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Yield loss and economic threshold estimates for pod borer (*Helicoverpa armigera*) in late maturing pigeonpea (*Cajanus cajan*)

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Pigeonpea [*Cajanus cajan* (L.) Millsp.] is a tropical grain legume mainly cultivated in the arid and semi-arid regions of the world. Crop represents about 6% of world's legume production with more than 78% being produced in India (FAOSTAT 2023, DAFW 2023). India produced about 4.3 million tonnes of pigeonpea from nearly 4.72 million hectares during 2021 (DAFW 2022). Pigeonpea fulfills the dietary protein needs of >1 billion people in the developing world and supports the livelihood of millions of resource poor farmers of Asia, Africa, South and Central America, and the Caribbean (Mir *et al.* 2014). The crop is reported to be infested by more than 250 insect species (Lateef and Reed 1990, Srivastava and Joshi 2011) and nearly 30 spp. of lepidoptera are found to feed on reproductive structures of the crop (Shanower *et al.* 1999). However, few insects [*Helicoverpa armigera* (Hubner), *Maruca vitrata* (Fab.) and *Melanagromyza obtusa* (Malloch)] were described as major yield constraints (Srinivasan *et al.* 2021). Among the many cultivated host crops, *H. armigera* strongly prefers and thrives on pigeonpea (Rajapakse and Walter 2007) causing substantial yield loss in India. Economic crop losses due to *H. armigera* were estimated at $317 million/annum in pigeonpea (ICRISAT 1992, Ranga Rao and Shanower 1999). On average, 48% pod damage was reported at farmers' fields of Uttar Pradesh (Yogesh *et al.* 2016).

Economic Threshold Level (ETL) quantifies level of pest population or extent of crop damage indicating that the crop is at risk of yield losses and demands insecticide sprays (Pedigo *et al.* 1986). ETL were reported for *H. armigera* by Goyal *et al.* (1990), Chaudhuri (1993) (one larva/plant at flowering stage and pod stage); and for pod borer complex by, Lal *et al.* (1992) (4–7% seed damage), Sahoo and Senapati (2000) (3.9 larvae/plant or 8.3% pod damage) in pigeonpea. Infestation with one larva/plant reduced about 4.95 green pods, 7.05 dry pods, 18.01 grains, 3.79 g pod and 2.05 g grain weight/plant, while the pod damage estimated was 5–7% at harvest (Reddy 2001). ETs are dynamic and varies from year to year, field to field within the same year depending on cultivars, crop stage, crop-produce value, geographical locations and management cost (Fathipour and Sedaratian 2013). Therefore, ETs need to be revalidated for adopted cultivars under the prevailing factors that affect the ETs. Hence an experiment was conducted to quantify the yield losses and estimate the ETs for *H. armigera* in adopted cultivar, IPA-203.

The experiment was conducted during 2022–2023 at ICAR-Indian Institute of Pulses Research, Kanpur (26°31'04", N 80°14'55" E), Uttar Pradesh to quantify yield losses and estimate economic thresholds for *H. armigera* under the prevailing agro-climatic conditions of Kanpur, Uttar Pradesh. The late maturing cultivar, IPA-203 was raised on 100 m^2 block under insecticide-free conditions at spacing of 90 cm × 20 cm and raised as per the recommended agronomic practices (Dhar *et al.* 2002). The individual plants were covered with white insect-proof nets (dimension: 150 cm × 120 cm; mesh size: 50 × 50/$inch^2$) and infested with 0, 1, 2, 3, 4 and 5 third-instar larvae of *H. armigera* at grain filling stage. Following infestation, lower end of the nets was tied with a piece of twine. Experiment was laid out in a randomized block design (RBD) with four replications. The uninfected plants served as controls. Nets were removed at three weeks' post-infestation and pods were harvested from each plant, threshed, and dried to record the grain weight. Grain yield/plant, pod damage and seed damage were recorded. Grain yield/plant was converted to hectare basis. Loss in grain yield at different infestation levels was calculated in relation to the uninfected plants. Correlation and regression of infestation parameters and yield was computed. Mean of pod and seed damage was subjected to appropriate transformation methods to stabilize the variance and analysed using one-way analysis of variance (ANOVA) followed by Tukey's HSD post hoc test ($\alpha = 0.05$) in SPSS Statistics 16.0 (SPSS Inc., Chicago, Ill., USA).

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Insect density, cost of management, yield loss and market value of the produce were taken into consideration for estimating EIL. Cost of protection was calculated by considering the recommended practices for pigeonpea. Cost of produce was fixed according to prevailing market price.

Avoidable yield losses were calculated according to Pradhan (1964):

$$\text{Avoidable yield loss} = \frac{\text{Seed yield of uninfested plant (g)} - \text{Seed yield of infested plant (g)}}{\text{Seed yield of uninfested plants (g)}}$$

Economic injury level, gain threshold (Stone and Pedigo 1972, Ogunlana and Pedigo 1974) were estimated as:

$$\text{Economic injury level (EIL)} = \frac{\text{Gain threshold (GT)}}{\text{Regression coefficient (b)}}$$

$$\text{Gain threshold (GT)} = \frac{\text{Cost of management (₹/ha)}}{\text{Market value of the produce (₹/qt)}}$$

The insect density corresponding to unit benefit cost ratio was the economic injury level hence economic threshold level were calculated to be 75% of EIL (Pedigo 1991).

Yield losses: There was progressive increase in pod and seed damage with increasing insect infestation from 1–5 larvae/plant in pigeonpea cultivar, IPA-203 (Table 1). Pod and seed damage varied significantly from 4.2–23.84% (ANOVA: $F_{5,18}$ = 51.61, P<0.05) and 0.49–1.88% (ANOVA: $F_{5,18}$ = 23.43, P<0.05). Seed damage was not prominent since pod borers (*H. armigera*) often completely devour the seeds within the infested pods.

Table 1 Avoidable yield losses due to pod borer infestation

Larval population/ plant	Pod damage (%)	Seed damage (%)	Yield (gm/ plant)	Avoidable yield loss (%)
0	0.00[a]	0.00[a]	150.30[a]	0.00
1	4.20[ab]	0.49[b]	100.99[b]	32.81
2	5.26[ab]	0.58[b]	97.83[b]	34.91
3	6.94[ab]	0.60[b]	95.75[b]	36.29
4	15.38[c]	1.70[c]	87.79[bc]	41.59
5	23.84[d]	1.88[c]	72.29[c]	51.90

Means followed by same letter(s) in a column are homogeneous subsets (α = 0.05, Tukey's HSD).

Grain yield declined with increasing pod borer density from 1–5/plant. Grain yield varied significantly from 150.30–72.29 gm/plant (ANOVA: $F_{5,18}$ = 45.24, P<0.05). Plant infested with 5 larvae yielded 72.29 gm as against 150.30 gm from uninfected plant. Avoidable yield losses ranged from 32.8–51.9% at corresponding infestation level of 1–5 larvae/plant. Highest yield loss (51.9%) was recorded at insect density of 5/plant.

Insect density-yield loss estimation indicated that more than 4 larvae/plant caused considerable seed and pod damage (>1.7 and 15.4%) and over 41.6% loss in grain yield. Present yield loss estimates are much higher than earlier estimates of Lal (1992) who reported 5% yield loss for one larvae/ plant. Sahoo and Senapati (2000) reported a yield loss of 28 kg/ha for each unit increase in larval population.

Economic thresholds (ETs): The correlation of yield loss and infestation parameters is presented in Table 2. Insect density [r (4) = − 0.876, P<0.05)] and pod damage [r (4) = − 0.810, P>0.05)] was negatively correlated with grain yield. The linear regressions fitted for the relationship between yield loss and infestation parameters are depicted in Fig. 1. The regression equation (Y = 4.56X + 6.89) revealed that for every unit increase in insect density, the yield loss was 4.56 kg/ha. Similarly, for every unit increase in pod damage (%), there was a corresponding yield loss of 900 gm/ha (Y = 0.90X + 9.97). Gain threshold obtained at pigeonpea price of ₹6300/quintal was 3.50. The economic threshold levels considering a control cost of ₹22,000/ha was 1.14 larva/2 plants or 3% pod damage for pod borer

Table 2 Estimation of economic threshold for pod borer in pigeonpea

Independent variables affecting yield	Correlation coefficient (r)	Regression equation	Economic threshold level
Insect density	−0.876*	Y=4.56X + 6.89	1.14 larva/2 plants
Pod damage	−0.810	Y=0.90X + 9.97	3% pod damage

*Correlation is significant at the 0.05 level (P<0.05).

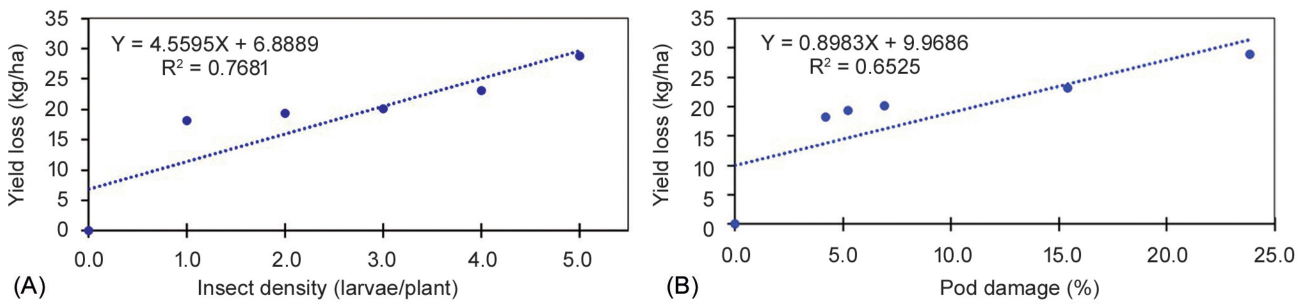

Fig. 1 Relationship of yield loss (Y) with infestation parameters (X): (A) insect density and (B) pod damage for pod borer infestation in IPA 203 cultivar.

infestation at podding stage. Subharani and Singh (2009) reported negative correlation between yield and pod borer (*H. armigera*) infestation parameters. Further, increase in infestation by one larva/plant caused corresponding increase in 5% pod damage and 2 gm grain weight loss/plant. The economic threshold estimates in the present study are lower than the previous reports. Chaudhuri (1993) and Lal (1995) reported ETL for *H. armigera* at one larva/plant during podding stage under Uttar Pradesh conditions. Similarly, Goyal *et al.* (1990) reported ETL estimates of one larva/plant or 2% pod damage. Economic thresholds could vary according to cost of management and crop value (Stacke *et al.* 2018). These ETL estimates could help the farmers in scheduling the control measure. Timely pest control interventions could be vital in curtailing the unjustified use of insecticides and thus reducing the crop production cost for the farmers.

SUMMARY

Pod borer [*Helicoverpa armigera* (Hubner)] is a major biotic constraint to global pigeonpea production. The farmers largely apply synthetic insecticides to control this pest in pigeonpea. The study was conducted to quantify yield losses and estimate economic thresholds for *H. armigera*. The late maturing cultivar, IPA-203 was infested with different larval densities to determine the insect density-yield loss relationships. The yield response was variable and grain yield declined with increasing larval density from 1–5/plant. Yield loss of 4.56 kg/ha was evident for each unit increase in larval population. Economic threshold estimates indicated that the control measures for pod borer in IPA 203 cultivar should be initiated at an insect density of ≈1 larva/2 plants or at 3% pod damage to avoid the economic crop losses. The damage potential and economic threshold estimates are prerequisite for integrated pest management and reducing production costs (Alves *et al.* 2017). Present results indicated that relatively low infestations of *H. armigera* can cause significant yield reduction in pigeonpea hence intensive monitoring and timely control measures are necessary. Based on present economic threshold estimates, the farmers could decide the timing and kind of control measures to be initiated against pod borer in late pigeonpea cultivars to avert the economic losses.

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