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FIELD TO LABORATORY STUDIES ON INFESTATION, DAMAGE, DEVELOPMENT AND METAMORPHOSIS BY *LEUCINODES ORBONALIS* GUENÉE (LEPIDOPTERA: PYRALIDAE) USING SIX VARIETIES OF EGGPLANT

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ABSTRACT
Field-to-laboratory studies on the infestation, damage, development and metamorphosis by *Leucinodes orbonalis* Guenée (Lepidoptera: Pyralidae) were carried out using six varieties of eggplants in Port Harcourt, Rivers State, Nigeria under laboratory mean temperature and relative humidity conditions of 29.8 ^{o}C and 78.1 %, respectively. Four local government areas (Etche, Khana, Obio-Akpor and Oyigbo) important for eggplant growing were surveyed for *L. orbonalis* infestation. Four local eggplant varieties (gauta green, yallow big white, yallow white oval and yallow white oval with green stripe) and two exotic varieties (barbentane and F1 African beauty) were used for the field and laboratory studies. The varieties were differentiated into two species, *Solanium aethiopicum* and *S. melongena*. Field experiment using a land area of 72 m^2 was laid out in a randomized complete block design with three replications while the laboratory experiment was arranged in a completely randomized design on workbenches with three replications. Results showed that the African eggplant (*S. aethiopicum*) farms in the local government areas investigated were infested with *L. orbonalis*. The indigenous and exotic varieties studied were not resistant to the insect pest infestation. There is need to develop *L. orbonalis* resistant eggplant varieties. Results of the metamorphosis of the eggplant fruit and shoot borer under humid tropical conditions in Rivers State, Nigeria agreed with the information in literature; in addition, the present study has revealed that pupation in cocoons off the fruits observed, has implications for the use of non-chemical control methods against the pest.

Keywords: Exotic varieties, *Solanum aethiopicum*, Key pest, Resistant, Cocoons

INTRODUCTION

Eggplants, *Solanum* spp. belong to the family Solanacaea. Members are close relatives of tomato, pepper and potato (Dias, 2012). In terms of production and consumption, China ranks first (Kemble, 1997). Eggplant is an important vegetable crop, cultivated for its fruits. The fruit contains vitamins A, B and C, carbohydrate, little protein, very low fat and high level of minerals such as calcium, phosphorus and iron (Dias, 2012). Eggplant is also considered important in places such as Kenya, Malaysia, Nigeria, Philippine and Senegal (PAN, 2010). In Nigeria, the Igbos offer visitors eggplant fruit (the African eggplant, *Solanum aethiopicum* L. in particular) to show hospitality as demanded by their custom. In Eastern Nigeria, the fruit is eaten fresh as food or used in salad preparation. In other parts of the world, eggplant fruit is eaten as a vegetable, boiled, fried or incorporated in stew. In fact, eggplant fruit deserves high level attention considering its nutritional profile and extent of use.

However, the production of eggplant is adversely affected by pests, diseases and unfavourable climatic conditions, resulting to yield losses in most cases (SEAME SEARCA, 2011). The most destructive insect pest of eggplant in Philippines and Asia is the fruit and shoot borer, *Leucinodes orbonalis* Guenée (Lepidoptera: Pyralidae). The pest is widespread and in Africa, countries such as Burundi, Cameroon, Congo, Ethiopia, Ghana, Kenya, Lesotho, Malawi, Mozambique, Nigeria, Rwanda, Sao Tome, Sierra Leone, Somalia, South Africa, Tanzania, Uganda, Zambia and Zimbabwe are affected (CIE, 1976; Tamaki and Miyara, 1982; Veenakumari *et al*., 1995). Estimates of yield losses due to the damage caused by the Lepidopteran vary from country to country (Francisco, 2007). Yield losses attributable to the pest can be up to 100 % (Talekar, 2002). In Nigeria, *L. orbonalis* also causes varying degree of damage to eggplant. The crop is attacked at all stages (nursery to harvest) by *L. orbonalis* (Onekutu *et al*., 2010). The larva bores into the tender shoots of seedling and older plants which inadvertently leads to wilting and death of the tips. When the fruits are affected, infestation leaves characteristic circular holes, sometimes containing frass. This leads to inevitable loss of visual appeal and poor market value of the fruits (Waterhouse, 1998).

Metamorphosis in the insect is complete and infestation and its development are related to some environmental factors of temperature, relative humidity and rainfall (Anilkumar *et al*., 1997). However, this is normal with most insects. Various control measures have been used to manage *L. orbonalis* infestation and development in eggplant fruits. Such measures apparently include use of chemical insecticides and non-chemical treatments (Onekutu and Omoloye, 2015). Chemical insecticides are associated with health, environmental and cost problems while the use of mechanical and cultural practices have not been found sustainable. Resistant varieties can reasonably minimize the problems of pesticide application. In addition, it is economical in the long-run and more sustainable when compared to mechanical manipulations (Onekutu and Omoloye, 2015). In fact, resistant varieties are safe and effective in controlling eggplant fruit and shoot borer (AVRDC, 2003). Interestingly, it can be easily incorporated into an integrated pest management programme (Mannan *et al*., 2003).

Routine monitoring and evaluation of *L. orbonalis* infestation and development are necessary due to the level of economic importance of the pest. Therefore, the objectives of the research were to investigate the rate of infestation and development of *L. orbonalis* in some local and exotic varieties of eggplant, their resistance status and to determine the metamorphosis of the insect pest in a humid tropical climate.

MATERIALS AND METHODS

Survey for *Leucinodes orbonalis* in Rural Eggplant Farms

Four local government areas in Rivers State, Nigeria were surveyed for *L. orbonalis* infestation. The local government areas were Obio-Akpor, Etche, Oyigbo and Khana situated on latitude 4.54^0 North and longitude 6.55^0 East. Two eggplant (*Solanum aethiopicum* L.) farms owned by local residents were considered in each local government area during the survey. Farms infested by *L. orbonalis* (after stand to stand survey) were designated positive or negative when un-infested. In addition, ten fruits were collected at random from each farm and put into clean, labeled glass jars for subsequent laboratory studies.

Solanum Varieties Used in the Field and Laboratory Experiments

Four local eggplant varieties of *S. aethiopicum* (gauta green, yallow big white, yallow white oval and yallow white oval with green stripe) and two exotic varieties (barbentane and F1 African beauty) were used for the field and laboratory studies. Barbentane is a variety of *S. melongena*.

Raising, Transplanting of Seedlings and Routine Maintenance

This part of the study was carried out on the research farm of Faculty of Agriculture, University of Port Harcourt, Rivers State, Nigeria. Seeds of each variety were purely sown in labeled plastic baskets filled with top soil (0 – 3 cm depth). Seedlings were transferred to the nursery 14 days after sowing (DAS). A total of 100 plantlets were raised in plastic cups for each variety. Transplanting was done 28 DAS (AVDRC, 2010). Each variety was transplanted (45 cm x 45 cm) on 1 m x 1 m plots in three replicates with a border space of 5 cm. Land-area of 72 m^2, 18 beds and 1 m walkways sufficed. The experiment was laid out in randomized complete block design. The crops were irrigated to ensure adequate moisture. They were staked at 4 weeks after transplanting to support the eggplants against fruit load and wind stress. Older leaves were removed from the lower portions of the plants (pruned) to allow free air circulation and lightening (AVRDC, 2010). The plots were weeded manually on regular basis. Organic fertilizer (poultry droppings) was applied over the beds in order to improve the overall structure and condition of the soil (AVRDC, 2010). Inorganic fertilizer (NPK 15:15:15) was applied at the rate of 50 kg per hectare 28 DAS. Ten eggplant fruits from each variety and from each replicate were randomly harvested and used for the laboratory investigations.

Laboratory Investigations

The extent of damage by *L. orbonalis* to the fruits of the test varieties, rate of development of the insect pest/ metamorphosis and varietal resistance were investigated in the Crop Protection laboratory of Department of Crop and Soil Science, University of Port Harcourt at ambient temperature and relative humidity of 29.8 ^oC and 78.1 %, respectively. The experimental glass jars (1-Litre capacity) were sterilized by washing with 5 % sodium hypochlorite solution. The harvested fruits used for the laboratory studies were washed with same solution to ensure disinfestations and to eliminate any agent of deterioration. To determine the functional capacity of the pest, four freshly harvested eggplant fruits obtained from farmers' fields and experimental sites were kept in each jar and were covered with nets held in place with jar-lids cut open. All designated openings ensured good ventilation while coverings prevented escape of emerged *L. orbonalis* and entry of intruders. The treatments were replicated three times and kept on the laboratory bench in a completely randomized design. After 7 days, data on exit holes, number of pupa, number of emerged adults and development period were collected and recorded per species and per variety to reveal species-varietal differences. Metamorphosis of *L. orbonalis*, its stages and their morphological characteristics were monitored and recorded.

Statistical Analysis

Data on insect exit hole, number of pupa, number of emerged adults and development period were transformed using square root of (x+1). One-way analysis of variance was employed to analyze collected data while SPSS (Statistical Package for the Social Sciences) version 19.0 software was used to run the analysis. Upon significance of the F-test, means were separated using Least Significant Difference (LSD) at α level of 0.05. Original data were presented in the result tables while transformed data were only used for the statistical analysis carried out.

RESULTS

Infestation, Damage and Development by *L. orbonalis* on Eggplant Fruits from Rural Farms

The African eggplant farms (owned by local residents) in the four local government areas of Rivers State, Nigeria surveyed were all positive for *L. orbonalis* infestation (100 % field infestation). Results of *L. orbonalis* exit holes, developmental period, pupa number and number of emerged adults from eggplants sampled from different fields in the four local government areas and investigated in the laboratory are presented in Table 1. There was significantly higher *L. orbonalis* exit holes, pupa number and number of emerged adults from eggplants sampled from Etche. Developmental period of the insect pest in fruits sampled from Etche was significantly longest and was closely followed by eggplant fruits sampled from Khana. There was no statistical difference in the period it took *L. orbonalis* to develop to the adult stage in samples from Obi-Akpor and Oyigbo.

Species-varietal Differences and Susceptibility of Eggplants from Research Farm to *L. orbonalis* Damage and Development

Table 2 presents the comparative results of *L. orbonalis* exit holes, developmental period, pupa number and adult progeny on two species and six varieties of eggplant harvested from the Research Farm. Gauta green variety (species, *S. aethiopicum*) had the highest number of exit holes, pupa number and adult progeny while variety F1 African beauty (species, *S. aethiopicum*) recorded the least. Variations in terms of insect exit holes, pupa

number and number of emerged adults among the two species and six varieties of eggplant were not statistically significant. *Leucinodes orbonalis* developmental period was statistically longest in F1 African beauty. However, developmental period of the moth in F1 African beauty did not differ significantly with that of Barbentane (species, *S. melongena*), Gauta green, Yallow big white and Yallow white oval (species, *S. aethiopicum*). Meanwhile, developmental period of *L. orbonalis* was shortest in Yallow oval with green stripes. The length of developmental period of the insect observed in variety Yallow oval with green stripes did not differ statistically with the time it took *L. orbonalis* to develop in Yallow big white and Yallow white oval varieties.

Species-varietal-related Metamorphosis of *L. orbonalis*

Table 3 presents the metamorphosis of *L. orbonalis* eggs to fourth larval instar, pre-pupa, pupa and adult on different species and varieties of eggplants. The longevity of each life stage was a range and varied from one another. Morphological characteristics of each developmental stage also varied from the other.

Table 1 Damage caused by *L. orbonalis* and its development on African eggplant fruits harvested from rural farms in four local government areas of Rivers State, Nigeria

L.G.A.	No of exit holes	No of pupa	No of emerged adults	Development period*
Etche	5.26±2.50[a]	4.73±2.40[a]	3.62±2.17[a]	11.09±3.48[a]
Khana	0.17±1.08[b]	0.17±1.10[b]	0.17±1.08[b]	0.14±1.46[b]
Obio-Akpor	0.00±0.00[c]	0.00±0.00[c]	0.00±0.00[c]	0.00±0.00[c]
Oyigbo	0.00±0.00[c]	0.00±0.00[c]	0.00±0.00[c]	0.00±0.00[c]
F statistic	118.4	94.9	97.7	84.9
P value	< 0.05	< 0.05	< 0.05	< 0.05

Mean ± SEM
*Development period in days

Table 2 Species-varietal differences of the eggplants from Research Farm and their susceptibility to *L. orbonalis* damage and development.

Eggplant species	Variety	Race	No of exit hole	No of pupa	No of emerged adult	Developmental period*
S. aethiopicum	Gat	Local	2.33±0.21[a]	2.33±0.50[a]	2.33±1.47[a]	11.00±2.71[a]
S. aethiopicum	Ybw	Local	2.00±0.13[a]	2.00±0.42[a]	1.67±0.66[a]	12.67±0.04[a]
S. aethiopicum	Ywo	Local	1.67±0.11[a]	1.67±0.13[a]	1.67±0.98[a]	10.67±2.50[a]
S. aethiopicum	Yog	Local	1.00±0.05[a]	1.00±0.15[a]	1.00±0.01[a]	11.00±0.22[a]
S. melongena	Bab	Exotic	0.67±0.29[a]	0.67±0.35[a]	0.67±0.02[a]	10.67±0.87[a]
S. aethiopicum	Fab	Exotic	1.00±0.15[a]	1.00±0.27[a]	1.00±0.01[a]	11.33±1.33[a]
F statistic			0.7	0.7	0.43	1.3
P value			> 0.05	> 0.05	> 0.05	> 0.05

Mean ± SEM
*Development period in days

Gat = Gauta green; Ybw = Yallow big white; Ywo = Yallow white oval; Yog = Yallow white oval with green stripes; Bab = Barbentane; Fab = F1 African beauty

Table 3 Stages of *L. orbonalis* development and metamorphosis on different species and varieties of eggplants in the laboratory

Insect stage	Period spent	Morphology and activity level
First larval instar	Un-quantified	Creamy white, active
Fourth larval instar	8 – 12 hours	Pinkish, reduced activity
Pre-pupa	4 – 6 hours	Pinkish to dark-pink, inactive
Pupa	10 – 13 days	Dirty brown-black, silky cocoons
Adult	4 – 5 days	White and brown, active

DISCUSSION

The field-survey showed presence of *L. orbonalis* in all the rural farms sampled and this suggests that the insect pest is well-distributed in Rivers State, Nigeria. This current observation therefore concurs with earlier findings by Parker *et al*. (1995) that *L. orbonalis* is a tropical pest which occurs in many countries of the world including Nigeria. Observations on the eggplants in the research farm showed that *L. orbonalis* infestation starts at the shoots and then migrates to the fruits where damage proceeds until infestation diminishes following harvest (outcome of regular inspection). This observation also corroborates the findings of earlier workers (Mall *et al*., 1992).

The two species and six varieties of eggplant investigated had *L. orbonalis* infesting, damaging and developing in their fruits suggests that none is immune. The analysis of results further revealed that the eggplant species and varieties did not differ considerably in their ability to resist *L. orbonalis* attack. In a recent study by Onekutu *et al.* (2015), no test variety of the eggplant was immune and as a matter of fact, no immune variety is known for *S. aethiopicum* and *S. melongena* against *L. orbonalis* infestation, damage and development. Indeed, the local and exotic varieties tested in this study showed varying degrees of susceptibility to the borer and this is strongly attributed to genetic effects. F1 African beauty and yallow white oval with green stripes of the species, *S. aethiopicum* resisted the borer best in the sense that they recorded least number of insect exit holes, pupa and adult progeny. Gauta green variety was most vulnerable on accounts of it having the highest number of insect exit holes, pupa and emerged adults. It is not surprising that the test crop varieties expressed varying magnitudes of susceptibility to the pest. Whereas, it is surprising that Barbentane variety of the species, *S. melongena* tested in this study was not resistant to *L. orbonalis* infestation and damage. In an earlier study, variety EGO75 belonging to the same species, *S. melongena* was found resistant to all aspects of the pest's bionomics (AVRDC, 2003). However, in terms of causing delay to the development of the borer, Barbentane matched variety EGO75 (inferred from literature) and this shows species similarity. Morphological and structural characters of host plants such as thickness of tissues, protective and anatomical structures affect the choice of phytophagus insects such as the eggplant fruit and shoot borer, *L. orbonalis* (Hossain *et al*., 2002; Mannan *et al*., 2003; Onekutu *et al*., 2015). It is known that they affect insect behavior such as feeding, mating and oviposition. No wonder, breeders and entomologists have been advised to capitalize on the genetic bases of resistance to develop varieties with good resistance, high yield and palatable qualities through hybridization and selection. In fact, the benefits of use of resistant varieties in coping with infestation,

damage and development by *L. orbonalis* cannot be over-emphasized.

It is interesting that the metamorphosis of *L. orbonalis* was revisited in Rivers State, Nigeria, a humid tropical climate. Mature larvae were pinkish in colour and turned darker as they neared pupation. First 2 hours into pupation, the cocoons were transparent with visible quiescence larvae in coiled orientation in which they remained throughout the pupal period. Cocoons went completely dirty-dark within 8 hours, leaving the pupating larvae invisible, unless cut open. In the present investigation in Rivers State, Nigeria, some larvae were incapable of producing cocoons (reasons not known), however, for such larvae pupation still occurred outside cocoons. The present observation on *L. orbonalis* young caterpillars' creamy white appearance and light pinkish when fully grown is in agreement with the observations of Wankhede *et al*. (2009). The pupal period of 10 – 13 days observed agrees with the findings of Mehto *et al*. (1980) and Baang and Corey (1991) that reported 9 – 13 days pupal period. The observation that larvae pupated in cocoons on the fruits in the glass jars tallied with the findings of Tamaki and Miyara (1982), Khoo *et al*. (1991) and Yin (1993) that mature larva pupates within a tough silken cocoon on the fruit. We observed that larvae also pupated on the floor of the glass jars; this has implications for non-chemical control of the pest.

In conclusion, *L. orbonalis* was a key pest of the African eggplant, *S. aethiopicum* in the local government areas of Rivers State, Nigeria investigated. The indigenous and exotic varieties screened were not resistant to the insect pest and if one must recommend any variety for growing based on the outcome of this study, it is F1 African beauty. The study calls for international concerted effort geared towards developing *L. orbonalis* resistant eggplant varieties. Results of the metamorphosis of the borer under humid tropical conditions agreed with the information in literature; in addition, the present study has revealed that pupation in cocoons off the fruits has implications for the application of non-chemical control measures on the pest.

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