder scraps the epidermal layer of the leaf, thereby reducing the photosynthetic activities of the plant which in turn have detrimental effect on the flowering and fruit formation. Meyer and Root, (1993) and Strauss, *et al*. (1996) reported that leaf herbivory can delay as well as alter developing flowers and fruit initiation. Damage on the fresh fruit in the study was characterized by grooves (Pitan and Filani, 2013) and scratches which lowered its marketability and storability (Marsh *et al*., 1990; Passam *et al*., 2009). At the 1-pair infestation level, compensation in terms of increase in yield (9.66% and 11.89%) was observed over the control in the screen house and field respectively. This increase however, was not a clear evidence of compensation by the plant since as beetle infestation level increased beyond 1-pair, the compensatory mechanism was easily overcome, due to the devastating presence of *Epilachna* beetles which surpassed the ability of the plants to replace damaged parts. Similar reaction was obtained on okra when flea beetle population increased beyond 5-pair infestation level as reported by Pitan and Ekoja, 2011. The growth and overall performance of the plant was affected at high beetle densities, which resulted in delay in fruit initiation and reduced productivity of the crop. The number of cucumber fruits produced in cages infested with 1-pair and 2-pairs beetle densities was statistically similar to what was obtained in the control. This implied that beetle population below 2-pairs infestation level did not have any reduction in the number of cucumber fruits and cucumber yield produced. However, as infestation level increased to 3-pairs a decline in the number of cucumber fruits and cucumber yield occurred indicating that 3-pairs infestation level is the damage threshold of *E. chrysomelina*. The 3-pairs level of infestation was the lowest density at which increase in the beetle density resulted into yield reduction and so introduction of management measure is justified at the stage. Furthermore, beetle density above the damage threshold (at 4-pairs and 5-pairs) infestation levels, a significant reduction in fruit yield (over 80%) were observed in both experiments. Regression analysis conducted showed that *E. chrysomelina* density had a positive relationship with fruit damage and a negative relationship with fresh fruit yield in both the screen cage and field cage experiments. Also, chi-squared analysis further revealed that both models were similar for the two experiments, and so either could be employed in predicting damage and yield with respect to *E. chrysomelina* infestation.

Conclusion

In the study, infestation level of *Epilachna chrysomelina* on cucumber was positively associated with fruit damage and negatively associated with fresh fruit yield in both the screen cage and field cage experiments. The result obtained could therefore, be used as a basis for further investigation and predicting damage or yield in cucumber as well as determining the action threshold and economy injury levels of the crop.

Table 1: Effect of different population densities of *Epilachna chrysomelina* on number of fruit produced and fruit damage of cucumber plants in potted screen and field cages

Infestation level (pairs)	Screen cage				Field cage			
	Number of fruits produced/plant		Number of damaged fruits/plant		Number of fruits produced/plant		Number of damaged fruit/plant	
	Means ± S.E	Reduction over check (%)	Means ± S.E	Reduction over check (%)	Means ± S.E	Reduction over check (%)	Means ± S.E	Fruit damage (%)
0	5.45 ± 0.21[a]	0.00	0.00 ± 0.00[e]	0.00	6.50±0.10[a]	0.00	0.00 ± 0.00[e]	0.00
1	4.28 ± 0.10[b]	21.47	0.25 ± 0.10[d]	5.84	5.30±0.20[b]	18.46	0.85 ± 0.10[d]	16.04
2	4.10 ± 0.10[b]	24.77	0.65 ± 0.25[c]	15.85	5.00±0.10[b]	23.08	1.00± 1.09[d]	20.00
3	2.00 ± 0.25[c]	60.30	1.45 ± 0.10[a]	70.00	3.15±0.20[c]	51.54	2.50 ± 1.00[a]	79.37
4	1.43 ± 0.30[d]	73.76	1.20 ± 0.20[a]	83.9	2.30±0.10[d]	64.62	2.00 ± 1.00[b]	86.95
5	1.01 ± 0.10[d]	81.46	0.86 ± 0.20[b]	85.15	1.85±0.10[d]	71.54	1.65 ± 1.25[c]	89.19
F-value	13.27		20.46		19.05		23.85	
P-value	< 0.0001		< 0.0001		< 0.0001		< 0.0001	
C.V (%)	5.75		16.62		9.46		31.20	

Means followed by the same letters within a column are not significantly different from one another (Student–Newman–Keuls test, $P < 0.05$).
Values are means of three replications, S.E= Standard error, C.V= coefficient of variation

Table 2: Effect of different densities of *Epilachna chrysomelina* on cucumber fruit morphometrics in screen and field cages

Infestation level (pairs)	Screen cage potted plants				Field cage plants			
	Fruit length (cm/plant)	Fruit length reduction over check (%)	Fruit width (cm/plant)	Fruit width reduction over check (%)	Fruit length (cm/plant)	Fruit length reduction over check (%)	Fruit width (cm/plant)	Fruit width reduction over check (%)
0	15.85±0.12[a]	0.00	14.86 ± 0.10[a]	0.00	19.75 ± 0.52[a]	0.00	16.95 ± 0.15[a]	0.00
1	15.45 ± 0.10[a]	2.52	14.25 ± 0.05[a]	4.11	19.15 ± 0.40[a]	3.04	16.25 ± 0.11[a]	4.13
2	15.20 ± 0.30[a]	4.10	13.85 ± 0.11[a]	6.80	18.72 ± 0.50[a]	5.22	15.55 ± 0.21[a]	8.26
3	11.7 ± 0.31[b]	26.18	10.50 ± 0.10[b]	29.34	14.50 ± 0.20[b]	26.58	11.65 ± 0.09[b]	31.27
4	10.65 ± 0.22[c]	32.81	8.45 ± 0.10[c]	43.14	11.74 ± 0.20[c]	40.56	9.25 ± 0.08[c]	45.42
5	10.15 ± 0.10[c]	37.00	8.2 ±0.08[c]	44.82	11.25 ± 0.10[c]	43.04	9.0 ± 0.1[c]	46.9
F- value	54.80		73.50		115. 60		65.83	
P-value	<0.0001		<0.0001		<0.0001		<0.0001	
C.V (%)	15.50		14.20		12.60		11.80	

Means followed by the same letters within a column are not significantly different from one another (Student–Newman–Keuls test, $P < 0.05$).
Values are means of three replications, S.E= Standard error, C.V= coefficient of variation

Table 3: Estimated yield of cucumber in screen and field cages at different population densities of *Epilachna chrysomelina*

Infestation level (pairs)	Screen cage potted plants			Field cage plants		
	Number of fruits/cage	Fresh fruit yield/cage (t/ha)	Yield reduction (%)	Number of fruits/cage	Fresh fruit yield/cage (t/ha)	Yield reduction (%)
0	16.34 ± 1.46[a]	7.35 ± 0.55[a]	0.00	19.8±1.10[a]	8.91± 0.12[a]	0.00
1	14.76 ± 1.25[ab]	6.64 ± 0.63[ab]	9.66	16.5±1.50[b]	7.85±0.35[b]	11.89
2	12.5 ± 1.10[b]	5.63 ± 0.76[b]	23.40	15.11±1.3[b]	6.85±0.15[b]	27.05
3	7.4 ± 1.30[c]	3.33 ± 0.45[c]	54.69	10.25±1.20[c]	4.00±0.11[c]	55.11
4	3.75 ± 1.62[d]	1.69 ± 0.35[d]	77.01	7.35±1.0[d]	2.00± 0.21[d]	77.55
5	2.55 ± 1.20[d]	1.15 ± 0.42[e]	84.35	4.86±1.0[e]	1.26 ± 0.16[e]	85.85
F-value	14.1	23.41		28.7	56.25	
P-value	< 0.0001	< 0.0001		< 0.0001	< 0.0001	
C.V (%)	7.65	11.23		10.45	12.80	

Means followed by the same letters within a column are not significantly different from one another (Student–Newman–Keuls test, $P < 0.05$). Values are means of three replications, S.E= Standard error, C.V= coefficient of variation.

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