Evaluation for soybean resistance to armyworm *Spodoptera litura* (Lepidoptera: Noctuidae)

MM Adie, A Krisnawati and Y Baliadi

Indonesian Legume and Tuber Crops Research Institute (ILETRI), JL. Raya Kendalpayak Km 8 Malang, East Java, Indonesia

Email: mm_adie@yahoo.com

**Abstract.** The army worm, *Spodoptera litura*, is one of the important soybean leaf-feeding pests in Indonesia. The objective of this study was to evaluate the resistance of several soybean genotypes to the army worm. Thirteen soybean genotypes were evaluated for their resistance against army worm. The experiment was conducted in Malang (East Java, Indonesia) from March to June 2018, using a randomized block design with three replicates. The evaluations for resistance were based on the choice and no-choice tests, and the preference index (C) using the resistant check (G100H). The intensity of leaf damage on the no-choice test (49.07%) was higher than the choice test (28.94%). The range of damage intensity caused by *S. litura* on the choice test and no-choice tests were 19.61–57.04% and 34.64–64.21%, respectively. On the choice test, it was obtained a resistant genotype, 11 moderately resistant genotypes, and one moderately susceptible genotype. On the no-choice test, two genotypes were categorized as moderately resistant, ten moderately susceptible genotypes, and one susceptible genotype. Based on the both of choice and no-choice tests, two genotypes (19 BE and G100H) were categorized as moderately resistant against *S. litura*. Based on the preference index, 14 DD has a similar degree of resistant with G100H. The number of filled pods was higher in the choice-test than those of in the no-choice test.

1. **Introduction**

The army worm, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) is considered to be significant economic leaf-feeding insect pests of soybean in Indonesia when compared to the other insect pests, such as soybean looper (*Chrysodeixis chalcites*), pod worm (*Helicoverpa armigera*), and the leaf roller (*Lamprosema indicata*). The yield losses caused by the armyworm attack may reach 80% [1]. In Ghana, the yield losses due to leaf-feeding pests may reach 90%, depend on the plant growth phases and the susceptibility of the plants [2]. Dubhbale et al. [3] reported that the reduction in soybean yield reached 68% in the uncontrolled condition compared to that controlled with cyhalothrin. The amount of yield loss is determined by the larval population density (higher larval density) and the severity of leaf defoliation [4].

The economic importance of the armyworm pests is related to the characteristic of insects as polyphagous pest which have broad host distribution. In America, the dominant species of Spodoptera are *S. frugiperda*, *S. albula*, *S. eridania*, and *S. cosmioides* [5]. Prasanna et al. [6] also reported that *S. frugiperda* is the major leaf-eating pest in maize in sub-Saharan Africa. In soybean and cotton plants, *S. frugiperda* was considered to be less harmful [7]. The control of the armyworm pests has been done with various efforts such as the use of sex-pheromone, biological control using *Bacillus thuringiensis*...
(Bt), and SiNPV (Spodoptera litura Nuclear Polyhedrosis Virus) [8,9,10]. So far, insecticides are still mostly used to protect crops against insect pests. However, the unwise use of insecticides has unwanted side effects on human health and the environment. Therefore, the use of resistant varieties as an alternative way is important to reduce the yield losses due to insect pests.

Evaluation for resistance to the army worm S. litura based on antibiosis and antixenosis has obtained the G511H/Anj-1-4 as a resistant soybean line [11]. Furthermore, Bayu et al. [12] which assessed the resistance of 18 soybean genotypes to the S. litura reported nine genotypes had antixenosis resistance to the armyworm. Farahani et al. [13] evaluated the resistance of five soybean genotypes to S. exigua and concluded that the L17 and BP genotypes exhibited higher resistant than the Williams genotype, based on the parameters of reproduction and population growths. An evaluation for resistance to the armyworm in peanut obtained three resistant genotypes (NC Ac 343, Mutant 28-2 and R 9227) which affected larval growth and survival, pupal development, adult emergence and fecundity indicating antibiosis as the principal mechanism of resistance [14].

Soybean genotype is considered resistant to the S. litura when the genotype was less preferred than another for feeding [12]. Soybean genotype IAC100 from Brazil was reported to have a high degree of non-preference for feeding to the larva of Spodoptera species [15]. Oki et al. [16] which studied the genetic analysis of antixenosis resistance in S. litura reported that the characteristics of pubescence related to the antixenosis resistance. Resistant varieties have become an important strategy in controlling herbivorous insect groups including S. litura [17,18]. The advantages of resistant variety are not detrimental to the environment, reduces pesticide input, reduces the cost for farmers, and also compatible with other control methods including the utilization of natural enemies [19].

The high damage potential of armyworm resulted in the yield losses in soybean caused the selection of more resistant genotypes to insect attack becomes highly desirable. Thus, the objective of this study was to evaluate the resistance of several soybean genotypes to the army worm using choice and no-choice tests.

2. Methodology

2.1. Rearing of S. litura
The larva of S. litura were collected from the soybean field in Kendalpayak Experimental Station, Malang, East Java. The insect rearing was done in the Laboratory of Breeding of Indonesian Legume and Tuber Crops Research Institute (ILETRI), feed by fresh soybean leaves. Newly emerged larvae were used in the study, which the first offspring (F1) of imago derived from rearing in the laboratory.

2.2. Experimental site and research material
The research was conducted in the Laboratory of Breeding (ILETRI), Malang from March to June 2018. The experiment was arranged using a randomized block design with 13 genotypes and three replications. The soybean genotypes consists of ten lines derived from crossing (11 AB, 13 ED, 14 DD, 19 BE, 2 EC, G511H/Kaba//Kaba///Kaba-8-6, G511H/Anj//Anj-2-10, G511H/Anj-1-3, G511H/Anj//Anj///Anj-11-2, and G511H/Arg//Arg-2-1) and three varieties of Demas 1 (high yield, medium seed size), Anjasmoro (high yield, large seed yield), and G100H (resistant to S. litura).

2.3. Choice and no-choice tests
Each genotype was planted in a plastic pot (Φ =28 cm) which contains a mixture of soil and manure in a ratio of 4:1, two plants/pot. Each plant was fertilized with 5.0 g NPK, and without pest and disease control. In the choice test, each soybean genotype at 20 days after planting (DAP) was enclosed in a meshed cage (50 cm in height and 26 cm in diameter), and arranged randomly according to per replication (three replications). A pair of newly emerged neonate larva were infested into each cage. In the no-choice test, thirteen soybean genotypes at 20 DAP was enclosed in a meshed cage (length = 200 cm, width = 200 cm, height = 200 cm). This treatment was replicated three times. Each meshed cage was infested by 26 neonate larvae. The damaged leaf was measured by scoring method with scale
from 0–4, in which 0 = no damage, 1 = 1-25% leaf damaged, 2 = 26-50% leaf damaged, 3 = 51-75% leaf damaged, 4 = >76% leaf damaged.

The leaf damage intensity was calculated as follows: $$P = \frac{\sum (n_i \times v_i)}{ZN} \times 100\%$$

where:
- $P$ = leaf damage intensity (%)
- $n_i$ = number of damaged leaf with score $i$
- $v_i$ = score $i$ ($i$: 0-4)
- $Z$ = the highest score (4)
- $N$ = total number of leaves

The resistance to army worm was grouped based on Asadi et al. [20] as follows: resistant (0-20%), moderately resistant (21-40%), moderately susceptible (41-60%), susceptible (61-80%), and highly susceptible (>80%). The agronomic characters were observed in the choice as well as no-choice tests, which consists of plant height, number of branches per plant, number of filled pod per plant, number of empty pod per plant, and number of node per plant. The data was subjected to the analysis of variance, and the mean differences were compared by LSD test ($\alpha = 5\%$).

2.4. Preference test

The preference test was using leaves from test plants (11 AB, 13 ED, 14 DD, 19 BE, 2 EC, G511H/Kaba//Kaba-8-6, G511H/Anj//Anj-2-10, G511H/Anj-1-3, G511H/Anj//Anj/// Anj-11-2, G511H/Arg//Arg-2-1, Demas 1, Anjasmoro) and resistant check (G100H). Two leaflets from each genotype and resistant check were excised, and washed with running water, drained, then placed in the petri dishes ($\Phi = 12$ cm, height = 2 cm) for each genotype. Two larvae of the third instar of *S. litura* were placed on the leaves on each petridish. Each genotype has three replications. The observation was made on the amount of leaves consumed by *S. litura* larvae on the test plants as well as the resistant check plant. The experiment was run until 100% area of leaves from tested or check genotype was consumed by *S. litura* larvae, and then the visual defoliation was assessed based on the preference index (C) [21]:

- $C < 1$ = more resistant (less preferred) than a check, indicates the test plant has higher resistance than the check plant.
- $C = 1$ = the feeding on the test plant has equalled the feeding on the test plant.
- $C > 1$ = more susceptible (more preferred) than a check, indicates a preference for the test plant.

3. Result and discussion

3.1. Choice and no-choice test

The resistance evaluation of several soybean genotypes to armyworm based on the choice test (49.07%) showed a higher average of leaf damaged intensity than those of no-choice test (28.94%) (Table 1). The damaged leaf intensity on the no-choice test ranged from 19.61 - 57.04%. The resistant check (G100H) had leaf damaged intensity as 22.28%, it was higher when compared to the genotype 25 EC (19.61%). Genotype 25 EC was classified as resistant to *S. litura* based on the choice test, whereas 11 genotypes found to be moderately resistant, and only one genotype was classified as moderately susceptible to *S. litura*. In the no-choice test, the range of leaf damaged was from 34.64 – 64.21%. Of 13 tested genotypes, two genotypes were moderately resistant, 10 genotypes were moderately susceptible, one genotype was susceptible, and one genotype (19 BE) has the equal resistant with the resistant check (G100H).

The different methods used in this study gave different results on the resistance to the *S. litura*. The 25 EC was resistant based on the choice test, but become moderately susceptible based on the no-choice test. Most of moderately resistant genotypes based on the choice test become moderately susceptible based on the no-choice test. The resistance evaluation based on the no-choice test provides a heavier pressure than the choice test. The no-choice test does not provide the opportunity for larva to select the most preferred host. Thus, it may cause the leaf damaged was higher than those of found in
the choice test [12]. In this study, two genotypes were found to be consistently moderately resistant based on choice as well as no-choice tests, i.e. 19 BE and G100H.

Table 1. The leaf damaged intensity caused by *S. litura* based on the choice and no-choice tests

| No | Genotype | Choice test | No-choice test |
|----|----------|-------------|----------------|
|    |          | Intensity (%) | Category | Intensity (%) | Category |
| 1  | 11 AB    | 57.04        | MS        | 42.67         | MS        |
| 2  | 13 ED    | 30.33        | MR        | 48.20         | MS        |
| 3  | 14 DD    | 30.78        | MR        | 42.82         | MS        |
| 4  | 19 BE    | 28.33        | MR        | 38.98         | MR        |
| 5  | 25 EC    | 19.61        | R         | 54.57         | MS        |
| 6  | G511H/Kaba/Kaba//Kaba-8-6 | 26.94 | MR | 57.49 | MS |
| 7  | G511H/Anjs//Anjs-2-10 | 28.06 | MR | 49.90 | MS |
| 8  | G511H/Anjs-1-3 | 29.00 | MR | 64.21 | S |
| 9  | G511H/Anjs//Anjs-11-2 | 29.83 | MR | 49.11 | MS |
| 10 | G511H/Arg//Arg-2-1 | 26.17 | MR | 47.16 | MS |
| 11 | Demas 1  | 24.56        | MR        | 56.90         | MS        |
| 12 | Anjasmoro| 23.28        | MR        | 51.25         | MS        |
| 13 | G100H    | 22.28        | MR        | 34.64         | MR        |
|    |          | Mean         | 28.94     | 49.07         |

R= resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible

According to Adie et al. [22], each soybean genotype has a different resistance mechanism to *S. litura*. Furthermore, resistant genotype may inhibit the growth development of larvae and pupae, and prolong the larval life period. Similar results were obtained by Kawre et al. [23], which asse the resistance of several soybean genotypes using biological parameters. They reported that the AMS-MB-5-18 had the highest pupal weight, whereas the lowest pupal weight was found in the JS-20-34 genotype, hence it was concluded that JS-20-34 was resistant to *S. litura*. Naik et al. [24] compared the biology of *S. litura* between vegetable and grain soybean, and the results showed that the life cycle of *S. litura* larvae that were fed by vegetable soybean ranged from 29.88 to 32.12 days, while those which fed by grain soybean ranged from 27.10 to 30.14 days. Prasad & Goewa [14] suggested that the weight of *S. litura* larvae was potentially used as a measure of resistance to *S. litura*.

3.2. Preference test

The preference index of the larvae *S. litura* to the several soybean genotypes as feeding plants varied from 1.01 to 1.44 (Table 2). The preference index 1.0 indicates the degree of resistance is equal with the check plant (G100H), the preference index less than 1.0 indicated that those genotypes have higher resistance than the check genotype (G100H) and vice versa. Eleven genotypes were more preferred by larva of *S. litura* to be eaten, or more susceptible than the G100H. There was one genotype (14 DD) which has equivalent resistance with G100H (C = 1.01).

When compared with the choice test, the 19 BE and G100H were found to be consistently moderately resistant based on choice as well as no-choice tests. However, in the preference test, the 19 BE was more preferred by *S. litura* or more susceptible than the G100H. The 14 GG which was moderately susceptible based on the no-choice test, but in the preference test has comparable resistance with the G100H.

G100H was derived from offspring selection of a cross between *S. litura* resistant genotypes, namely IAC 100 and Himeshirazu. Bayu et al. [12] which evaluated the resistance of 18 soybean genotypes against army worm *S. litura* using no-choice method obtained nine moderately resistant genotypes and IAC100 as a highly resistant genotype. A study by Oki et al. [16] in Japan about the genetic analysis of antixenosis resistance to the common cutworm using Himeshirazu as resistant
cultivar and Fukuyutaka as susceptible cultivar to *S. litura*. The characteristics of soybeans resistant to the defoliating insect are having a thick leaf surface and dense trichomes [25].

Table 2. The preference index of several soybean genotypes using standard check of G100H

| No | Genotype | Preference index (C) | Category       |
|----|----------|----------------------|----------------|
| 1  | 11 AB    | 1.13                 | More susceptible |
| 2  | 13 ED    | 1.44                 | More susceptible |
| 3  | 14 DD    | 1.01                 | Equal resistance |
| 4  | 19 BE    | 1.04                 | More susceptible |
| 5  | 25 EC    | 1.52                 | More susceptible |
| 6  | G511H/Kaba/Kaba/Kaba-8-6 | 1.44 | More susceptible |
| 7  | G511H/Anjs/Anjs-2-10 | 1.02 | More susceptible |
| 8  | G511H/Anjs-1-3 | 1.22 | More susceptible |
| 9  | G511H/Anj/Anj/Anj-11-2 | 1.34 | More susceptible |
| 10 | G511H/Arg/Arg-2-1 | 1.21 | More susceptible |
| 11 | Demas 1  | 1.31                 | More susceptible |
| 12 | Anjasmor0 | 1.16                | More susceptible |
| Mean |          |                      | 1.23            |

3.3. Morphological characters

The performance of agronomic characters of 13 soybean genotypes which evaluated their resistance to *S. litura* based on choice and no choice test were presented in Table 3 and Table 4. On the choice test, the genotype effect was significant on the plant height and number of empty pods. On the no-choice test, the genotype effect was significant on plant height and number of nodes. The average plant height, number of branches, and number of nodes were similar between choice and no-choice test environments. The number of filled pods in the choice test was higher than those of the no-choice test, whereas the number of the empty pods was higher in the no-choice test than those of the choice tests. A greater pressure in the no-choice test environment caused a decrease in the number of filled pods, then followed by an increase in the empty pods.

Table 3. Morphological characters of the plant on the choice test

| No | Genotype       | Plant height (cm) | Number of branches per plant | Number of filled pods per plant | Number of empty pods per plant | Number of nodes per plant |
|----|----------------|-------------------|-------------------------------|--------------------------------|-------------------------------|---------------------------|
| 1  | 11 AB          | 90.50 ab          | 2.83                          | 15.50                          | 4.33 ab                       | 7.33                      |
| 2  | 13 ED          | 91.00 a           | 3.50                          | 16.00                          | 1.83 c                        | 7.33                      |
| 3  | 14 DD          | 92.33 a           | 2.33                          | 16.50                          | 4.67 a                        | 7.67                      |
| 4  | 19 BE          | 85.00 abc         | 2.67                          | 17.33                          | 3.00 abc                      | 7.83                      |
| 5  | 25 EC          | 58.83 e           | 3.00                          | 18.17                          | 1.67 c                        | 8.00                      |
| 6  | G511H/Kaba/Kaba/Kaba-8-6 | 80.83 abcd | 2.50                          | 16.67                          | 1.67 c                        | 7.17                      |
| 7  | G511H/Anjs/Anjs-2-10 | 84.17 abc | 3.33                          | 16.83                          | 3.67 ab                       | 7.67                      |
| 8  | G511H/Anjs-1-3 | 87.00 ab0        | 3.00                          | 16.67                          | 3.00 abc                      | 8.17                      |
| 9  | G511H/Anj/Anj/Anj-11-2 | 89.50ab | 2.17                          | 18.50                          | 0.00 d                        | 8.17                      |
| 10 | G511H/Arg/Arg-2-1 | 78.50 abcd | 2.50                          | 15.33                          | 3.50 ab                       | 8.00                      |
| 11 | Demas 1        | 73.67 bede        | 1.83                          | 16.00                          | 3.67 ab                       | 7.50                      |
| 12 | Anjasmor0       | 69.83 ede        | 3.17                          | 17.67                          | 2.83 c                        | 9.00                      |
| 13 | G100H          | 66.8 de3          | 3.00                          | 21.33                          | 1.83 c                        | 10.17                     |
| Mean |              | 80.62             | 2.76                          | 17.12                          | 2.74                          | 8.00                      |

Genotype effect | ** | ns | ns | ** | ns

** = significant at 1% probability level, ns = not significant
The characteristics of 13 tested genotypes generally had plant height, number of branches and number of the nodes which are ideal to be developed in the tropical regions of Indonesia, including 19 BE which was classified as moderately resistant to S. litura. The G100H and Anjasmooro tend to be shorter than the other genotypes. The environmental factors that increase S. litura population were weather, high temperature, rainfall, sunshine, and wind speed [26]. Indonesia's tropical climate has the potential to be an ideal environment for the development of the S. litura. Therefore, the availability of soybean varieties resistant to S. litura is needed to support the enhancement of soybean productivity in Indonesia.

**Table 4.** Morphological characters of the plant on the no-choice test

| No | Genotype                           | Plant height (cm) | Number of branches per plant | Number of filled pods per plant | Number of empty pods per plant | Number of nodes per plant |
|----|-----------------------------------|-------------------|------------------------------|---------------------------------|--------------------------------|--------------------------|
| 1  | 11 AB                             | 88.33 a           | 2.67                         | 12.33                           | 5.00                           | 6.83 bc c                |
| 2  | 13 ED                             | 87.50 a           | 2.50                         | 13.00                           | 4.83                           | 6.50 bc                  |
| 3  | 14 DD                             | 88.83 a           | 3.00                         | 13.50                           | 3.83                           | 6.50 bc                  |
| 4  | 19 BE                             | 90.00 a           | 2.33                         | 14.50                           | 3.83                           | 7.67 bc                  |
| 5  | 25 EC                             | 49.83 d           | 2.33                         | 15.33                           | 3.50                           | 8.67 ab                  |
| 6  | G511H/Kaba/Kaba/Kaba-8-6           | 82.33 ab          | 2.33                         | 13.17                           | 4.33                           | 6.50 bc                  |
| 7  | G511H/Anjs/Anjs-2-10              | 85.50 ab          | 2.50                         | 14.83                           | 3.83                           | 7.76 bc                  |
| 8  | G511H/Anjs-1-3                    | 87.83 a           | 2.17                         | 13.83                           | 4.50                           | 6.33 bc                  |
| 9  | G511H/Anj//Anj//Anj-11-2           | 83.67 ab          | 2.50                         | 15.33                           | 3.83                           | 7.50 bc                  |
| 10 | G511H/Arg//Arg-2-1                | 81.00 abc         | 2.50                         | 16.17                           | 4.33                           | 7.33 bc                  |
| 11 | Demas 1                           | 84.67 ab          | 3.17                         | 11.67                           | 3.67                           | 7.00 bc                  |
| 12 | Anjasmooro                        | 70.67 bc          | 2.33                         | 9.50                            | 4.50                           | 5.67 c                   |
| 13 | G100H                             | 65.17 dc          | 3.67                         | 19.67                           | 4.50                           | 10.67 a                  |
|    | Mean                              | 80.41             | 2.62                         | 14.06                           | 4.19                           | 7.29                     |
|    | Genotype effect                   | **                | ns                           | ns                              | ns                             | *                        |

** = significant at 1% probability level, * = significant at 5% probability level, ns = not significant

4. Conclusion
The evaluations for resistance based on the no-choice test provides a greater pressure than based on the choice test. The 19 BE and G100H were categorized as moderately resistant against S. litura based on the choice and no-choice tests. The 14 DD has a similar degree of resistant with G100H based on the preference index test. The number of the filled pods was higher in the choice-test than those of on the no-choice test.

Acknowledgment
The author would like to thank the Indonesian Agency for Agricultural Research and Development (IAARD) for the financial support through KP4S Program 2018. The authors would also like to thank Arifin, S.P., and Anthoni Mafia, who have helped during the research.

References
[1] Marwoto and Suharsono 2008 Strategy and technology component of army worm (Spodoptera litura Fabricius) control in soybean J. Litbang Pert. 27 (4) 131–136 [in Bahasa Indonesia]
[2] Abudulai M, Salifu AB, Opare-Atakora D, Haruna M, Denwar NN and Baba IIY 2012 Yield loss at the different growth stages in soybean due to insect pests in Ghana Archives Phytopathol. Plant Prot. 45 (15) 1-14
[3] Duhdhole C, Surpam A, Kohikar R and Koche M 2017 Bio-efficacy of chemical insecticides against Spodoptera infesting soybean Am. J. Entomol. 1 (1) 16-18
[4] GeonHwi I, SoonDo B, HyunJoo K, SungTae P and Young CM 2006 Economic injury levels for the common cutworm, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) on soybean *J. Appl. Entomol.* 45 (3) 333-337

[5] Bergamasco VB, Mendes DRP, Fernandes OA, Desidério JA and Lemos MVF 2013 *Bacillus thuringiensis* Cry1Ha10 and Vip3Aa protein interactions and their toxicity in *Spodoptera* spp. (Lepidoptera) *J. Invertebr. Pathol.* 112 (2) 151-158

[6] Prasanna BM, Huesing JE, Eddy R and Peschke VM 2018 *Fall Armyworm in Africa: A Guide for Integrated Pest Management* First Edition Mexico, CDMX: CIMMYT

[7] Silva DM, Bueno AF, Andrade K, Stecca CS, Neves PMOJ and de Oliveira MCN 2017 Biology and nutrition of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) fed on different food sources *Sci. Agric.* 74 (1) 18-31

[8] Yang S, Sun W, Jianping LV and Kuang R 2009 Use of sex pheromone for control of *Spodoptera litura* (Lepidoptera: Noctuidae) *J. Ent. Res. Soc.*. 11 (1) 27-36

[9] Pratiwi K, Trisyono YA and Martono E 2016 The effect of *Bacillus thuringiensis* toxin Cry1A.105 and Cry2Ab2 on the survival of the non-target pest, *Spodoptera litura* J. Perlindungan Tan. Indon. 20 (1) 7–14 [in Bahasa Indonesia]

[10] Bedjo 2017 The potential of various isolates of *Spodoptera litura* Nuclear Polyhedrosis Viruses from East Java (Indonesia) to control *Spodoptera litura* on soybean *Biodiversitas* 18 (2) 582-588

[11] Krisnawati A, Bayu MSYI and Adie MM 2017 Identification of soybean genotypes based on antixenosis and antibiosis to the armyworm (*Spodoptera litura*) *Nusantara Biosci.* 9 164-169

[12] Bayu MSYI, Krisnawati A and Adie MM 2018. Response of soybean genotypes against armyworm, *Spodoptera litura* based on no-choice test IOP Conf. Ser.: Earth Environ. Sci. 102 012033

[13] Farahani A, Talebi AA and Fathipour Y 2012 Life table of *Spodoptera exigua* (Lepidoptera: Noctuidae) on five soybean cultivars *Psyche* 2012 7p

[14] Prasad MNR and Gowda MVC 2006. Mechanisms of resistance to tobacco cutworm (*Spodoptera litura* F.) and their implications to screening for resistance in groundnut *Euphytica* 149 (3) 387-399

[15] Souza BHS, Boica-Junior AL, Janini JC, Silva AG and Rodrigues NEL 2012 Feeding of *Spodoptera eridania* (Lepidoptera: Noctuidae) on soybean genotypes *Revta. Colomb. Entomol.* 38 (2) 215-223.

[16] Oki N, Komatsu K, Sayama T, Ishimoto M, Takahashi M and Takahashi M 2012 Genetic analysis of antixenosis resistance to the common cutworm (*Spodoptera litura* Fabricius) and its relationship with pubescence characteristics in soybean (*Glycine max* (L.) Merr.) *Breeding Sci.* 61 (5) 608–617.

[17] Smith CM and Clement SL 2012 Molecular bases of plant resistance to arthropods. *Annu. Rev. Entomol.* 57 309-328

[18] Seifi A, Visser RGF and Bai Y 2013 How to effectively deploy plant resistances to pests and pathogens in crop breeding *Euphytica* 190 (3) 321-334.

[19] Jesus FG, Boica-Junior AL, Alves GC, Busoli AC and Zanuncio JC 2014 Resistance of cotton varieties to *Spodoptera frugiperda* *Rev. Colombiana Entomol.* 40 (2) 158-163

[20] Asadi, Purwantoro, A., Yakub, S. (2012). Genetic control of soybean pod sucker (*Riptortus linearis* L.) *Agrivita* 34 (1) 28-35

[21] Kogan M and Goeden RD 1970 The host plant range of *Lema tritineata daturaphila* (Coleoptera: Chrysomelidae) *Ann. Entomol. Soc. Amer.*. 62 1175-1180

[22] Adie MM, Bayu MSYI and Krisnawati A 2015 The variability of resistance of soybean to armyworm *Seminar Proceedings* Indonesian Legume and Tuber Crops Research Institute Malang Indonesia [in Bahasa Indonesia]

[23] Kawre PR, Sadawarte AK and Thakare VS 2017 Effect of soybean geno types on biologi cal parameters of *Spodoptera litura* (Fab.) *Progressive Res.* 12 1925-1927
[24] Naik CM, Nataraj K and Santhoshakumara GT 2017 Comparative biology of *Spodoptera litura* on vegetable and grain soybean [*Glycine max* (L.) Merrill] *Int. J. Curr. Microbiol. App. Sci.* 6 366-371

[25] Sasane AR, Bhalkare SK, Rathod PK and Undirwade DB 2018 Biophysical basis of resistance in soybean genotypes against defoliators. *J. Entomol. Zool. Studies* 6 1-7

[26] Babu SR, Kalyan R, Ameta GS and Meghwal ML 2015 Analysis of outbreak of tobacco caterpillar, *Spodoptera litura* (Fabricius) on soybean *J.Agromet.* 17 (1) 61-66