Journal of Animal &Plant Sciences, 2015. Vol.27, Issue 1: 4182-4192
Publication date 2/12/2015, http://www.m.elewa.org/JAPS; ISSN 2071-7024

Evaluation of the larvae abundance of *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae) in the phenological stages of eggplants (*Solanum aethiopicum*) in Azaguié, Côte d'Ivoire

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Keywords: *Leucinodes orbonalis,* borer larvae, abundance, *Solanum aethiopicum*, phenological stages.

1 SUMMARY

Eggplant shoot and fruit borer (EFSB), *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae) is a major pest that causes damage to the eggplants in Côte d'Ivoire. In order to establish an effective control method against this pest, a study of the abundance of larvae *L .orbonalis* according to phenological stages of eggplant was conducted in the locality of Azaguié, in Guinean area of Côte d'Ivoire. Investigations were carried out from October 2013 to June 2014. The method used were to a weekly counting of larvae on three varieties of the specie *Solanum aethiopicum* (Djamba F_1, Kotobi and N'drowa issia) from 21^{th} day after transplanting until the end of the harvest. All varieties recorded larvae during three phenological stages. The three varieties recorded more larvae at the fruiting stage than at the flowering and stage before flowering with 123.38 ± 4.09; 114.33 ± 4.22 and 106.18 ± 4.25 larvae per 24 plants respectively on Djamba F_1, Kotobi and N'drowa issia. Moreover, larvae were most abundant in the fruits than the shoots.

2 INTRODUCTION

Eggplant is one of the most consumed fruit vegetables in the world (FAO, 2008). *Solanum aethiopicum* commonly called African eggplant (De Bon, 1984; Djidji and Fondio, 2013). It is grown for its fruits and leaves that are used in various cooking techniques in Africa (N'Tamon, 2007). In Côte d'Ivoire, the crop is grown by small scale producers and is an important source of income for them (Fondio et *al.*, 2007). Unfortunately this vegetable is subject to attack by many pests among which the most damaging is the shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera : Pyralidae) (Figure 1). The larvae of this species attacks plants at all the stages development (CABI, 2007). Indeed larvae penetrate in the shoots and fruits affecting plant growth, fruit quality and leading to a sharp drop in production (Srinivasan, 2008). The losses caused by *L.orbonalis* can go up to 70 % of the production (Islam and Karim, 1991; Dhandapani et *al.*, 2003). In Côte d'Ivoire, the methods used to manage against pests of eggplant were ineffective for this pest, due to the ignorance of the dynamics of its population. The literature does not mention any study in Côte d'Ivoire on *L.orbonalis*. This study aims to determine larvae abundance of *L.orbonalis* according of the phenological stages of eggplant, to determine the stage most attacked and set up an effective control method.


Figure 1 : *Leucinodes orbonalis* (A : Larva ; B : Adult)

3 MATERIAL AND METHODS

3.1 Study area: The study was conducted in the locality of Azaguié (Latitude: 5°37' N and longitude: 4°02'W) located in the south of Côte d'Ivoire. The climate is subequatorial characterized by four seasons: two annual rainy seasons (from April to mid-July and September to November) and two dry seasons (from mid-July to August and December to March) (Vennetier and Laclavère, 1978; Anonymous, 1979). The study period extended from October 2013 to June 2014 with average temperatures varying from 26.3 to 28.3 °C, relative humidity ranging between 81.9 - 86.5% and total rainfall of 1702.56 mm.

3.2 Methods: Three varieties of eggplant of the specie *Solanum aethiopicum* were used in this study: Djamba F_1, Kotobi and N'drowa issia. The choice of these varieties was justified by their abundance in the market and their preference by consumers.

3.2.1 Nursery: To make the nursery, ground (1 m x 1 m) for each variety was ploughed to 20 cm high in October, 14 th 2013. After an application of poultry manure at 10 Kg / m^2 and chemical fertilizer NPK (10-22-22) at 50 g / m^2, the plot was again ploughed and disinfected by Furadan® 10 G (50 g / m^2). Fourteen days after (October, 28 th 2013), the seeds were sown. Five days after, the seedling obtained seedlings obtained were covered with palm leaves to 1.5 m above the ground. The seedling has were regularly watered until obtaining seedlings ready to be transplanted.

3.2.2 Experimental field: The size of the experimental plot was 393.3 m^2 with 28.5 m at length and 13.8 m at wide. It was a Randomized Complete Block Design (RCBD) with three replications. Each block consisted of three subplots each measuring 7.5 m length and 2.6 m wide, the subplots were spaced 3 m. Each sub plot was composed of three in ploughed land spaced to 1 m from each other. Forty-five days old seedlings are transplanted to December 13 th 2013 on the in ploughed land spaced 0.5 m on the same line. A line was composed of 16 plants so 48 plants per subplot and 432 plants on the whole plot. After transplanting, the plants were watered twice a day during twenty-one days and after once a day during fourteen days. The chemical fertilizer NPK (2 kg / 100 m^2) and urea (1 kg / 100 m^2) were applied the 14 th and 28 th days after transplanting respectively to favour good plant growth. A mixture urea (1 kg / 100 m^2) and sulphate potash (2 kg / 100 m^2) was brought to the ground the 70th day after transplanting. The experimental plot were not treated with any pesticide during the experimentation.

3.2.3 Counting of larvae *Leucinodes orbonalis:* The counting larvae on the plants of eggplant began twenty-one days after transplanting (DAT) from the stage before flowering stage until fruiting stage. Every week the larvae were counted on 24 randomly selected plants of each variety. Stage before flowering stage and flowering stage plants were inspected meticulously for to search and to count the larvae in the shoots. At the fruiting stage besides counting the larvae in the shoots, five fruits per plant were harvested for to count larvae in infested fruits.

3.2.4 Statistical Analysis: All data processing was performed using statistical software version 7.1. An analysis of variance (ANOVA) revealed significant differences between the data; the test of Newman-Keuls at 5% was used for to separations the means.

4 RESULTS

4.1 Larvae abundance at the stage before flowering: The three varieties did not have larvae by the 21th and 28 th days after transplanting (DAT). At the 35, 42 and 49 th DAT, the highest larvae numbers (4.33 1.20; 7 ± 0. 57 and 8.66 ± 0.88 larvae per 24 plants) were recorded on Kotobi and the lower mean numbers of larvae (0.66 ±0.33; 1.33 ± 0.88 and 2 ± 0.57 larvae per 24 plants) were observed on N'drowa issia. Statistical analysis indicated high significant differences between the mean numbers of larvae ($F = 28.94$; $df = 14$; $P < 0.001$) on the varieties (Table 1).

Table 1: Mean numbers of larvae of L. *orbonalis* in the shoot of the eggplant varieties at the stage before flowering

Number of days after transplanting (DAT)	Varieties – Larvae per 24 plants		
	Djamba F_1	Kotobi	N'drowa issia
21	0 ± 0^{f}	0 ± 0^{f}	0 ± 0^{f}
28	0 ± 0^{f}	0 ± 0^{f}	0 ± 0^{f}
35	3 ± 0.57^{d}	4.33 ± 1.20^{cd}	0.66 ± 0.33^{f}
42	4.66 ± 0.33^{cd}	7.00 ± 0.57^{b}	1.33 ± 0.88^{ef}
49	5.33 ± 0.33^{c}	8.66 ± 0.88^{a}	2 ± 0.57^{ef}

The averages followed by the different letters are significantly different (Newman-Keuls test at the threshold of 5 %).

4.2 Larvae abundance at the flowering stage: At the beginning of flowering (56 th DAT the larvae counted on the N'drowa issia were 3 ± 0. 57 per 24 plants. Larvae recorded on the varieties Djamba F_1 and Kotobi were 6.33 ± 0.33 and 6.66 ± 1.20 per 24 plants respectively which is double of larvae number registered on N'drowa issia. These mean numbers have increased progressively for to reach of the values at the end flowering stage (84th DAT) of 11.66 ± 2.18; 13.33 ± 1.45 and 17.66 ± 2.02 larvae per 24 plants respectively on N'drowa issia, Kotobi and Djamba F_1. The analysis of variance revealed significant differences between mean numbers of larvae ($F = 8.10$; $df = 14$; $P < 0.001$) (Table 2).

Table 2: Mean numbers of larvae of *L. orbonalis* in the shoot of the eggplant varieties at the flowering stage

Number of days after transplanting (DAT)	Varieties		
	Larvae per 24 plants		
	Djamba F_1	Kotobi	N'drowa issia
56	6.33 ± 0.33^{bcd}	6.66 ± 1.20^{bcd}	3 ± 0.57^{e}
63	8 ± 1.15^{bc}	5 ± 1.64^{cde}	5 ± 1.52^{cde}
70	6.66 ± 1.45^{bcd}	7 ± 2^{bcd}	4.33 ± 0.33^{de}
77	12.33 ± 0.66^{ab}	8.33 ± 2.02^{bc}	5.66 ± 0.33^{cde}
84	17.66 ± 2.02^{a}	13.33 ± 1.45^{b}	11.66 ± 2.18^{bc}

The averages followed by the different letters are significantly different (Newman-Keuls test at the threshold of 5 %).

4.3 Larvae abundance at the fruiting stage: The larvae were counted in both the shoots and fruits. On the three varieties the larvae population increased progressively from beginning fruiting stage (91th DAT) until their peaks (158.67 ± 1.45 larvae per 24 plants) on Djamba F_1 at 133 th DAT and 140 th DAT on the varieties Kotobi (150.67 ± 0.33 larvae per 24 plants) and N'drowa issia (141.67 ± 2.52 larvae per 24 plants). From 140 th and 147 th DAT, the numbers of larvae progressively decreased on each variety until to reach of values at the end of fruiting stage (175 th DAT) of 65.67 ± 2.19 ; 52.33 ± 3.28 and 42 ± 1.15 larvae per 24 plants on Djamba F_1, Kotobi and N'drowa issia respectively Analysis of variance showed significant differences between the mean numbers of larvae ($F = 136.57$; $df = 38$; $P < 0.001$) on the three varieties (Table 3).

Table 3: Mean number of larvae of *L. orbonalis* in the shoot of the eggplant varieties at the fruiting stage

Number of days after transplanting (DAT))	Varieties		
	Larvae per 24 plants		
	Djamba F_1	Kotobi	N'drowa issia
91	113.67 ± 2.73^{hij}	105.33 ± 1.76^{jk}	100.67 ± 1.2^{kl}
98	119.33 ± 1.76^{ghi}	109.33 ± 1.86^{ij}	103.33 ± 1.33^{jkl}
105	124 ± 2.89^{gh}	112 ± 0.58^{hij}	107.67 ± 1.86^{ijk}
112	130.33 ± 2.85^{fgh}	117 ± 2.89^{ghi}	113.67 ± 0.67^{hij}
119	137 ± 1.53^{efg}	123 ± 0.58^{gh}	119 ± 1.15^{ghi}
126	146.67 ± 0.67^{c}	133 ± 1.15^{fg}	123.67 ± 1.33^{gh}
133	158.67 ± 1.45^{a}	136.33 ± 2.33^{efg}	129.67 ± 0.33^{fgh}
140	146.33 ± 1.33^{c}	150.67 ± 0.33^{b}	141 ± 2.52^{e}
147	141 ± 0.58^{e}	140.33 ± 0.67^{ef}	133 ± 2^{fg}
154	129 ± 1.73^{fgh}	128.33 ± 6.77^{fgh}	110.33 ± 2.6^{ij}
161	108 ± 6.11^{ijk}	102 ± 1.53^{jkl}	85 ± 2^{klm}
168	84.33 ± 3.48^{klm}	76.67 0.33^{lmn}	71.33 ± 0.88^{mn}
175	65.67 ± 2.19^{n}	52.33 ± 3.28^{o}	42 ± 1.15^{p}

The averages followed by the different letters are significantly different (Newman-Keuls test at the threshold of 5 %).

4.4 Comparison larvae counted in shoots than those counted in the fruits of each variety

- **Djamba F1:** During the fruiting stage larvae were counted in large numbers in fruits than in shoots. At the beginning of fruiting stage (91th DAT) Djamba F_1 hosted 93 ± 2.08 larvae per 24 plants in the fruits and 20.67 ± 1.45 larvae per 24 plants in the shoots. These numbers progressively increased in the two organs until to reach their peaks at 133 th DAT with 40.67 ± 0.33 and 118.67 ± 1.15 larvae per 24 plants in the shoots and fruits respectively. From 140 th until the end of the fruiting stage (175 th DAT) the population larvae decreased progressively for to reach 14.33 ± 0.67 and 51.33 ± 2.03 larvae per 24 plants in shoots and fruits respectively. Statistical analysis revealed highly significant differences between the mean numbers of larvae ($F = 64.52$; $df = 38$; $P < 0.001$) in the two organs (Figure 2 A).
- **Kotobi :** Kotobi registered more larvae in fruits than in the shoots during fruiting stage. At the beginning of fruiting stage the mean numbers of larvae were 16 ± 0.58 larvae per 24 plants in the shoots and 89.33 ± 1.2 in the fruits. The larvae population increased for to reach their maximum in shoots (35.33 ± 0.88 larvae per 24 plants) and fruits (115.33 ± 0.67 larvae per 24 plants) to 140 th DAT. From 147 th, the larvae population decreased progressively until the end of fruiting (175 th DAT) for to reach 11.67 ± 0.33 and 40.67 ± 2.96 larvae per 24 plants in the shoots and fruits respectively .The statistical analysis showed highly significant differences between the mean numbers of larvae ($F = 504.11$; $df = 38$; $P < 0.001$) in the two organs (Figure 2 B).
- **N'drowa issia:** N'drowa issia as the first two varieties (Djamba F_1 and Kotobi) also recorded more larvae in fruits than in the shoots during the fruiting stage. At the beginning of fruiting stage (91 th DAT) shoots and fruits registered respectively the mean numbers of the larvae of 14.33 ± 0.67 and 86.33 ± 1.85 larvae per 24 plants. These numbers increased progressively for reach their peaks in shoots (30.33 ± 1.45 larvae per 24 plants) and fruits (110.67 ± 1.45 larvae per 24 plants) to 140 th DAT. These mean numbers decreased progressively from 147 th DAT to 175 th DAT for to reach 9.33 ± 0.33 larvae per 24 plants in the shoots and 32.67 ± 1.45 larvae per 24 plants in the fruits. The statistical analysis indicated highly significant differences between the mean numbers of larvae ($F = 1115.10$, $df = 38$; $P < 0,001$) in the two organs (Figure 2 C).

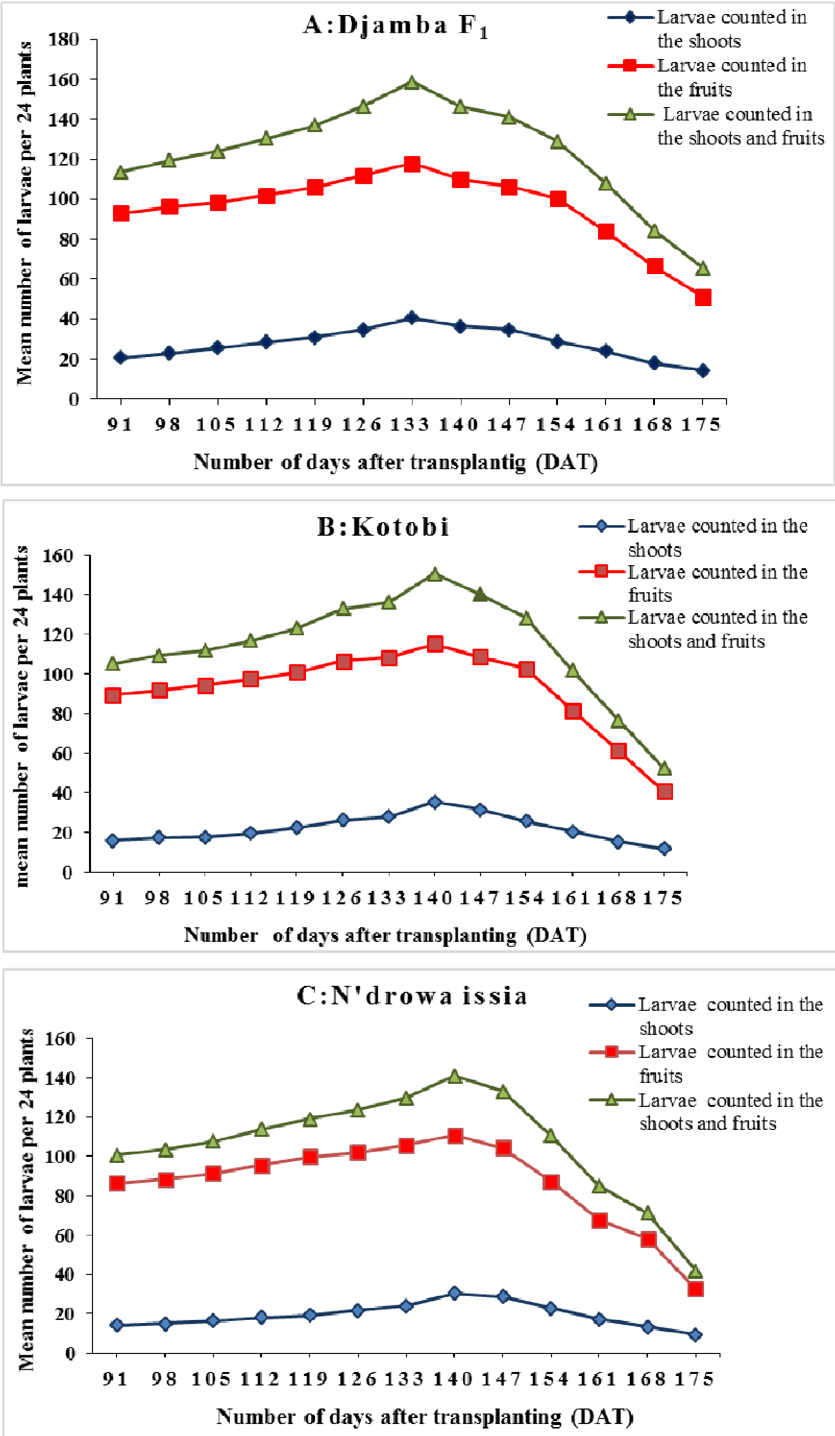

Figure 2: Mean numbers of larvae counted in the shoots and fruits of three Eggplant varieties Djamba F_1 (A), Kotobi (B) and N'drowa issia (C).

4.5 Comparison larvae abundance following the three phenological stages : The highest mean numbers of larvae were recorded at the fruiting stage for the three varieties (Djamba F_1: 123.38 ± 4.09 per 24 plants ; Kotobi : 114.33 ± 4.22 per 24 plants ; N'drowa issia : 106.18 ± 4. 25 per 24 plants). Flowering stage and stage before flowering have registered lower larvae for each variety with respectively 10.20 ± 1.33 and 2.60 ± 0.61 per 24 plants for Djamba F_1 ; 8.33 ± 0.92 and 4.00 ± 0.98 per 24 plants for Kotobi ; 5.86 ± 0.93 and 0.80 ± 0.27 per 24 plants for N'drowa issia. Analysis of variance showed highly significant differences between the mean numbers of larvae for the three varieties following phenological stages ($F = 192.56$; $df = 8$; $P < 0.001$) (Figure 3).

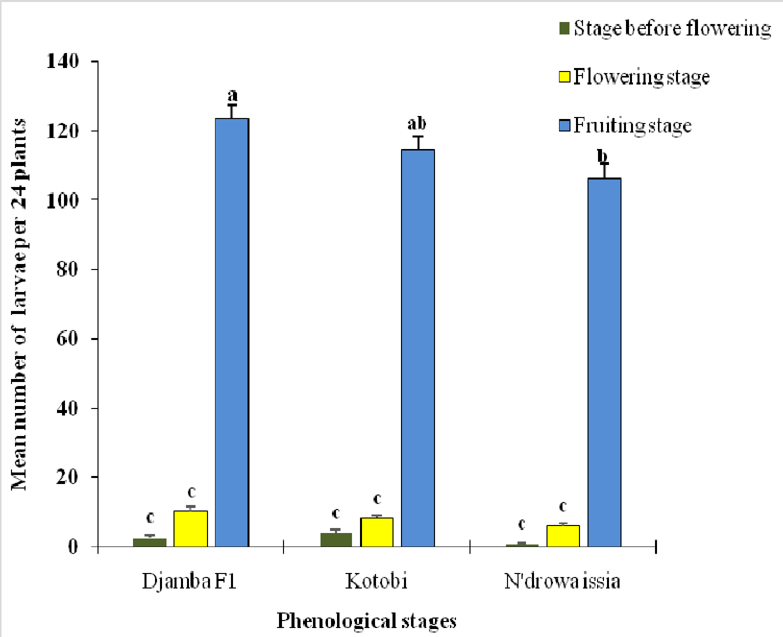

Figure 3: Mean numbers of larvae of L. *orbonalis* of the eggplant varieties following the three phenological stages.

5 DISCUSSION

During this study, no larvae were observed on the 3 varieties of eggplant between 21th and 28 th days after transplanting (DAT). This would be due to absence of laying site for adults and nutrient source for larvae. So we could think that there would have been no mating and eggs laying by *L.orbonalis* adults Indeed females of species of insects whose larvae are less mobile like those *L.orbonalis* reassure is the existence of laying site can to provide an available source of food and favourable shelter for to development of their offspring (Robert, 1986). The lower numbers of larvae observed on N'drowa issia at 35, 42 and 49 th DAT could be explained by the small size of the plants of this variety. At this stage of before flowering, plants have to emit amount of kairomone that probably attracts a small number of females for laying. That be can related also to the presence of natural enemies notably the predator *Cheilomenes sulphurae* (ladybird) (Coleoptera: Coccinelidae) that we observed in our samples (Kadam et *al.*, 2006). The high numbers of larvae at 35, 42 and 49 th DAT on the variety Kotobi would be due to the fact of that fairly large plants that offer more tender shoots are used as shelter and food source for larvae. Females would have been attracted in large numbers by kairomones emitted by variety kotobi.

At the beginning flowering stage, the lower number of larvae observed on N'drowa issia is due to small number of females was attracted to lay egg on this variety. The high number of larvae at the end of flowering (84 th DAT) on each variety could be explained by the fact that plants bearing at this stage many flowers and tender shoots, have emitted quantity important of kairomone that therefore has attracted a high number of adults for mating and laying. In indeed in addition that kairomones attract insects, also stimulates the laid eggs (Stadler, 1978; Dindonis and Miller, 1980; Harris and Miller, 1982; Auger and Thibout, 1983; Levinson and Haisch 1984). The high number larvae on three varieties at 84 th DAT would be also due to temperature and relative humidity condition favourable for the development of the larvae during the observation period. This argument is similar to that of Douan et *al.* (2013) who reported that the high number of the cabbage pest, *Plutella xylostella* to 21 and 28 th DAT was related to favourable weather conditions. At the fruiting stage, the mean numbers of larvae reached its evolution peak at 133 th DAT for Djamba F_1 and for Kotobi and N'drowa issia at 140 th DAT. This is due to the fact that the plants have reached their maximum size and have therefore many branches containing enough young tender shoots, leaves, floral bud, flowers and fruits. That offer at the females of *L. orbonalis* of many laying substrate and an abundant food source for the larvae. The plants at this stage would have emitted an important quantity of kairomones that would have favoured mating and stimulated the egg laying of many females. Indeed Taley et *al.* (1984) and Alpuerto (1994) mentioned that *L. orbonalis* females could lay a large number of eggs during the night on leaves, flower buds and fruits calyx. This study results corroborate those N'Depo et *al.* (2009) who mentioned that it is during the period of fruiting mango trees that the population of *Bactrocera invadens* increased. The results also are similar to those of Seri - Kouassi (2004), who reported a high number of *Calosobruchus maculatus* during the fruiting stage. For this author the high number would be the consequence of the attraction of volatile substances emitted by *Vigna unguiculata* cloves on *C.maculatus*. The number of larvae in the three varieties decreased progressively at 140 th and 147th DAT until the end harvest (175 thDAT). This decrease would be related the lower of laying substrates females and nutrient resources larvae (less leaves, less shoots tender and less fruits) because plants were practically at the end of their cycle and have tendency to dry. At the end of the fruiting stage, plants have emitted a small quantity of kairomone with low odour that would be not too attractive to *L.orbonalis*. These results are in agreement with those of N'Zi et *al.* (2010) who reported that low numbers of adults and larvae of *Bemisia tabaci* at the end of cycle of the tomato was related at low attraction exerted by plants on *B.tabaci*. This study results rejoin those of Douan et *al.* (2013) who indicated that the lower number of adults and larvae of the cabbage pests, *Plutella sylostella, Hellula undalis and Spodoptera littoralis*, would be due to ageing the plants that rendered them less attractive. The counting of the larvae in sampled organs showed that they were more abundant in the fruits than in the shoots. This could be explained by the fact that during the period fruiting stage the plants would emit more attractive substance for females. Besides fruits, contain a high quantity of nutrients necessary for the development of larvae (N'Guessan et *al.*, 2011). The results of this study are also similar to those of Obodji et *al.* (2015) which revealed that mealybugs were encountered in large numbers on the pods that constituted a fixation site and nutrient sources for these. The results also corroborate those of Nguyen-ban (1984) which indicated that the pods constituted the reassembly points and nutrition for mealybugs with 60 - 80 % of the population.

6 CONCLUSION

The study of the larvae abundance of *L.orbonalis* of the three eggplant varieties showed that the population size of larvae varied with varieties and phenological stages of plant. On all the three varieties larvae have been counted to the three phenological stages. The fruiting stage registered high number of larvae corresponds the outbreak period of this pest. Besides the variety Djamba F_1 hosted at the fruiting stage the highest number larvae than the other two varieties. Djamba F_1 could be considered the preferred variety of *L.orbonalis*. The variety N'drowa issia has registered the low number of larvae during the three phenological stages than two other varieties. N'drowa issia could be considered less preferred. This variety would be probably being more resistant to *L.orbonalis*. The fruiting is the stage during which the pest is most abundant. These results should to enable establish an appropriate timetable of fight against *L.orbonalis*.

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