Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.3, No.18, 2013

Evaluation of Eggplant, *Solanum* spp. Germplasm against Field Insect Pests' Infestation at Bunso in the Eastern Region of Ghana

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Abstract
Eggplant (*Solanum* spp.) germplasm from CSIR – Plant Genetic Resources Research Institute, Bunso, Ghana were evaluated in field experiments against insect pests' infestation during the major rainy seasons of 2009 and 2010. Twenty-six accessions were evaluated in 2009 and five were subjected to further evaluation in 2010. Insect species recorded on eggplant accessions in both years included *Aphis gossypii* (Glover), *Thrips tabaci* (Lindeman) and *Leucinodes orbonalis* (Gueneé). *Camponatus* sp. (carpenter ants) was also collected in 2009. In both 2009 and 2010, leaves of accession GH 5171 harbored significantly lower numbers of *A. gossypii*. Leaves of accessions GH 1208 and GH 1113 also harbored the least number of *T. tabaci* in 2009 and 2010, respectively. *T. tabaci* preferred flowers to leaves of all eggplant accessions evaluated in 2010. The population dynamics of *T. tabaci* also fluctuated less on eggplant flowers than on the leaves. The percentage stems attacked by *L. orbonalis* were not significantly different among accessions in both years. With respect to fruit infestation by *L. orbonalis*, although fruits of accessions GH 1208, GH 3944 and GH 3947 were significantly ($P < 0.001$) less susceptible to infestation in 2009 their yields were relatively low. Yield obtained ranged from 0 kg/ha in accession GH 1202 (2009) to 837.86 kg/ha in accession GH 5183 (2010). Accessions GH 1113 and GH 5171 combined a relatively good yield with moderate levels of tolerance to all insect pest species identified in this experiment and are consequently recommended for crop improvement programs.
Keywords: Accession, Aphis gossypii, eggplant, Leucinodes orbonalis, Thrips tabaci

1.0. Introduction

Eggplant, *Solanum* spp. is a fruit and leafy vegetable widely cultivated in West Africa (de Bon, 1984). Eggplant together with tomato and chili pepper constitute the three most consumed vegetables in Ghana (Horna and Gruère, 2006). Owing to the fact that eggplant is widely consumed on a daily basis especially in the forest zone, the crop represents a very important source of income for many rural and urban households (Danquah, 2000; Owusu- Ansah *et al.,* 2001).

Although currently, the crop is produced largely for the local market, small amounts are exported to Europe (Horna and Gruère, 2006). According to a report by the United States Agency for International Development and the West Africa Trade Hub (USAID and WATH, 2005) exports of eggplant from Ghana increased steadily from under 500 metric tonnes in 1996 to 1, 867 metric tonnes in 2003. Thus, whilst increased and year-round production of the crop has significant potential for poverty alleviation and livelihood diversification of poor rural and peri-urban households in Ghana, yields are still low owing to pest and disease constraints. For example, although the achievable yield for the crop is estimated at 15 metric tonnes/hectare/year, current average yield is 8 metric tonnes/hectare/year (MoFA, 2010).

Major insect pests that constraint eggplant production in Ghana includes whiteflies (*Bemisia tabaci* Gennadius), Aphids (*Aphis gossypii*), thrips (*Thrips tabaci*), Budworms (*Scrobipalpa blasigona*) Epilachna beetles (*Epilachna chrysomelina*) and the eggplant fruit and shoot borer (*Leucinodes orbonalis*) (Owusu-Ansah *et al.,* 2001; Srinivasan, 2009; Mochiah *et al*., 2011; MoFA, 2011). Whilst infestation by aphids and whiteflies can lead to the transmission of viral diseases and reduction of photosynthetic efficiency through the production of sooty mould, that by fruit borers can result in a significant reduction of yield. Patnaik (2000) for instance reported that *L. orbonalis* damage to fruit in the field ranges from 47.6 % to 85.8 % of harvest.

According to Horna *et al.* (2008), infestation by some of these pests significantly increases the probability that farmers would apply insecticides. Botwe *et al.* (2011) observed that some of these applications are done a day prior to harvest in order to obtain a good looking vegetable. Repeated application of insecticides at short intervals in disregard of pre-harvest intervals however exposes the environment, consumers and farmers to toxic residues that can persist even after processing (Bull, 1992) and also increases production costs and consequently, reduces profits from sale of produce. A study conducted by Davis (1997) in Akumadan in the Ashanti Region revealed that whilst farmers spent an average of US$ 300.00 on pesticides/acre, profits obtained from sale of produce ranged between US$ 250 – 1,500. In view of the problems associated with the use of insecticides to manage pests on eggplant, the identification and use of new sources of resistance/tolerance to eggplant pests for breeding resistant cultivars has been proposed as a sustainable alternative (Horna *et al.,* 2008). Although the development and dissemination of such a technology would enhance smallholder livelihoods by providing them with a more secure means of generating income, little research attention has been devoted to screening eggplant germplasm in Ghana. This study therefore undertook field screening of 26 accessions of eggplant in order to identify insect pest resistant/tolerant accessions for exploitation in crop improvement.

2.0. Materials and Methods

The studies were conducted on the research fields of the Plant Genetic Resources Research Institute of the Council for Scientific and Industrial Research (CSIR-PGRRI), Bunso, Ghana during the major rainy seasons of 2009 (March - August) and 2010 (April - September). Twenty-six accessions were evaluated in 2009, out of which five were selected and further evaluated against accession GH 5171 in 2010.

2.1. Field lay-out: Eggplant seedlings were transplanted at 1 m x 1 m four weeks after emergence at one plant per hill on three 8 m by 130 m blocks in 2009 and four 8 m x 30 m blocks in 2010. There were four rows of 7 plants of each accession per block and plants were maintained according to recommended production practices except that no insecticides or fungicides were applied.

A broadcast application of 15-15-15 (N-P-K) fertilizer at a rate of 7.3 g per plant was done three weeks after transplanting. The experimental design was randomized complete block replicated three times in 2009 and four times in 2010. Weeds were controlled manually when necessary.

2.2. Insect sampling: Foliage insect pests sampling commenced two weeks after transplanting of seedlings and was undertaken between 0800 and 1030 h. Two leaves from 10 randomly selected plants in the two middle rows of each plot were randomly collected and separately placed into 500 ml plastic bottles containing 70 % ethyl alcohol. Samples were transported to the laboratory where the leaves were washed to dislodge insects. The contents of the containers were examined under a stereo microscope at 40 magnification to identify adult insects. Due to logistical challenges, sampling of flower inhabiting insect pests could not be undertaken in 2009. The procedure for sampling foliage inhabiting pests was followed for sampling flower inhabitants when flowers became available in 2010.

Assessment of shoot damage by *L. orbonalis* was undertaken eleven weeks after seedling transplanting by closely examining eight randomly selected plants in each accession in each block for signs of *L. orbonalis* infestation (presence of frass or emergent holes on shoots as well as signs of drooping). The number of plants with signs of *L. orbonalis* infestation (plates 1 and 2) was expressed as a percentage of the total number of plants assessed.

2.3. Yield data: Mature eggplant fruits were harvested weekly. Harvested fruits of each accession were placed in labeled polythene bags and transported to the laboratory where the total number of fruits harvested per accession was counted and weighed using an electronic balance. The number of fruits with *L. orbonalis* damage was determined by visually inspecting the exterior surface of fruits for signs of *L. orbonalis* infestation (Plate 3). Damaged fruits were counted and expressed as a percentage of the total number of fruits harvested. Yield (kg/hectare) was estimated using the total weight of fruits harvested per accession.

2.4. Data analyses: Data collected were subjected to analysis of variance (ANOVA) using GENSTAT Discovery edition 4 (VSN International). Insect data were square root transformed using $\sqrt{x} + 0.5$ to normalize the distribution of the populations. Means were separated using the least significant difference (Lsd at 5 %).

3.0. Results

Insect species recorded on eggplant accessions in both years included *Aphis gossypii* (aphids), *Thrips tabaci* (thrips), *Camponotus* sp. (carpenter ants), nymphal stages of *Zonocerus variegatus* (variegated grasshopper), *Cheilomenes* sp. (lady bird beetles), *Leucinodes orbonalis* (Eggplant fruit and shoot borer) and fungus weevils (family Anthribidae). *A. gossypii* and *Camponotus* sp. were collected from the leaves and *T. tabaci* from both the leaves and flowers of eggplant accessions. *L. orbonalis* was recorded on eggplant shoots and harvested fruits.

In 2009, the number of *A. gossypii* and *T. tabaci* per leaf varied significantly ($P<0.001$) amongst accessions evaluated (Table 1). Relatively high numbers of *A. gossypii* were collected on accessions GH 4925 (2.72 per leaf), GH 3935 (2.04 per leaf) and GH 5172 (2.12 per leaf) whilst low numbers were collected on accessions GH 3949 (0.04 per leaf) as well as accessions GH 3943 and GH 1111 (0.11 per leaf). No *A. gossypii* were however collected from the leaves of the check, accession GH 5171 (Table 1). The number of *A. gossypii* collected per leaf over the sampling period in 2009 significantly ($P< 0.0001$) correlated ($r = 0.73$) with that of *Camponotus* sp. (ants). In 2010, although the number of *A. gossypii* collected per leaf of GH 5171) was less than that collected per leaf of all other accessions, the difference was not significant (Table 2).

Compared to *A. gossypii* infestation, the level of infestation by *T. tabaci* was generally low (less than 2.0 insects per leaf in both years). In 2009, a significantly ($P<0.001$) higher number of *T. tabaci* were collected per leaf of accessions GH 4928 (1.21), GH 3898 (1.11), 3944 (1.05) and accession GH 3947 (1.00) than per leaf of accessions GH 1208 (0.15), GH 1202 (0.21) and GH 1205 (0.25) (Table 1). Similarly, in 2010, significantly more *T. tabaci* were collected per leaf of accessions GH 1113 and GH 5162 than per leaf of the check accession (GH 5171). With respect to flower inhabitants, whilst the number of *T. tabaci* per flower of accession GH 5162 was not significantly (P<0.001) different from that of the check accession, it was significantly less than that found in flowers of other evaluated accessions (Table 2). Generally, more *T. tabaci* were collected from the flowers than the leaves of all accessions evaluated.

Table 1. Mean number (±SEM) of insect pest inhabitants of leaves of 26 accessions of eggplant (*Solanum* spp.) evaluated against field insect pests in 2009 at Bunso, Ghana.

Accession	Mean number of insects collected/leaf	
	A. gossypii	*T. tabaci*
GH 1090	0.82 ± 0.38	0.42 ± 0.16
GH 1111	0.11 ± 0.08	0.33 ± 0.09
GH 1113	0.37 ± 0.16	0.38 ± 0.14
GH 1154	0.57 ± 0.17	0.31 ± 0.14
GH 1164	0.25 ± 0.14	0.37 ± 0.14
GH 1172	0.26 ± 0.10	0.33 ± 0.16
GH 1202	0.75 ± 0.17	0.21 ± 0.15
GH 1205	0.17 ± 0.12	0.25 ± 0.12
GH 1208	0.23 ± 0.10	0.15 ± 0.10
GH 3896	0.63 ± 0.11	0.91 ± 0.18
GH 3898	1.06 ± 0.17	1.11 ± 0.18
GH 3923	0.29 ± 0.12	0.46 ± 0.12
GH 3935	2.04 ± 0.52	0.72 ± 0.18
GH 3943	0.11 ± 0.08	0.31 ± 0.10
GH 3944	0.12 ± 0.06	1.05 ± 0.11
GH 3947	1.57 ± 0.28	1.00 ± 0.14
GH 3949	0.04 ± 0.04	0.43 ± 0.15
GH 4925	2.72 ± 0.71	0.59 ± 0.17
GH 4928	0.23 ± 0.09	1.21 ± 0.21
GH 5162	1.54 ± 0.31	0.68 ± 0.15
GH 5168	0.76 ± 0.25	0.61 ± 0.15
GH 5170	0.49 ± 0.23	0.39 ± 0.14
GH 5171	0.00 ± 0.00	0.45 ± 0.15
GH 5172	2.12 ± 0.58	0.33 ± 0.11
GH 5180	0.42 ± 0.13	0.47 ± 0.14
GH 5183	0.76 ± 0.23	0.68 ± 0.18
Lsd 0.05)	1.09	0.45

Table 2. Mean number (±SEM) of insect pest inhabitants of leaves and flowers of five accessions of eggplant (*Solanum* spp.) evaluated against field insect pests in 2010 at Bunso, Ghana.

Accession	Mean number of insects collected on plants		
	A. gossypii/leaf	*T. tabaci*/leaf	*T. tabaci*/flower
GH 1113	0.07±0.02	0.25±0.04	2.03 ± 0.16
GH 3898	0.06±0.02	0.44±0.05	2.03 ± 0.14
GH 3949	0.32±0.01	0.46±0.05	2.60 ± 0.23
GH 5162	0.05 ±0.02	0.38±0.05	1.48 ± 0.13
GH 5183	0.08±0.02	0.41±0.05	2.15 ± 0.19
Check	0.02±0.01	0.42±0.05	1.53 ± 0.11
Lsd (0.05)	N.S	0.14	0.46

The population dynamics of *A. gossypii* and *T. tabaci* on the leaves of selected eggplant accessions subjected to further evaluation in 2010 is shown in Fig 1. The incidence of both insects commenced on 7th July and peaked on 14th July 2010. Between the 14th of July and 4th of August the population density of *A. gossypii* experienced a sharp decline after which it increased sharply and attained its peak (1.0 insect per leaf) on 11th August. With respect to *T. tabaci*, the minor population peak occurred on 4th July and the major population peak (0.4 insects per leaf) occurred on 18th August. The population dynamics of *T. tabaci* on eggplant flowers was however less variable than on eggplant leaves (Fig 2). The number of *T. tabaci* collected per flower of accession GH 1113 on different sampling dates for instance ranged between 2.4 and 3.0 per flower. For accessions GH 3898, GH 5162 and GH 5171, the number per flower ranged between a low of 1.2 and a high of 2.0 insects per flower.

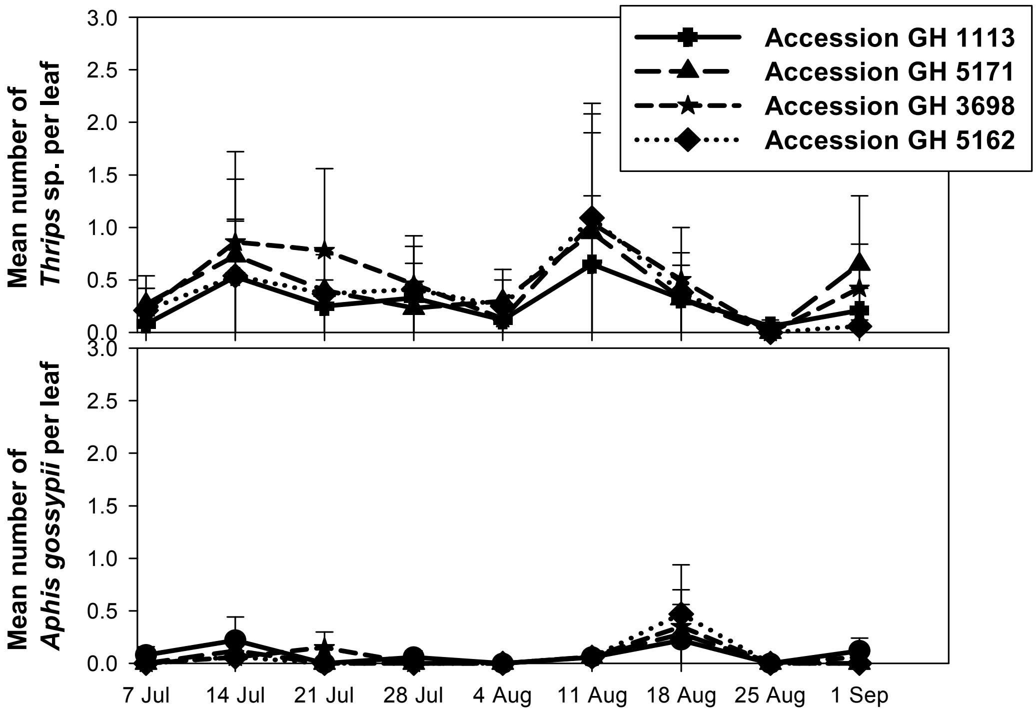

Fig. 1. Mean densities of *T. tabaci* and *A. gossypii* on *Solanum* spp. leaf samples collected between July and September 2010 at Bunso, Ghana.

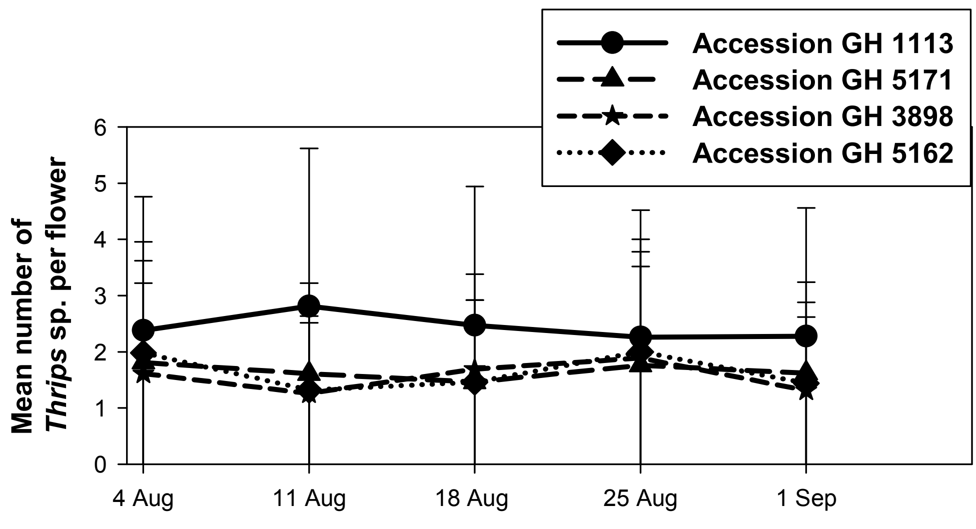

Fig. 2. Mean densities of *T. tabaci* on eggplant (*Solanum* spp.) flower samples collected between August and September 2010 at Bunso, Ghana.

Differences in the percentage of plants with visible signs of *L. orbonalis* infestation (Plate 1) amongst eggplant accessions in both years were not significant. Results for *L. orbonalis* damage to eggplant fruits are shown on Tables 3 and 4. Fruits of all accessions harvested in both years suffered attack (Plates 2 and 3). In 2009, the percent of fruits of accessions GH 1208 (0.3 %), GH 3944 (0.3 %) and GH 3947 (0.3 %) with *L. orbonalis* damage were significantly (P < 0.001) lower than that harvested from accessions GH 3945 (41.7 %), GH 5180 (39.3 %), GH 3898 (38.2 %) and GH 4925 (35.4 %) (Table 3). In 2010, a higher level of infestation was observed on fruits. Fruits of accessions GH 3898 (85.1 %) and GH 1113 (62.9 %) for instance were significantly more than damage on all other accessions (Table 4).

Significant (P < 0.001) differences in fruit yield were observed in both 2009 and 2010. Yield obtained in 2009 ranged from 0 kg/ha (accession GH 1202) to 674.29 kg/ha (accession GH 5183) (Table 3) whilst that for 2010 ranged from 133.93 kg/ha (accession GH 1113) to 837.86 kg/ha (GH 5183) (Table 4).

Table 3. Yield and susceptibility of fruits of 26 eggplant (*Solanum* spp.) accessions to *L. orbonalis* infestation at Bunso, Ghana in 2009.

Accession	Yield characteristics	
	Yield (kg/ha)	% infested fruits
GH 1090	104.7	18.6
GH 1111	70.2	2.1
GH 1113	236.1	15.2
GH 1114	28.8	2.2
GH 1164	44.5	2.1
GH 1172	154.7	3.1
GH 1202	0.0	0.0
GH 1205	42.6	2.6
GH 1208	15.4	0.3
GH 3896	20.2	2.6
GH 3898	301.1	38.2
GH 3923	338.8	1.7
GH 3935	140.9	41.7
GH 3943	93.8	2.7
GH 3944	126.4	0.3
GH 3949	72.8	2.1
GH 3947	102.1	0.3
GH 4925	43.1	35.4
GH 4928	138.3	1.8
GH 5162	391.4	4.9
GH 5168	21.4	1.5
GH 5170	183.1	10.5
GH 5171	134.5	1.5
GH 5172	211.9	6.3
GH 5180	53.5	39.3
GH 5183	674.2	20.2
Lsd 0.05)	200.7	29.7

Table 4. Yield and susceptibility of fruits of 26 eggplant (*Solanum* spp.) accessions to *L. orbonalis* infestation at Bunso, Ghana in 2010

Accession	Yield characteristics	
	Yield (kg/ha)	% infested fruits
GH 1113	133.9	24.5
GH 3898	250.6	85.1
GH 3949	287.8	54.9
GH 5162	608.5	34.7
GH 5183	837.8	51.4
Check	165.1	30.7
Lsd (0.05)	343.1	29.1

Plate 1 Plant **s**tem tunneled by *L. orbonalis* larvae

Plate 3 Cross section of eggplant fruits with *L. orbonalis* damage

Plate 2. Points of *L. orbonalis* infestation on eggplant fruits

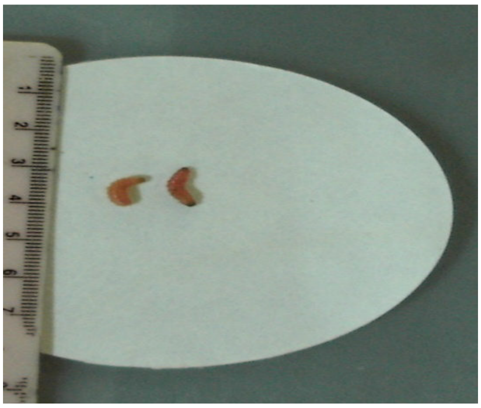

Plate 4. Larvae of *L. orbonalis*

4.0. Discussion

Low numbers of *A. gossypii* and *T. tabaci* were collected on the leaves in 2009 and 2010. The population densities of *A. gossypii* and *T. tabaci* per leaf amongst accessions were however higher and more variable in 2009 than in 2010. Although the reasons for the non-infestation of the accession which was used as a check (accession GH 5171) by *A. gossypii* in 2009 are unclear, the relatively low numbers of *A. gossypii* collected on the leaves of the same accession (GH 5171) in 2010 suggests a non-preference of this accession by *A. gossypii*; probably due to the fact that the accession had properties that impact negatively on the development of *A. gossypii*. Thus differences in the accumulated amounts of either physical or/and chemical properties in the various accessions may have influenced the differential aggregation of the various insects on the accessions.

It is quite understandable to have collected more thrips from the flowers than on the leaves. Kirk (1997) has suggested that thrips prefer flowers to other plant parts because flowers provide thrips with microclimates that reduce desiccation and access by predators. Toapanta *et al*. (1996) noted that thrips aggregate and feed on leaves in the early stage of the plant growth but migrate to the flowers when blooming begins. A comparison of the population dynamics of *T. tabaci* on eggplant leaves and flowers also indicates that the population density of *T. tabaci* on flowers on different sampling dates was less variable than that on leaves. Generally, thrips prefer a plant part that is succulent and more stable in terms of the nutritional and physical appearance and that may be the reason they prefer young plants (seedlings).

The high correlation of *A. gossypii* numbers with that of *Camponotus* sp. (ants) shows the complementary role they play to sustain each other. In most cases this association also resulted in increased presence of sooty mold on the leaves, which might have negatively impacted yield.

The feeding activity of *A. gossypii* and *T. tabaci* causes significant yield reduction and economic loss (Vendramin & Nakano, 1981; Head, 1992). Additionally, these insects are primarily controlled by use of insecticides, which increases production costs and hasten the development of resistance (Hosoda *et al.,* 1993; Kajita *et al., 1*996). Owusu (1997) for instance has observed that *A. gossypii* populations on eggplant are becoming resistant to commonly used insecticides in Ghana. In view of this, the breeding of improved eggplant varieties from locally available *A. gossypii* tolerant eggplant genetic resources like GH 5171 would enhance pest management and boost food safety.

Compared with the average eggplant yield of 8,000 kg/ha in Ghana (MoFA, 2010), yields obtained in this study were low. The highest yield obtained was 674.29 kg/ha in 2009 and 837.86 kg/ha in 2010 (accession GH 5183). The relatively low yield may be explained by the fact that the materials used in this study were mainly landraces that have undergone little or no crop improvement. According to Nwaiwu *et al.* (2004) improved cultivars grown under favourable conditions may yield between 50 - 80 tonnes/ha (50,000-80,000 kg/ha).

Fruits of accession GH 5183 which produced the highest yield in both 2009 and 2010 suffered heavy damage by *L. orbonalis* larvae (plate 4) in both years whilst fruits of accessions GH 1205 and GH 1208 which had very low yields were significantly less susceptible to *L. orbonalis* infestation. Accessions GH 5171 and GH 1113 however combined good yields with low fruit susceptibility to all insect pest species identified as infesting eggplant in this experiment in both years. Although the reasons for the seeming tolerance of these accessions are readily unclear, Prabhu *et al.* (2009) have stated that eggplant accessions with a high or moderate level of various biochemical components such as glycoalkaloid, solasodine, total phenol content and enzymes like peroxidase and polyphenol oxidase suffer less pest infestation.

Although some infested fruits appeared to be healthy on the outside, dissection of such fruits revealed that they were unwholesome and un-marketable (Plate 3). Thus, apart from rendering eggplant fruits unmarketable, *L. orbonalis* infestation also increases the chances of having net returns below zero (to as high as 75 percent)

(Horna *et al.,* 2007) and significantly increases the probability that farmers would apply insecticides as an attempt to control this pest. About 98 % of eggplant farmers surveyed in Bangladesh for instance exclusively applied pesticides in order to kill *L. orbonalis* larvae before it entered the eggplant fruit (Alam *et al.,* 2003; Gapud and Canapi cited by Srinivasan, 2009). In Ghana, Horna *et al.* (2008) observed that approximately, 90 % of eggplant farmers surveyed in four regions of Ghana applied doses (2.9 L/ha) above nationally recommended rates (200 - 800 ml/ha) in single applications, adding on average, US$ 26.00 to the cost of production. Such extensive use of pesticides not only reduces profitability of eggplant production but poses health hazards, and causes environmental pollution and resource degradation which ultimately impacts negatively on society.

6.0. Conclusion

A. gossypii and *T. tabaci* infestation has serious adverse impacts on plant growth and yield. Infestation by *T. tabaci* for instance results in leaves with small size and deformed fruits whilst that of *A. gossypii* results in honeydew production and subsequent discoloration of leaves and reduction of the marketable value of fruits. Given these facts, the very low populations of *A. gossypii* and *T. tabaci* observed on some accessions in both years is particularly significant as they can be incorporated into breeding programs to develop *A. gossypii* (GH 1113 and GH 5171) and *T. tabaci* (GH 5171) tolerant varieties which will reduce pesticide use and boost food safety as well as human and environmental health. Accessions GH 1113 and GH 5171 are therefore recommended for further study and incorporation into *A. gossypii* tolerance breeding programs.

7.0. Acknowledgement

The authors would like to express their gratitude to the Director and management of CSIR-PGRRI for funding this study.

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