

**Effect of ten soybean cultivars on development and reproduction of lima bean pod borer, *Etiella zinckenella* (Lepidoptera: Pyralidae) under laboratory conditions**

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**Abstract**

The effect of ten soybean cultivars, *Glycine max* (L.) (including, 'Clark', 'Sahar', 'JK', '032', '033', 'Williams', 'L17', 'Zane', 'Gorgan3' and 'DPX') on developmental parameters and reproduction of the lima bean pod borer, *Etiella zinckenella* Treitschke (Lepidoptera: Pyralidae), was studied at 25±1°C, 60±5% RH and a photoperiod of 16:8 h (L:D). The larval period ranged from 13.42±0.10 days on 'Clark' to 16.28±0.14 days on '033'. The female and male lifespans were longest on '032' (55.84±0.27 and 56.80±0.10 days) and shortest on 'Clark' (51.18±0.11 and 52±0.13 days), respectively. The oviposition period was longest on 'Clark' (15.46±0.19 days) and shortest on 'Gorgan3' (9.52±0.13 days). The mean number of eggs laid per female was significantly different among the cultivars, ranging from 11.21±0.22 eggs (on 'JK') to 16.16±0.56 eggs (on 'Clark'). Based on development and reproduction parameters, it can be concluded that 'Clark', 'Zane', 'Williams', 'L17' and '033' might be the susceptible host plants and 'DPX', 'Sahar', '032', 'JK' and 'Gorgan3' might be the partially resistant host plants for *E. zinckenella*.

**Key words:** *Etiella zinckenella*, Host suitability, Development, Reproduction, Soybean cultivars.

چکیده

تأثیر ده رقم سویا (*Glycine max* (L.)) شامل 'Clark'، 'Sahar'، 'JK'، '032'، '033'،

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'Williams'، 'L17'، 'Zane'، 'Gorgan3' و 'DPX' روی پارامترهای رشد و نمو و تولید مثل شب پره دانه خوار سویا، *Etiella zinckenella* Treitschke (Lepidoptera: Pyralidae) در دمای ۱ ± ۲۵ درجه سلسیوس، رطوبت نسبی ۵۰±۶۰ درصد و دوره نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی تعیین شد. دوره لاروی از ۱۰/۱۳±۴۲ روز روی رقم Clark تا ۱۴/۲۸±۰/۱۶ روز روی رقم 033 متفاوت بود. طولانی ترین طول دوره زندگی حشرات کامل نر و ماده روی رقم 032 (۲۷/۵۵±۰/۸۴ و ۱۰/۵۶±۰/۸۰ روز) و کوتاه ترین آن روی رقم Clark (۱۱/۵۱±۰/۱۱) و ۱۳/۵۲±۰/۱۳ (روز) مشاهده شد. طول دوره تخم‌ریزی روی رقم Clark بلندتر (۱۹/۱۵±۰/۴۶ روز) و روی رقم Gorgan3 کوتاه ترین (۱۳/۹/۵۲±۰/۱۳ روز) تعیین شد میانگین تعداد تخم‌های گذاشته شده به ازای هر ماده در هر روز به طور معنی داری تحت تأثیر ارقام سویا قرار گرفت و از ۲۲/۱۱±۰/۲۲ تخم (روی رقم JK) تا ۵۶/۱۶±۰/۱۶ تخم (روی Clark) متفاوت بود. بر اساس پارامترهای رشد و نمو و تولید مثل ارقام 'Clark'، 'Zane'، 'Williams'، 'L17' و '033' به عنوان ارقام احتمالاً حساس و ارقام 'DPX'، 'Sahar'، '032'، 'JK' و 'Gorgan3' به عنوان ارقام احتمالاً نسبتاً مقاوم به *E. zinckenella* پیشنهاد شدند\*.

**واژه‌های کلیدی:** *Etiella zinckenella*، مناسب بودن میزبان، رشد و نمو، تولید مثل، ارقام سویا.

## Introduction

Soybean, *Glycine max* (L.) (Papilionaceae), is one of the economically important oil seed crops in Iran. It is also one of the major agricultural crops in the United States of America, Brazil, Argentina, China, Indonesia and India (Favre and Myint, 2009). Utilization of soybean cultivars with potential levels of insect-resistance can increase profits by reducing the use of insecticides and risk of insecticide residues in the human food chain (Rowan et al., 1991). Soybean crop is attacked by 350 species of insects in different parts of the world (Luckmann, 1971). In Iran, the most soybean important lepidopteran pests are the beet armyworm, *Spodoptera exigua* (Hübner), (Mehrkhou, 2011), the cotton bollworm,

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*Helicoverpa armigera* (Hübner) (Lep.: Noctuidae) (Naseri *et al.*, 2010) and the lima bean pod borer, *Etiella zinckenella* Treitschke (Lep.: Pyralidae) (Parvin, 1981). The Lima bean pod borer (LBPB) is an important pest of soybean as well as other cultivated crops including medics, clovers, lucerne, field peas (especially blue boilers), lupins, vetch and lentils (Hopkins, 2003). This pest is widely distributed in Asia, Europe, Africa, North America, Central and South America and Australia (Naito, 1960). It causes crop losses of about 40% in the Lorestan province and adjacent regions in Iran (Parvin, 1981).

The obvious sign of LBPB infestation are the tiny holes on soybean pods, from where the larvae left after damage. Larvae destroy the seeds during development inside a pod (Semeada *et al.*, 2001; Tohamy and El-Hafez, 2005). The larvae cause considerable direct-damage and yield losses by feeding on seeds and indirect-damage by reducing quality and marketability of infested crops (Edmonds *et al.*, 2000). The LBPB is considered as the most serious pest in Java, where most Indonesian soybean is grown (Naito *et al.*, 1986). Control of *Etiella* spp. using contact insecticides is difficult because the larvae feed within the pods under a closed canopy (Talekar, 1987). Chemical pesticides application must be precisely timed to ensure that larvae receive a lethal dose prior to entering the pods (Bindra and Singh, 1969; Harnoto *et al.*, 1984; Supriyatin, 1992). Marwoto and Saleh (2003) reported that chemical pesticides are not effective against LBPB, so alternative control methods should be considered to control pest damage. The egg parasitoid *Trichogrammatoidea bactrae* Nagaraja (Hymenoptera: Trichogrammatidae) was evaluated in controlling soybean pod borers, *Etiella* spp. The results showed that this parasitoid was able to parasitize up to 73.60% of pod borer eggs in soybean fields (Marwoto and Saleh, 2003). Naito and Harnoto (1984) and Kalshoven (1950) found that the *Etiella* spp. population density on soybean was the highest during the dry season in Indonesia. However, on the alternate host (*Crotalaria juncea* L.) its population density was highest in the rainy seasons (Mangundojo, 1959). Such a difference in *Etiella* spp. population densities between the two seasons could be explained by the quality of host plant in the area in each season. Apriyanto *et al.* (2008) studied the incidence of the LBPB on groundnut (*Arachis hypogaea* L.) in Bengkulu (Indonesia). They found that the pest infestation or damage on groundnut varied from one location to another.

The objective of this study was to assess the effects of 10 soybean cultivars on biological parameters of *E. zinckenella* to reduce the possibility of resistance development of LBPB to chemical insecticides (Gehan and Abdalla, 2006). Understanding the differences among host plants could have practical implications for the management of insect pests

(Saeed *et al.*, 2010). Information about development and reproduction of the LBPB is necessary to understand the population dynamics of this pest in the field. The impact of soybean cultivars on *E. zinckenella* performance is unknown. There are only few studies about this pest specifically dealing with its biology, sex attractant pheromones and population density (Edmonds *et al.*, 2000; Tabata *et al.*, 2008; Hirano *et al.*, 1992).

### Materials and methods

**Experimental conditions:** Seeds of 10 soybean cultivars ('Clark', 'Sahar', 'JK', '032', '033', 'Williams', 'L17', 'Zane', 'Gorgan3' and 'DPX') were obtained from the Seed and plant improvement Institute in Karaj, Iran. They were cultivated in fertilized field soil in the research field of Tarbiat Modares University in the suburb of Tehran, Iran, in 2009. All soybean cultivars were irrigated weekly during the growing season. Moreover, no pesticides were used but nitrogen fertilizer was used at the rate of 250 kg/h. The distance between rows was 50 cm. The pods of different soybean cultivars were transferred to a growth chamber ( $25\pm1^{\circ}\text{C}$ ,  $60\pm5\%$  RH and a photoperiod of 16:8 h (L: D)). The soybean pods were used for feeding the first to fifth instar larvae of *E. zinckenella*.

**Lima bean pod borer rearing:** The LBPB larvae were originally collected from chickling pea (*Lathyrus sativus* (L.)) fields in the Fars province of Iran in August 2009. Infested pods were placed in plastic rearing containers (20×10×30 cm) and covered with fine nylon mesh. A colony of LBPB was reared on each soybean cultivar pods for one generation before they were used in the experiments. Regular introduction of LBPB larvae from the field into the colony were made to reduce any inbreeding effects. The LBPB colony was maintained in a growth chamber with above mentioned condition.

**Development and Reproduction:** Developmental times of LBPB were studied in the laboratory on 10 soybean cultivars. To obtain eggs of the same age, 30 pairs of both sexes of moths were collected from the colony and transferred into mating cages (14 cm in diameter and 19 cm high) on different soybean cultivars. Adult males were distinguished from the females by enlarged base of antennae. After 12 h, a cohort of 100 newly laid eggs on fresh pods from each soybean cultivar were placed in rearing containers (20×10×30 cm). The eggs were checked daily to determine the egg incubation period. Newly emerged larvae were transferred individually with a fine camel hair brush into the tightly sealed plastic containers (3 cm in diameter and 5 cm high) containing a fresh pod of the different host plants. The petioles of pods were inserted into water-soaked cotton ball to maintain freshness. Fifth-instar

larvae (large and red in color) were individually kept in plastic containers (3 cm in diameter and 5 cm high) for pupation. Larval, pre-pupal, pupal periods and their mortality were recorded daily on each soybean cultivar.

After adult emergence, 30 pairs (30 replicates) of newly emerged male and female adults were placed into mating cages containing fresh soybean pods from the same cultivars for oviposition. A 20% honey-water solution was provided on cotton wicks for feeding adult moths. Adult moths were recognized by comparing their antennae. Male and female adult longevity and lifespan, developmental time, pre-oviposition, oviposition and post-oviposition period, mean daily fecundity and lifetime fecundity were recorded until the death of the last female in the cohort for different soybean cultivars.

**Statistical analysis:** The effect of different soybean cultivars on egg, larval, pre-pupal, pupal, developmental time, female and male adult longevity and lifespan, pre-oviposition, oviposition and post-oviposition period, mean daily fecundity and lifetime fecundity were analyzed by one-way ANOVA (Minitab ver. 15 )(MINITAB, 2007). Statistical differences among means were evaluated using the Student Newman Keuls (SNK) test at  $\alpha < 0.05$  (SPSS ver.17.0, Chicago, IL, USA). A dendrogram of soybean cultivars based on biological characteristics and reproduction parameters was constructed after hierarchical clustering (using the Euclidean Distance) by Ward's Minimum Variance method using R program (ver. 2.12.0) (R Development Core Team, 2011).

## **Results and Discussion**

**Development:** The LBPB successfully developed to adult stage on the studied soybean cultivars. The development times of immature stages of the LBPB on different soybean cultivars are presented in Table 1. The egg incubation period was significantly different among cultivars ( $F = 9.89$ ;  $df = 9, 897$ ;  $P < 0.01$ ). The shortest and longest incubation periods were recorded on 'Clark' ( $4.32 \pm 0.04$  days) and '033' ( $4.84 \pm 0.03$  days), respectively. Soybean cultivars significantly affected the larval developmental time ( $F = 33.34$ ;  $df = 9, 781$ ;  $P < 0.01$ ), ranging from  $13.42 \pm 0.10$  days on 'Clark' to  $16.28 \pm 0.14$  days on '033'. No significant difference was observed between pre-pupal periods on soybean cultivars. The pupal period was significantly affected by soybean cultivars ( $F = 165.00$ ;  $df=9, 702$ ;  $P < 0.01$ ). This parameter ranged from  $11.48 \pm 0.11$  to  $16.03 \pm 0.15$  days on 'Clark' and '032', respectively. The total immature developmental time (oviposition to adult emergence) of LBPB was significantly affected by soybean cultivars ( $F = 315.91$ ;  $df= 9, 696$ ;  $P < 0.01$ ), with

the highest and lowest values on '032' and 'Clark', respectively.

The male and female adult longevity and lifespan of the LBPB on various soybean cultivars are presented in Table 2. Soybean cultivars significantly affected the adult longevity of LBPB males and females ( $F = 290.11$ ;  $df = 9, 335$ ;  $P < 0.01$  for males and  $F = 433.40$ ;  $df = 9, 351$ ;  $P < 0.01$  for females). The male and female adult longevity was shortest on 'Gorgan3' ( $13.56 \pm 0.10$  and  $14.33 \pm 0.09$  days, respectively) and longest on 'Clark' ( $17.28 \pm 0.08$  and  $18.83 \pm 0.12$  days, respectively). Lifespan of males and females varied from  $52.00 \pm 0.13$  and  $51.18 \pm 0.11$  to  $56.80 \pm 0.10$  and  $55.84 \pm 0.27$  days and were significantly longer on 'Clark' as compared with the other cultivars ( $F = 113.01$ ;  $df = 9, 333$ ;  $P < 0.01$  and  $F = 90.07$ ;  $df = 9, 351$ ;  $P < 0.01$ ). The results suggested that the lifespan of lima bean pod borer males and females were significantly affected by soybean cultivars.

**Table 1.** Development time (Mean  $\pm$  SE) of immature stages of *Etiella zinckenella* on 10 soybean cultivars in the laboratory

| Soybean cultivars | Eggs                  | Larvae                | Pre-pupae         | Pupae                 | pre-imaginal development |
|-------------------|-----------------------|-----------------------|-------------------|-----------------------|--------------------------|
| 'Clark'           | $4.32 \pm 0.04^e$     | $13.42 \pm 0.10^e$    | $3.64 \pm 0.05^a$ | $11.48 \pm 0.11^e$    | $33.32 \pm 0.20^d$       |
| 'Sahar'           | $4.52 \pm 0.05^{bc}$  | $15.61 \pm 0.15^b$    | $3.71 \pm 0.05^a$ | $15.29 \pm 0.10^{bc}$ | $40.10 \pm 0.20^a$       |
| 'JK'              | $4.58 \pm 0.05^{bc}$  | $15.41 \pm 0.61^b$    | $3.80 \pm 0.05^a$ | $15.59 \pm 0.10^b$    | $40.21 \pm 0.17^a$       |
| '032'             | $4.56 \pm 0.05^{bc}$  | $15.46 \pm 0.20^b$    | $3.73 \pm 0.05^a$ | $16.03 \pm 0.15^a$    | $40.50 \pm 0.25^a$       |
| '033'             | $4.84 \pm 0.03^a$     | $16.28 \pm 0.14^a$    | $3.71 \pm 0.05^a$ | $11.77 \pm 0.14^e$    | $38.16 \pm 0.17^b$       |
| 'Williams'        | $4.34 \pm 0.05^{de}$  | $14.39 \pm 0.18^{cd}$ | $3.70 \pm 0.05^a$ | $12.00 \pm 0.09^e$    | $33.51 \pm 0.13^d$       |
| 'L17'             | $4.42 \pm 0.05^{cde}$ | $14.58 \pm 0.12^c$    | $3.77 \pm 0.05^a$ | $12.42 \pm 0.18^d$    | $36.57 \pm 0.12^c$       |
| 'Zane'            | $4.51 \pm 0.05^{bcd}$ | $14.03 \pm 0.13^d$    | $3.61 \pm 0.05^a$ | $11.81 \pm 0.08^e$    | $33.42 \pm 0.08^d$       |
| 'Gorgan3'         | $4.60 \pm 0.05^b$     | $15.21 \pm 0.10^b$    | $3.77 \pm 0.05^a$ | $15.08 \pm 0.18^c$    | $40.12 \pm 0.17^a$       |
| 'DPX'             | $4.68 \pm 0.04^b$     | $15.40 \pm 0.10^b$    | $3.76 \pm 0.05^a$ | $14.92 \pm 0.25^c$    | $40.09 \pm 0.22^a$       |

The means followed by different letters in the same column are significantly different ( $P < 0.05$ ; *SNK*)

**Reproduction:** The pre-oviposition, oviposition and post-oviposition periods are presented in Table 3. The pre-oviposition period of the LBPB was significantly affected by soybean cultivars ( $F = 2.64$ ;  $df = 9, 290$ ;  $P < 0.01$ ).

**Table 2.** Male and female longevity and lifespan (Mean  $\pm$  SE) of *Etiella zinckenella* on different soybean cultivars in the laboratory

| Soybean cultivars | Adult longevity (Days)         |                                | Lifespan (Days)               |                               |
|-------------------|--------------------------------|--------------------------------|-------------------------------|-------------------------------|
|                   | Male                           | Female                         | Male                          | Female                        |
| 'Clark'           | 17.28 $\pm$ 0.08 <sup>a</sup>  | 18.83 $\pm$ 0.12 <sup>a</sup>  | 52.00 $\pm$ 0.13 <sup>f</sup> | 51.18 $\pm$ 0.11 <sup>f</sup> |
| 'Sahar'           | 13.69 $\pm$ 0.11 <sup>ef</sup> | 15.00 $\pm$ 0.00 <sup>e</sup>  | 56.69 $\pm$ 0.11 <sup>a</sup> | 55.66 $\pm$ 0.19 <sup>a</sup> |
| 'JK'              | 14.00 $\pm$ 0.00 <sup>e</sup>  | 14.95 $\pm$ 0.04 <sup>e</sup>  | 56.00 $\pm$ 0.06 <sup>b</sup> | 55.08 $\pm$ 0.28 <sup>b</sup> |
| '032'             | 13.48 $\pm$ 0.10 <sup>f</sup>  | 14.92 $\pm$ 0.05 <sup>e</sup>  | 56.80 $\pm$ 0.10 <sup>a</sup> | 55.84 $\pm$ 0.27 <sup>a</sup> |
| '033'             | 15.08 $\pm$ 0.08 <sup>d</sup>  | 16.07 $\pm$ 0.05 <sup>d</sup>  | 55.41 $\pm$ 0.13 <sup>c</sup> | 53.92 $\pm$ 0.18 <sup>c</sup> |
| 'Williams'        | 16.50 $\pm$ 0.10 <sup>b</sup>  | 17.02 $\pm$ 0.02 <sup>c</sup>  | 52.13 $\pm$ 0.20 <sup>f</sup> | 51.21 $\pm$ 0.20 <sup>f</sup> |
| 'L17'             | 15.68 $\pm$ 0.09 <sup>c</sup>  | 16.07 $\pm$ 0.07 <sup>d</sup>  | 54.08 $\pm$ 0.11 <sup>e</sup> | 53.07 $\pm$ 0.13 <sup>d</sup> |
| 'Zane'            | 17.28 $\pm$ 0.08 <sup>a</sup>  | 17.68 $\pm$ 0.41 <sup>ab</sup> | 52.21 $\pm$ 0.15 <sup>f</sup> | 52.09 $\pm$ 0.11 <sup>e</sup> |
| 'Gorgan3'         | 13.56 $\pm$ 0.10 <sup>f</sup>  | 14.33 $\pm$ 0.09 <sup>f</sup>  | 55.30 $\pm$ 0.28 <sup>c</sup> | 54.42 $\pm$ 0.19 <sup>c</sup> |
| 'DPX'             | 13.91 $\pm$ 0.08 <sup>e</sup>  | 14.92 $\pm$ 0.05 <sup>e</sup>  | 54.78 $\pm$ 0.33 <sup>d</sup> | 54.42 $\pm$ 0.18 <sup>c</sup> |

The means followed by different letters in the same column are significantly different ( $P < 0.05$ ; SNK)

**Table 3.** The pre-oviposition, oviposition and post-oviposition periods (Mean  $\pm$  SE) of *Etiella zinckenella* on different soybean cultivars in the laboratory

| Soybean cultivars | Pre-oviposition period (days) | Oviposition period (days)      | Post-oviposition period (days) |
|-------------------|-------------------------------|--------------------------------|--------------------------------|
| 'Clark'           | 1.73 $\pm$ 0.13 <sup>b</sup>  | 15.46 $\pm$ 0.19 <sup>a</sup>  | 1.84 $\pm$ 0.15 <sup>bc</sup>  |
| 'Sahar'           | 2.25 $\pm$ 0.10 <sup>a</sup>  | 10.41 $\pm$ 0.16 <sup>e</sup>  | 2.33 $\pm$ 0.13 <sup>ab</sup>  |
| 'JK'              | 2.39 $\pm$ 0.12 <sup>a</sup>  | 10.08 $\pm$ 0.21 <sup>ef</sup> | 2.52 $\pm$ 0.16 <sup>a</sup>   |
| '032'             | 2.12 $\pm$ 0.09 <sup>ab</sup> | 10.37 $\pm$ 0.21 <sup>e</sup>  | 2.45 $\pm$ 0.15 <sup>a</sup>   |
| '033'             | 2.04 $\pm$ 0.12 <sup>ab</sup> | 12.36 $\pm$ 0.12 <sup>cd</sup> | 1.76 $\pm$ 0.10 <sup>bc</sup>  |
| 'Williams'        | 2.19 $\pm$ 0.07 <sup>a</sup>  | 12.80 $\pm$ 0.27 <sup>c</sup>  | 1.69 $\pm$ 0.13 <sup>c</sup>   |
| 'L17'             | 2.08 $\pm$ 0.08 <sup>ab</sup> | 12.12 $\pm$ 0.15 <sup>d</sup>  | 2.08 $\pm$ 0.08 <sup>abc</sup> |
| 'Zane'            | 2.19 $\pm$ 0.14 <sup>a</sup>  | 13.80 $\pm$ 0.26 <sup>b</sup>  | 2.26 $\pm$ 0.18 <sup>abc</sup> |
| 'Gorgan3'         | 2.26 $\pm$ 0.09 <sup>a</sup>  | 9.52 $\pm$ 0.13 <sup>f</sup>   | 2.69 $\pm$ 0.11 <sup>a</sup>   |
| 'DPX'             | 2.25 $\pm$ 0.10 <sup>a</sup>  | 9.95 $\pm$ 0.20 <sup>ef</sup>  | 2.16 $\pm$ 0.20 <sup>c</sup>   |

The means followed by different letters in the same column are significantly different ( $P < 0.05$ ; SNK)

The longest and shortest pre-oviposition periods were recorded on 'JK' ( $2.39 \pm 0.12$  days) and 'Clark' ( $1.73 \pm 0.13$  days), respectively. Whereas, the post-oviposition period ( $F = 5.16$ ;  $df = 9, 290$ ;  $P < 0.01$ ) was longest on 'Gorgan3' and shortest on 'Williams'. The oviposition period varied significantly among soybean cultivars ( $F = 92.82$ ;  $df = 9, 290$ ;  $P < 0.01$ ) with longest on 'Clark' ( $15.46 \pm 0.19$  days) and shortest on 'Gorgan3' ( $9.52 \pm 0.13$  days), respectively.

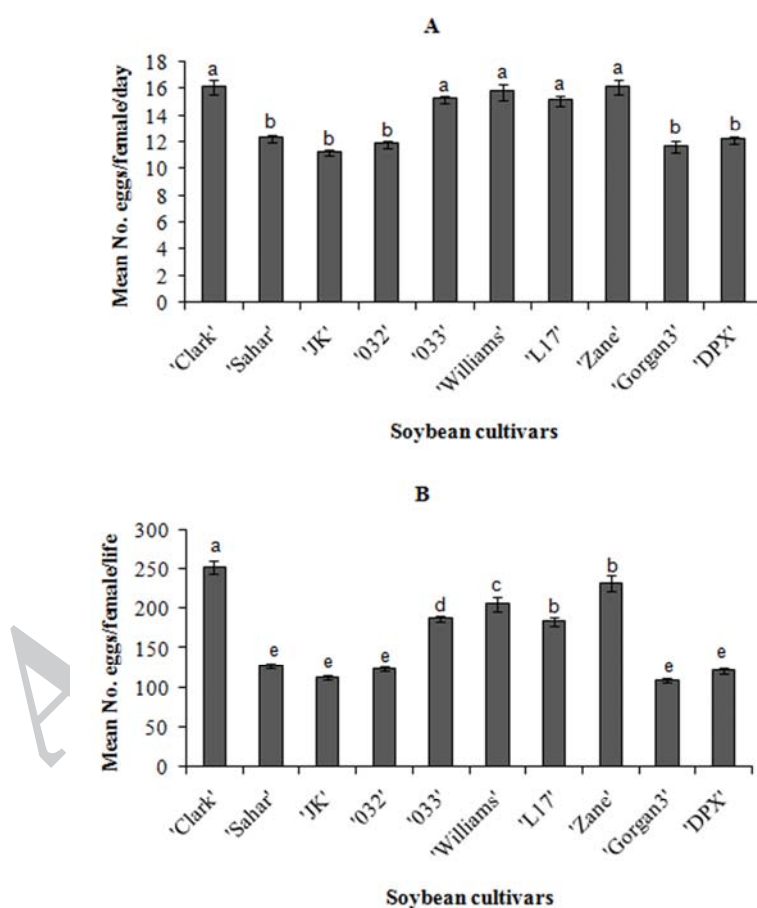
Mean number of eggs laid daily (mean daily fecundity) and mean number of eggs produced per female during adult life (mean lifetime fecundity) are presented in Fig. 1. There was significant difference between mean number of eggs per day on different soybean cultivars ( $F = 24.31$ ;  $df = 9, 290$ ;  $P < 0.01$ ) (Fig. 1A). Daily fecundity was highest on 'Clark' ( $16.16 \pm 0.56$  eggs) and lowest on 'JK' ( $11.21 \pm 0.22$  eggs). Lifetime fecundity was significantly higher on 'Clark' ( $252.8 \pm 8.93$  eggs) and lower on 'Gorgan3' ( $109.43 \pm 3.02$ ) compared with the other cultivars ( $F = 75.27$ ;  $df = 9, 290$ ;  $P < 0.01$ ) (Fig. 1B).

**Cluster analysis:** A dendrogram of soybean cultivars based on the biological parameters of *E. zinckenella* reared on different soybean cultivars is presented in Fig. 2. Cutting branches of the dendrogram at height  $>100$  exhibited two distinct clusters labeled A and B. Different cultivars of soybean were grouped within each cluster based on the comparison of development and fecundity of *E. zinckenella* reared on related cultivars. Cluster A included 'Clark', 'Zane', 'Williams', 'L17' and '033' as susceptible group and cluster B consisted of 'DPX', 'Sahar', '032', 'JK' and 'Gorgan3', which can be categorized as partially resistant group.

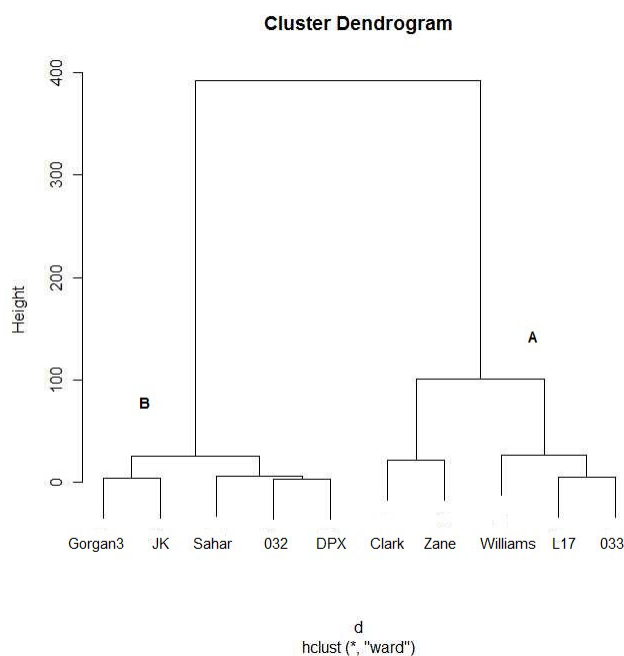
In the present study, developmental parameters and fecundity of *E. zinckenella* were evaluated on different soybean cultivars in the laboratory. The developmental time, survivorship and fecundity of an insect, reflects the suitability of the host species (Ju *et al.*, 2011). Our findings indicated that the soybean cultivars can influence the performance of *E. zinckenella* as indicated by the long reproduction period, high oviposition rate and short developmental time of pest on 'Clark', 'Zane', 'Williams', 'L17' and '033'. Consequently, these cultivars can be considered as sensitive hosts for lima bean pod borer based on our research in laboratory conditions. Our results showed that the developmental times and reproduction parameters of LBPB are significantly affected by different soybean cultivars. The incubation period was similar to previous studies on soybean at 25 °C, ( $4.72 \pm 0.02$  days, Edmonds *et al.*, 2000;  $4.16 \pm 0.01$  days, Naito and Hornato, 1984), whereas Owatsakul (1998) reported that the average duration of egg incubation was  $5.45 \pm 0.25$  days on vegetable



soybean at approximately mean temperature of 34.6 °C. Last instar larvae exhibited negative phototaxis that was in agreement with Edmonds *et al.*, (2000). The larval stages of *E. zinckenella* were developed in five larval instars on all cultivars of soybean, which is in agreement with the previous investigations on other host plants (Apriyanto *et al.*, 2008; Edmonds *et al.*, 2000; Tabata *et al.*, 2008). Edmonds *et al.* (2000) reported a shorter duration of the larval stage ( $10.59 \pm 0.17$  days), female and male longevity ( $11.27 \pm 1.47$  and  $7.64 \pm 0.66$  days) and longer duration of the pre-pupal stage of pest ( $4.29 \pm 0.19$  days) at temperatures between 25-30°C in comparison with our data.



**Fig. 1.** Mean ( $\pm$ SE) number of eggs laid per female per day (A) and mean ( $\pm$ SE) number of eggs laid per female during adult life (B) on different soybean cultivars



**Fig. 2.** Dendrogram of the effect of different soybean cultivars on life table and fecundity parameters of *Etiella zinckenella* reared in the laboratory.

A (the best suitable host plants) and B (the least suitable host plants)

It is possible that the observed differences may be due to physiological differences depending on the type of the soybean cultivar, genetic or geographic variations of the pest (Yanqun *et al.*, 2003).

In this study, much longer total duration of development were estimated for *E. zinckenella* at 25°C, compared with those reported by Bindra and Singh (1969), who found the life cycle was completed in 22-24 days at 25°C on pigeon peas, and in a shorter period at higher temperatures. Thus, pigeon peas may be a more suitable host than soybeans. Generally, females lived longer than males on all 10 soybean cultivars. Similar results were obtained by Edmonds *et al.* (2000) and Hattori and Sato (1983).

No other studies have previously examined the effect of soybean cultivars on development and reproduction of *E. zinckenella*. However, there are some studies on soybean that assessed ecological characters, especially infestation, damage percentages, yield loss and seasonal changes in population density of *Etiella* spp. (Hottori and Sato, 1983; Apriyanto

*et al.*, 2008; Hirano *et al.*, 1992; Naito and Harnoto, 1984; Semeada *et al.*, 2001). It is difficult to compare ecological characters in different studies, because of species differences, genetic variation, differences in rearing methods and conditions. Variation in performance of *E. zinckenella* on different cultivars might be due to differences in levels of nutrients and secondary compounds (Van Emden and Bashford, 1969).

Hierarchical cluster analysis based on development and fecundity of *E. zinckenella* indicated that grouping the different cultivars of soybean within each cluster might be due to a high correspondence of physiological traits of soybean cultivars, whereas the separate clusters might represent significant variability in host plant suitability between clusters. Similar results were observed on the effect of different canola cultivars on *Plutella xylostella* (Lepidoptera: Plutellidae) (Soufbaf *et al.*, 2010). In conclusion, cluster A included the pest-susceptible host plants with higher fecundity, longer oviposition period and longevity, shorter developmental time and lifespan of *E. zinckenella*. However, cluster B cultivars had lower fecundity, higher mortality, shorter oviposition period, longevity as well as longer developmental time and lifespan on the same soybean cultivars.

Information about susceptibility or resistance among soybean cultivars against *E. zinckenella* and recognition of biological features of *E. zinckenella* are fundamental components of integrated pest management (IPM) program. These are important in detection and monitoring of pest infestation, cultivar selection and crop breeding. However, further studies are needed to determine the effect of physico-chemical properties of various soybean cultivars against *E. zinckenella*.

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